4th International Congress of the ESSC

Proceedings Volume

25-29 May 2004
Budapest – Hungary

Editor in Chief: Ádám Kertész
Editors: Alexandra Kovács, Gergely Jakab, Balázs Madarász

Hungarian Academy of Sciences, Geographical Research Institute, 1112 Budapest, Budaörsi út. 45., Hungary
http://www.mtafki.hu

2004.

CONTENTS

Conference Programme

24th May, Monday

Arrival of participants

17.00 – 19.00 ESSC Council Meeting
19.00 Welcome reception

25th May, Tuesday

08.00 – 13.00 Registration
09.00 – 10.00 Opening ceremony

09.00 – 09.15 Welcoming address by Attila Meskó, Deputy Secretary of the Hungarian Academy of Sciences
Ádám Kertész, Vice-President of the ESSC, President of the local Organizing Committee

09.15 – 09.30 Jose Luis Rubio, President of the ESSC: General introduction about the activities of the European Society for Soil Conservation

09.30 – 10.00 György Várallyay, Member of the Hungarian Academy of Sciences – Soil conservation strategies in the extended EU

10.00 – 10.20 Coffee Break

10.20 – 12.50 Paper session I.
"Land use and land cover change"

10.20 – 10.50 Key-note: ***Helming, K.*** – Zander, P. – Schuler, J. – Müller, K. – Wiggering, H.: Integration of soil conservation issues into multifunctional land use

10.50 – 11.05 Boer, M. – Puigdefábregas, J. – Hill, J.: Remote sensing-based assessment of land condition in Mediterranean Europe

11.05 – 11.20 Kõlli, R. – Lemetti, I. – Penu, P.: The influence of land-use change to soil cover properties and functioning

11.20 – 11.35 Thanawood, C. – Yongchalermchai, C. – Bennui, A.: Land use change and its environmental consequences in southern Thailand

11.35 – 11.50 Ajibefun, I.A. – Wenkel, K-O. – Wieland, R. – Mirschel, W.: Development and Evaluation of Integrated Ecologi-Economic Regional Land Use Models to Study Land Use and Landscape Changes in North East Germany

11.50 – 12.05 Tóth, G. – Debreczeni, K. – Gaál, Z. – Hermann, T. – Makó, A. – Máté, F. – Vass, J. – Várallyay, Gy.: Land use planning decision support based on land evaluation and Web-GIS modeling: an integrated approach in Hungary

12.05 – 12.20 Sishkov, T. – Marinova, S. – Petrova, L. Identification of reclaimed soils and assessment of anthropogenic impact

12.30 – 14.00 Lunch

14.00 – 15.30 Paper Session II.
"Measurement and modeling of soil erosion"

14.00 – 14.30 Key-note: ***Imeson, A.***: Soil erosion measurements at different scales: are they necessary and how should they be made?

14.30 – 14.45 Blavet, D. – De Noni, G. – Roose, E.: Cultural practices and risks of runoff and sheet erosion under vineyard in Ardeche (Southern France)

14.45 – 15.00 Martínez-Mena, M. – Castillo, V. – Albaladejo, J.: Conditions for rill initiation on marl soils. A field experiment in South East of Spain

15.00 – 15.15 Andreu, V. – Rubio, J.L. – Gimeno-García, E. – Gonzalez, O. – Campo, J.: Initial response of recently burned soil to water erosion processes in a Mediterranean environment

15.15 – 15.30 Coutinho, M.A. – Antunes C.R.: Throughfall Drop Sizes for Mediterranean Vegetation Species

15.30 – 16.20 **Poster session I. (Posters 1-11) and Coffee Break**
"Land use and land cover change"

1. González-Arias, A. – Martínez de Arano, I. – Gartzia, N. – Aizpurua, A.: Soil Disturbance Surveys in Pine Tree Plantations of the Basque Country
2. Boix Fayos, C. – González Barberá, G. – Martínez Mena, M. – Castillo, V. – Albaladejo, J.: Effects of land use change on the production of sediments at the subcatchment scale in a Mediterranean landscape
3. Sierra, C. – Martínez, F.J. – Roca, A. – Sierra, M.: A method for the evaluation of soils for olive cultivation with a G.I.S.
4. Rodríguez Rodríguez, A. – Arbelo, C.D. – Guerra, J.A. – Mora, J.L. – Fuentes, F. – Armas, C.M.: Influence of age of abandonment on soil fertility in a bioclimatic sequence of abandoned fields on Tenerife Island (Canary Islands, Spain)
5. Mitsimponas, Th. – Karyotis, Th. – Noulas, Ch. – Tziouvalekas, M.: Non arable soils in the highlands of Central Greece: nature, properties and vegetation
6. Jiménez-Delgado, M. – Martínez-Casasnovas, J.A. – Ramos, M.C.: Land transformation, land use changes and soil erosion in vineyard areas of NE Spain
7. Cots-Folch, R. – Laporta, L. – Martínez-Casasnovas, J.A. – Ramos, M.C.: Impacts of land transformations on soil physical properties in the Priorat vineyard region (NE Spain)
8. Madarász, B. – Fehér, O.: Historical land use change on volcanic soils in Hungary
9. Dorronsoro B. – García I. – Dorronsoro-Diaz C. – Diez M. – Santos, F. – Dorronsoro-Fdez C.: SoilCap.html
10. Dorronsoro-Diaz, C. – Martinez, F.J. – Martin, F. – Dorronsoro, B. – Simon, M. – Fernandez, E. – Dorronsoro-Fernandez, C.: SoilUseChange.html
11. Martínez-Raya, A. – Francia, J.R. – Cárceles, B. – Ruiz-Gutiérrez, S. – Martínez Vilela, A.: Erosion control throught the establishment of a shrub with economical use, in the mediterranean conditions

16.20 – 17.35 **Paper Session II.**
"Measurement and modeling of soil erosion"

16.20 – 16.35 Ramos, M.C. – Martínez-Casasnovas, J.A.: Nutrient losses by runoff affected by rainfall characteristics in Mediterranean vineyards

16.35 – 16.50 Van Oost, K. – Van Muysen, W. – Govers, G. – Heckrath, G.: Soil Erosion and Carbon dynamics In Agricultural Landscapes

16.50 – 17.05 Zubov, A.: Soil water erosion and its control in steppe zone of Ukraine

26th May, Wednesday

09.00 – 10.30 **Paper session II.**
"Measurement and modeling of soil erosion"

09.00 – 09.15 Kainz, M. – Fiener, P. – Auerswald, K.: Erosion potential of organic and conventional farming – results of a country-scale modelling in Bavaria

09.15 – 09.30 Cerdan, O. – King, C. – Baghdadi, N. – Desprats, J-F. – Le Bissonnais, Y. – Couturier, A.: Modelling soil erosion at the regional scale using LANDSAT TM and RADARSAT data

09.30 – 09.45 Olsen, P. – Klith Bøcher, P. – Humlekrog Greve, M.: Modelling potential risk of water erosion on a national scale in Denmark based on the Revised Soil Loss Equation

09.45 – 10.00 Casermeiro, M.A. – de la Cruz Caravaca, M.T. – Hernando, M.I. – Molina, J.A.: Soil texture versus soil structure in the evaluation of erodibility in sandy soil

10.00 – 11.15 **Poster session II – III. (Poster 12-35) and Coffee Break**
"Measurement and modeling of soil erosion"
"Pollution of soil and water resources"

"Measurement and modeling of soil erosion"

12. Chinea, E. – Rodríguez Rodríguez, A. – Mora, J.L: Response of soil with endemic shrubs from Canary Islands to simulated rainfall
13. García, I. – Martín, F. – Dorronsoro, C. – Simón, M. – Diez M. – Bouza, P. – Aguilar, J.: Mineralogical transformations in carbonate soils affected by a spill of pyrite tailings
14. Farsang, A. – Rácz, P. – Barta, K.: The temporal and spatial changes of the soil's macro- and micro element content as an indicator of soil erosion
15. Burai, P. – Tamás, J. – Kovács, E.: Evaluation of erosion risk at an abundant heavy metal mining site
16. Regoyos, M. – Casermeiro, M.A. – Espluga, A. – Otero, I. – García, A. – Hernando, M.I. – de la Cruz, M.T. – Molina, J.A.: Zoom effect on soil data for soil erosion evaluation in a small mediterranean basin using GEOWEPP
17. Djurhuus, J. – Højsgaard, S. – Heckrath, G. – Olsen, P.: ErosPredict – A new model for predicting water erosion in Denmark
18. Tóth, A.: Application of the MEDRUSH model in a hilly catchment
19. Josan, N. – Nistor, S.: The first large scale digital elevation model of the upper catchment area of Barcau-Berettyó river basin
20. Auerswald, K. – Kainz, M. – Fiener, P.: Erosion potential of organic and conventional farming – validation of large scale modelling by results of a long term field study
21. Antal, S. – Máté, F. – Sisák, I.: Development of a field-scale erosion model
22. Jakab, G.: Spatial distribution and classification of gullies in the hilly areas of Hungary

"Pollution of soil and water resources"

23. Szalai, Z.: Predicting the vertical distribution of groundwater Cd and Cu contents in calcareous alluvial soils and sediments of River Danube
24. Stępniewska, Z. – Szafranek A.: Dynamic of twenty-four hours methane emission from the Lake Moszne in the east part of Poland
25. Bennicelii, R.P. – Stępniewska, Z. – Banach, A. – Szajnocha, K – Górski, A.: Determination ability of aquatic fernazolla caroliniana to remove biogens from municipal wastewater
26. Bennicelii, R.P. – Stępniewska, Z. – Szajnocha, K. – Banach, A.: The ability of azolla filiculoides to remove precious metals (Ag(I), Au(III), Pt(IV)) from water solution
27. Stępniewska, Z. – Ostrowska, A.: Nitrate (V) elimination from waste water trough sorption on the rock spoils of different degree of weathering
28. Stępniewska, Z. – Wolińska, A.: Enzyme activity in soils contaminated by chromium forms
29. Stępniewska, Z. – Kosiorowska, I. – Nowak, D.: Effect of waste water on wettability eutric histosol soil
30. Olubunmi, O.T.: Livestock as a case study
31. Füleky, Gy. – Rétháti, G.: Pollution of deeper soil horizons after long term placement of liquid manure
32. Rétháti, G. – Füleky, Gy. – Enczi, Zs.: Sorption of chlorinated aromatic compounds on soil and soil constitutents
33. Aleksza, L. – Dér, S. – Kovács, D. – Füleky, Gy.: Soil improvement with composted agricultural waste materials
34. Aydinalp, C. – Füleky, Gy.: Cadmium and trace element levels in some agricultural soils under various crops in the Bursa Province of Turkey
35. Andreu, V. – Rubio, J.L. – Picó, Y.: Presence of alkylbenzenesulfonates in a mediterranean forest soil amended with sludges

11.15 – 13.00 **Paper session III.**
"Pollution of soil and water resources"

11.15 – 11.45	*Key-note:* ***Németh, T.*** – Kádár, I.: Heavy metals in the soil-plant system
11.45 – 12.00	Szalai, Z.: Heavy metal availability in Hungarian Alluvial Soils
12.00 – 12.15	Csillag, J. – Lukács, A. – Osztoics, E. – Csathó, P. – Baczó, Gy. Trace metal concentrations in the soil solution at increasing phosphate rock doses and acid loads in a bulk soil experiment

12.15 – 12.30 Tripolskaja, L. – Romanovskaja, D.: Influence of green manure on migration of nitrogen compounds in fine texture soils in Lithuania

12.30 – 12.45 Zubova, L.: The biological recultivation of waste banks in Donbas

13.00 – 14.30 Lunch

14.30 – 16.00 **Paper session IV.**
"Soil conservation and water management"

14.30 – 15.00 <u>*Key note:*</u> ***Pla Sentís, I.*** – Ramos, M.C. – Nacci, S. – Fonseca, F. – Abreu, X.: Soil and Water Conservation as Affected by Changing Mediterranean Climate and Land Management in Vineyards of Catalonia (NE Spain)

15.00 – 15.15 Sisák, I. – Máté, F. – Strauss, P. – Azazoglu, E.: Particulate and dissolved phosphorus loss by rill erosion from the watershed of the Tetves-stream

15.15 – 15.30 Davies, K. – Fullen, M.A.: Evaluating the soil conservation potential of palm leaf geotextiles at the Hilton Experimental Site, Shropshire, U.K.

15.30 – 15.45 Marinari, S – Mancinelli, R. – Campiglia, E. – Grego, S.: Chemical and physical properties of soil under organic management in Central Italy

15.45 – 16.00 Dimitrov, P. – Klevtzov, A.: Simulaneous assessment and control of water and soil quality - Methodology and some GIS applications

16.00 – 16.50 **Poster session IV. (Posters 36-49) and Coffee Break**
"Soil conservation and water management"

36. Stępniewska, Z. – Szmagara, A. – Ostrowski, J.: Redox resistance of soils enriched with nitrates
37. Reintam, E. – Kuht, J. – Puust, J. – Neem, P.: Composition of phytocoenose and uptake of nutrients depending on soil compaction in barley field
38. Uhlířová, J.: Soil and water protection – principles and realizations in agriculture
39. Novak, P. – Vopravil, J. –Tomasek, M. – Vetisková, D.: Water retention capacity of soils in the Czech Republic
40. Beltrán, E. M. – Miralles de Imperial, R. – Porcel, M.A. – Beringola, M.L. – Martin, J.V. – Calvo, R. – Delgado, M.M.: Olive grove soil conservation by addition of sewage sludge compost
41. Jigeu, G. – Slonovski, V. – Lupu, M. – Jolondkovski, A. – Jigeu, R.: The premises to institution to guaranteeing of soil preservation in Pricernomorski basin
42. Takács, K. – Füleky, Gy.: Medieval water conservation system in Hungary
43. Szlávik, L. – Deseő, É.: Flood control as a part of integrated river management in Hungary
44. Sisák, I. – Máté, F. – Szűcs, P.: Soil and phosphorus loss differences between two study catchments on the watershed of Lake Balaton
45. Spugnoli, P. – Melani, E.M.: Mechanical properties of a soil treated with brackish water
46. Díaz, F. – Jiménez, C.C. – Tejedor, M.: Influence of the thickness and grain-size of tephra mulch on soil water evaporation
47. Nikolova-Belcheva, B. – Alexandrova, P.: Investigation the qualitative parameters on basin water with reference to use it for irrigation
48. Chitanu, G.C. – Filipov, F. – Tomita, O. – Popescu, I. – Suflet, D.M.: The effect of the copolymer maleic anhydride-vinyl acetate on some chemical properties of the main organic components of horticultural substrata
49. Dumitru, E. – Canarache, A.: Soil Conservation in Romania - problems, research, control

16.00 – 17.00 ESSC Council Meeting

17.00 – 19.00 ESSC General Assembly

<u>**27th May, Thursday**</u>

09.00 – 10.15 **Paper session IV.**
"Soil conservation and water management"

09.00 – 09.15 Gillijns, K. – Govers, G.: Introduction of conservation agriculture in a highly mechanised agricultural system in Flanders, Belgium

09.15 – 09.30 Hecker, J.-M.: High resolution determination of bulk density – distribution in sealed soils

09.30 – 09.45 Schjønning, P.: Sustainability, the soil quality concept and the precautionary principle in soil conservation

09.45 – 10.00 Ginanni, M. – Bonari, E. – Risaliti, R. – Silvestri, N. – Pampana, S.: Environmental impact of energetical cropping systems in central Italy

10.00 – 10.15 Freer, J.E. – Quinton, J.N.: A simplified semi-distributed approach for mapping the risk of phosphorus sources connecting with surface water bodies

10.15 – 11.05 **Poster sessions V – VI. (Posters 50-57) and Coffee Break "Socio-economic aspects of soil degradation" – "Tillage erosion"**

"Socio-economic aspects of soil degradation"

50. Adiloglu, S. – Adiloglu, A.: An investigation on fertilizer production, consumption, export and import between 1998 and 2002 in Turkey
51. Michéli, E. – Szegi, T. – Montanarella, L.: Missing items for the developing European Soil Protection Strategy
52. Márton, L.: Rainfall and mineral fertilization interactions on crops yield

"Tillage erosion"

53. Rejman, J.: Comparison of tillage and water erosion rates on a loess slope: a case study from south-eastern Poland
54. László, P. – Gyuricza, Cs. – Liebhard, P. – Rosner, J.: Soil conservation by ridge tillage in Central Europe
55. Farkas, Cs. – Várallyay, Gy. – Tóth, E.: The effect of conventional and soil conserving tillage systems on soil hydraulic properties and soil water regime of a loamy Mollisol
56. Bádonyi, K: Measurement of ecological consequences of conventional and minimum tillage
57. Akande, O.O.: Studies in tillage and fertilizer interactions in a degraded alfisol

11.05 – 12.20 **Paper session V. "Socio-economic aspects of soil degradation"**

11.05 – 11.35 *Key-note:* Bakker, M.M. – ***Govers, G.*** – Rounsevell, M.A.: The crop productivity-erosion relationship

11.35 – 11.50 Szafranek, A. – Skłodowski, P.: Properties and sustainable management of cambic arenosols

11.50 – 12.05 Bakšienė, E.: The influence of sapropel on the changes of Haplic Luvisols properties and on the productivity of crop rotation

12.05 – 12.20 Dragović, N. – Zlatić, M. – Kostadinov, S.: Minimisation of direct costs in the construction of longitudinal structures for torrent management

12.30 – 14.00 Lunch

14.00 – 16.00 **Paper session VI. "Tillage erosion"**

14.00 – 14.30 *Key-note:* ***Kertész, Á.***: Conventional and conservation tillage from pedological and ecological aspects. The SOWAP project

14.30 – 14.45 Lane, M.: The concept and first results of the GECAP project

14.45 – 15.00 de Alba, S. – Borselli, L. – Torri, D. – Lindstrom, M.J.: Field evidence of intense tillage erosion

15.00 – 15.15 van Lynden, G. – Jones, C. – Leake, A.: A case study of soil and water protection using conservation tillage in N. Europe

15.15 – 15.30 Kisic, I. – Basic, F. – Othmar, N. – Mesic, M.: Soil erosion under different tillage systems in Croatia

15.30 – 15.45 de Alba, S. – Borselli, L. – Torri, D. – Reina, L. – Bartolini, D.: Assessment of tillage erosion rates in Tuscany (Italy) studying field features produced by past tillage practices
15.45 – 16.00 Tobias, S.: Deriving threshold values for soil compaction from expert judgement

16.00 – 16.20 Coffee break

16.20 – 17.50 Paper session VII. "Land degradation & desertification"

16.20 – 16.50 Key-note: ***Rubio, J.L.***: Forest fires and land degradation
16.50 – 17.05 Várallyay, Gy.: Control of extreme moisture events and soil degradation processes as priority tasks of soil conservation in the Carpathian Basin
17.05 – 17.20 Dazzi, C. – Monteleone, S. – Scalenghe, R.: Anthropogenic soils from severe soil disturbance due to large scale farming
17.20 – 17.35 Laudicina, V.A. – Pisciotta, A. – Territo, C.: Soil inorganic carbon in benchmark forest soils of Mediterranean environment: a case study from Sicily
17.35 – 17.50 Vacca, S. – Capra, G.F. – Biagioli, M. – Muntau, H.W. – Buondonno, A. – Loi, A.: A contribution to the knowledge about anthropogenic soils on and in urban waste deposits

28th May, Friday

09.00 – 10.30 Paper session VII. "Land degradation & desertification"

09.00 – 09.15 Karyotis, Th. – Argyropoulos, G. – Toulios, M. – Haroulis, A. – Mitsimponas, Th. – Katsilouli, E. – Georgiou, Th.: Factors influencing the properties and productivity of acid arable soils in the Tirnavos area, Central Greece
09.15 – 09.30 Castillo, V.M. – Barberá, G.G. – Navarro, J.A. – Mosch, W. – Martínez-Mena, M. – Albaladejo, J.: Reforestation of degraded shrublands for combating desertification in SE Spain: effects on soil properties
09.30 – 09.45 Blaskó, L.: GIS evaluation of a long-term experiment on salinization processing
09.45 – 10.00 Jigeu, G. – Konishesku, A. – Jolondkovski, A.: Conceptual and methodical bases of preservation physically soil degradation
10.00 – 10.15 Tarasov, V.I.: Control over stability of agricultural land to wind erosion

10.15 – 11.15 Poster session VII. (Posters 58-66) and Coffee Break "Land degradation & desertification"

58. Lóki, J.: Erosion sensitivity of the soils in Hungary – experiments based on wind tunnel experiences
59. Csuták, M.: Land degradation and desertification problems of the Great Hungarian Plain
60. Ingelmo, F. – Albiach, M.R. – Canet, R. – Gamón, S.: Water stable aggregates in an amended soil affected by simulated processes of soil degradation
61. Kuht, J. – Reintam, E. – Nugis, E. – Edesi, L.: About effect lupine (Lupinus luteus) root system on the properties of compacted soils
62. Dufkova, J. – Toman, F.: Water and wind erosion and its influencing by climate conditions
63. Van Oost, K. – Govers, G. – Heckrath, G. – Olesen, J.: Modelling the effect of soil redistribution by water and tillage on carbon dynamics in agricultural landscapes
64. Dikkeh, M.: Comparing Wind Erosion (Field Measurements) with Simulated by (WEPS)
65. Vacca, S. – Capra, G.F. – Muntau, H.W. – Loi, A. – Biagioli, M.: Heavy metal contamination of urban soils: A case study (Nuoro/Sardinia, Italy)
66. Vacca, S. – Banov, M.D. – Petrov, N. – Muntau, H.W. – Aru, A. – Buondonno, A. – Capra, G.F. – Biagioli, M.: Evaluation of the state of contamination from heavy metals in the soils and the waters in the mining district of Mikaljlovgrad (North-Western Bulgaria)

11.15 – 12.45 ESSC and the Advisory Forum on EU Soil Policy

13.00 – 14.30 Lunch

14.30 – 15.30 Conclusions of the Main Topics of the Congress
15.30 Closing ceremony

19.00 Congress dinner

29th May, Saturday

FIELD TRIP

All day field trip to Lake Balaton Catchment
Main scientific topic: Soil erosion, conservation measures, minimum and conventional tillage
For detailed programme please see the “Fieldguide”.

30th May, Sunday

Departure

– ORAL PRESENTATIONS –

Integration of soil conservation issues into multifunctional land use

Helming, K.[1] – Zander, P. – Schuler, J. – Müller, K. – Wiggering, H.

Soil erosion in Europe is inevitably related to agricultural land use. Whereas the off-site damages of soil erosion are often effective at the catchment scale, the actual run-off and soil erosion risk is determined by decisions on agricultural management practices taken at the farm scale. Therefore, farming system management plays a key role in combating run-off and soil erosion, implementing best management practices, run-off prevention and soil conservation measures.

Soil erosion and degradation processes have extensively been studied during the last decades and soil conservation measures have successfully been developed. However, the implementation of conservation measures in farming systems in Europe has not been satisfactory. One reason for this might be due to a lack of reconciliation of soil conservation issues with further agricultural management targets. Any operation on agricultural land has to fit within the farm organisation, which involves the simultaneous consideration of social, economic and environmental concerns. Farmers generally follow the economic rationality in their decision making, which is determined by the economic and political conditions.

Agricultural policies on EU, national and regional level are powerful measures to govern farmers decision making and include environmental and social concerns in management practices. The concept of multifunctionality of agriculture as developed by the OECD and EU opens new opportunities to consider and value environmental, social and economic effects of agricultural production as “non commodity outputs”, which complement the production of food and fibre (commodity outputs). With adequate policy instruments, the production of non-commodity outputs such as soil conservation can then be remunerated as an environmental service, which is demanded by the society.

This paper describes, based on the exemplary case of soil conservation, an analytical framework for the implementation of multifunctionality issues into agricultural policies and management practices.

[1] ZALF, Leibniz-Centre for Agricultural Landscape and Land Use Research, Müncheberg, Germany., Tel.: +49 33432 82155; Fax: +49 33432 82223; E-mail: khelming@zalf.de

Remote sensing-based assessment of land condition in Mediterranean Europe

Boer, M.[1] – Puigdefábregas, J. – Hill, J.

Background and approach

Much of the land in the Mediterranean Region is inherently vulnerable to degradation processes, due to the combination of pronounced relief, erodible soils, high-intensity rainfall, prolonged droughts, and a long history of human land use (e.g. Brandt et al. 2002). Existing information on the actual land degradation status is highly fragmented and often of a qualitative nature, which makes it practically impossible to obtain an overview of the situation at a European scale. As part of the LADAMER project (*'Land degradation assessment in Mediterranean Europe'*), a new procedure for land condition assessments at continental scales is being developed. It focuses on the dryland environments within Mediterranean Europe and uses remotely-sensed vegetation indices and spatially-distributed climate information as the main data inputs.

A major symptom of dryland degradation is the gradual loss of the land's capacity to retain and utilise local water resources for primary production (Ludwig et al. 1997; Boer 1999). In non-degraded drylands, practically all local precipitation is retained on-site and is potentially available for plant growth. As the land degrades, plant available moisture (PAM) is reduced to increasingly smaller fractions of the long-term precipitation (P). The ratio PAM/P, when measured over several growth cycles, potentially forms an objective measure of dryland condition. For non-degraded sites PAM/P approaches 1.0, whereas (much) smaller values indicate degradation. The accuracy of PAM/P as a land condition indicator would be enhanced by stratifying for spatial variation in climate and soil characteristics that form boundary conditions for plant water use but are independent of the condition of the land (e.g. soil texture). A key research issue for the operationalisation of this approach is the development of procedures for the spatially explicit quantification of PAM over timescales of several years or longer. Existing methods for the remote sensing of soil moisture content (Carlson & Gillies 1991; Goward et al. 2002; Nemani et al. 1993; Schmugge 1978; Wang et al. 2004) are impractical for the mapping of long-term conditions. The general moisture limitation of primary production in dryland environments provides possibilities for the assessment of long-term PAM/P from the analysis of the remotely-sensed vegetation response to local climate and soil conditions. The vegetation response integrates short-term fluctuations in soil and weather conditions into a seasonal signal and can therefore convey relevant information on the condition of the land more efficiently than observations of more variable land properties such as soil moisture.

These considerations are leading us to the development of an approach for the assessment of land condition from remotely-sensed vegetation observations that consists of two basic components: i) a model for the prediction of the potential vegetation response (V_{max}) corresponding to: $PAM/P \cong 1.0$, ii) a procedure for the quantification of the deviation between the predicted potential response (V_{max}) and the actually observed response (V) in terms of PAM/P. To be operational both steps of the assessment need to be based on readily available spatially explicit information. In this paper we report on preliminary results obtained with the approach for the Iberian Peninsula using NOAA-AVHRR images.

Material and methods

Sixty monthly Normalised Difference Vegetation Index (NDVI) images for the Iberian Peninsula covering the period September 1996-August 2001 were extracted from the MEDOKADS archive of NOAA-AVHRR data (source: D. Koslowski, FU Berlin), and resampled to a 1 km grid with a Lambert Transverse Azimuthal Equal Area projection. A time-integrated NDVI (TINDVI) image was computed for every pixel by summation of the sixty monthly NDVI values and used as an indicator of V. Time-integrated NDVI is correlated with the photosynthetically active radiation intercepted by the vegetation canopy (Sellers et al. 1992) and was used before as a measure of aboveground net primary production in different environmental settings (Holm et al. 2003; Paruelo & Lauenroth 1995; Hill & Donald 2003). By basing the assessment on five consecutive hydrological years spatial differences in vegetation response are likely to convey relevant information on land condition and less affected by short-term events and disturbances (Ludwig & Tongway 1992). Spatially-distributed estimates of mean annual precipitation (P) and potential evapotranspiration (E_0) were computed for mainland Spain using, respectively, a multiple regression model with latitude, longitude and altitude as independent variables (Sanchez Palomares et al. 2003), and a linear function of mean annual temperature (Le Houérou 1995). A spatially distributed estimate of the soil water holding capacity (SWHC) in the top 1 metre was computed from soil texture and soil depth data. A simplified version of the Corine Land Cover Classification was used as a map of current land use.

[1] Consejo Superior de Investigaciones Científicas - Estación Experimental de Zonas Áridas, General Segura 1 04001 Almería, Spain. Tel.: +34-950-281045; Fax: +34-950-277100; E-mail: mboer@eeza.csic.es

As a first step in the assessment the dryland environments in mainland Spain were identified by selecting all grid cells where mean annual E_0 exceeds mean annual P. Next, the remaining study area was sub-divided into 24 sub-areas by stratifying for four SWHC classes (i.e. < 50 mm, 50-100 mm, 100-150 mm, > 150 mm) and six E_0 classes (i.e. < 900 mm.y^{-1}, 900-1000 mm.y^{-1}, 1000-1100 mm.y^{-1}, 1100-1200 mm.y^{-1}, 1200-1300 mm.y^{-1}, > 1400 mm.y^{-1}). We assumed that the observed maxima of TINDVI, for a given climate and soil, correspond to non-degraded sites where TINDVI≅$TINDVI_{max}$ and PAM/P≅1.0. A suite of regression models for the prediction of $TINDVI_{max}$ was constructed by plotting observed TINDVI against mean annual precipitation (P) for each sub-area and fitting a logarithmic or exponential function through the upper edge of the data envelop (Figure 1). The upper edge of the data envelop was defined by the 99% TINDVI values for every 100 mm interval of mean annual P (Boer & Puigdefábregas 2003), and was interpreted as the maximum response of the vegetation for the situation where long-term PAM/P=1.0. To focus on rainfed systems, grid cells of the following land cover types were excluded from the regression analyses: urban, industrial, irrigated agriculture, wetlands, and water bodies.

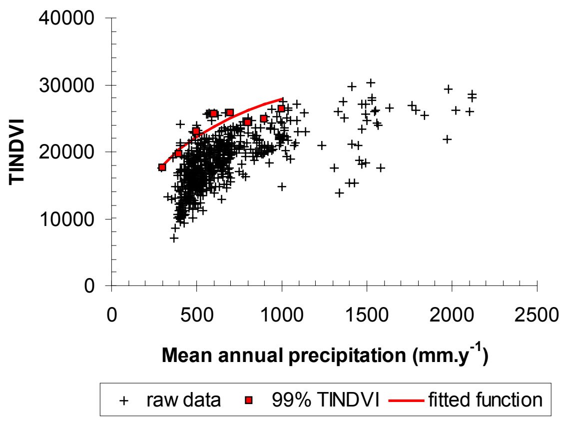


Figure 1. Example of a P-TINDVI data envelop and P-$TINDVI_{max}$ reference function (red curve) for the population of grid cells with SWHC class 2 (i.e. 50-100 mm) and mean annual E_0 class 2 (900-1000 mm.y^{-1}). The analysis was restricted to data from dryland environments, defined by mean annual E_0 being equal to, or greater than, mean annual P (in this example 1000 mm.y^{-1}).

The suite of regression equations define a reference surface for each SWHC class with mean annual P and E_0 as independent variables and $TINDVI_{max}$ as the dependent variable (Figure 2). All grid cells that plot below the reference surface were supposed to be degraded. To quantify the condition of the land in terms of PAM/P we assumed that: i) as far as long-term water relations of the vegetation are concerned, non-degraded sites (i.e. TINDVI≅$TINDVI_{max}$) with low mean annual precipitation and/or inherently small soil water holding capacity (e.g. shallow sandy soils) can be used as spatial analogues of degraded land (i.e. TINDVI<$TINDVI_{max}$) with higher mean annual precipitation and/or inherently greater soil water holding capacity (e.g. deep loamy soils), and hence ii) inversion of the reference surface function (Figure 2) provides an estimate of PAM/P for sites where the actually observed vegetation response (TINDVI) is inferior to the predicted potential vegetation response ($TINDVI_{max}$).

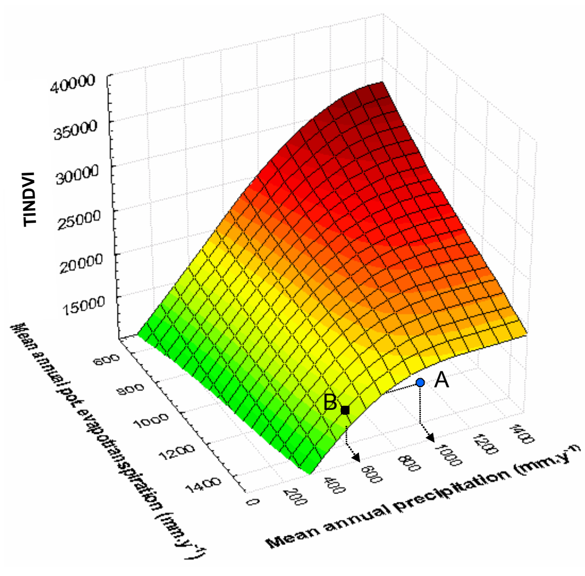


Figure 2. Hypothetical reference surface representing the maximum vegetation response, $TINDVI_{max}$, for given mean annual precipitation (P), pot. evapotranspiration (E_0) and soil water holding capacity. At site A, with P and E_0 of, respectively, 1000 mm.y^{-1} and 1400 mm.y^{-1}, the observed TINDVI is inferior to the predicted $TINDVI_{max}$ for A, but equal to the actually observed TINDVI at site B, with the same soil water holding class and E_0 but P of only 600 mm.y^{-1}. The land condition index, for A would then be 600/1000=0.6

Discussion of results

The plotted P-TINDVI data envelops had rather sharp upper edges. Fitted functions of the form $TINDVI_{max}$=a+b.log10(P), and in some cases $TINDVI_{max}$ = a.(1-exp(-b.P^c)), generally explained more than 90% of the variance in the 99% TINDVI values and were highly significant. This finding confirmed the assumed moisture limitation of the vegetation response at the spatial and temporal scales of this study (i.e. 1 km^2 and 5 years). The land condition index, PAM/P, was computed by inversion of the reference functions for each of the sub-areas (Figures 2, 3). Our assessment indicates that extensive areas in relatively poor condition occur on the Northern and Southern Mesetas and in the upper Guadalquivir basin, while areas in relatively good condition are found, for example, in the central Ebro valley and in the mountain ranges of the interior.

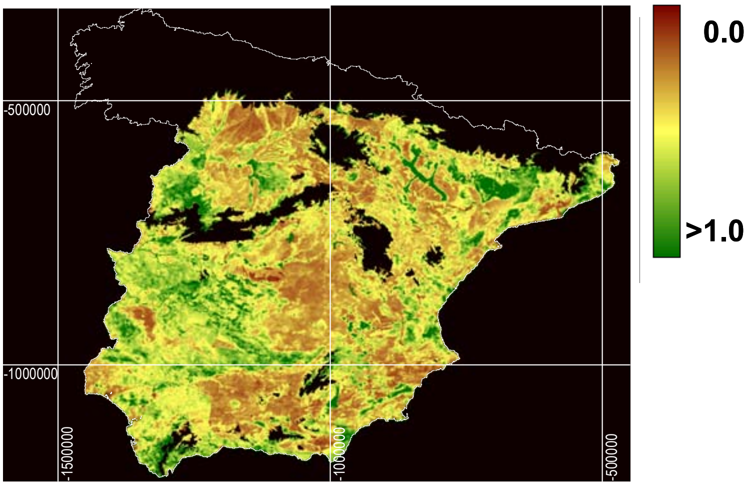


Figure 3. Land condition index, computed from the ratio of long term PAM and P. The black areas correspond to non-dryland environments.

This land condition assessment was based on readily available information only. It provides an interpretation of the deviation between the actually observed state of the vegetation and the potential state predicted from local climate conditions and soil water holding capacity. By comparing observed vegetation responses with a spatially-distributed reference situation, confusion of land degradation with 'natural' phenomena, due to spatial or temporal variability in environmental boundary conditions, is being reduced. The assessment of land condition in terms of a vegetation response relative to climatically available soil moisture is conceptually sound with current ecological understanding of dryland degradation (e.g. Ludwig et al. 1997), and in line with recent recommendations for the detection of desertification (Prince 2002). So far, the approach has been applied without distinguishing agricultural land cover types (e.g. annual crops) from non-agricultural types (e.g. evergreen shrubland), thus assuming that the same reference function applies to all land use types. The resulting assessments suggest that land in poor condition is particularly widespread in areas of rainfed agriculture, whereas land in relatively good condition is frequent in areas dominated by shrub or forest vegetation. From a soil hydrological point of view this pattern makes good sense, since dynamic soil properties, such as infiltration capacity, organic matter content and aggregate stability, that are used as indicators of the 'health' of the soil e.g. are known to be negatively affected by many forms of agricultural land use (e.g. Cammeraat & Imeson 1998). A validation of the land condition assessment against independent data (e.g. agricultural and forestry statistics) is now underway to determine whether the contrasting condition of areas with agricultural and semi-natural vegetation covers is justified or, for example, a stratification for gross differences in growth forms should be made. Other research priorities include the implementation of enhanced methods for the quantification of the vegetation response, and the use of improved climate surfaces.

References

Boer, M. M. Assessment of dryland degradation: linking theory and practice through site water balance modelling. 1999. Dept. Phys. Geography, Utrecht University, Utrecht, The Netherlands.

Boer, M. M. & Puigdefábregas, J. 2003. Predicting potential vegetation index values as a reference for the assessment and monitoring of dryland condition. *International Journal of Remote Sensing* 24: 1135-1141.

Brandt, J., Geeson, N. & Thornes, J. B. (eds.) 2002. *Mediterranean desertification: a mosaic of processes and responses*. John Wiley & Sons, Chichester.

Cammeraat, L. H. & Imeson, A. C. 1998. Deriving indicators of soil degradation from soil aggregation studies in southeastern Spain and southern France. *Geomorphology* 23: 307-321.

Carlson, T. N. & Gillies, R. R. 1991. Remote sensing of soil moisture over vegetation. Sensitivity and limitations of the infrared temperature method. *Proceedings of the 20th Conference on Agricultural and Forest Meteorology, held at Salt Lake City, Utah, September 1991*, pp. 214-217. American Meteorological Society, Boston, Massachusetts.

Goward, S. N., Xue, Y. & Czajkowski, K. P. 2002. Evaluating land surface moisture conditions from the remotely sensed temperature/vegetation index measurements; An exploration with the simplified simple biosphere model. *Remote Sensing of Environment* 79: 225-242.

Hill, M. J. & Donald, G. E. 2003. Estimating spatio-temporal patterns of agricultural productivity in fragmented landscapes using AVHRR NDVI time series. *Remote Sensing of Environment* 84: 367-384.

Holm, A. M., Cridland, S. W. & Roderick, M. L. 2003. The use of time-integrated NOAA NDVI data and rainfall to assess landscape degradation in the arid shrubland of Western Australia. *Remote Sensing of Environment* 85: 145-158.

Le Houérou, H. N. 1995. *Bioclimatolgie et biogeographie des steppes arides du Nord de l'Afrique*. CIHEAM / ACCT, Zaragoza.

Ludwig, J. A. & Tongway, D. 1992. Monitoring the condition of australian arid lands: linked plant-soil indicators. In: McKenzie, D. H., Hyatt, D. E. & McDonald, V. J. (eds.) *Ecological Indicators. Proceedings of an International Symposium, Fort Lauderdale, Florida, USA, October 16-19, 1990*, pp. 765-772. Chapman & Hall, London.

Ludwig, J. A., Tongway, D., Freudenberger, D., Noble, J. & Hodgkinson, K. 1997. *Landscape ecology, function and management. Principles from Australia's rangelands*. CSIRO Australia.

Nemani, R. R., Pierce, L. L., Running, S. W. & Goward, S. N. 1993. Developing satellite derived estimates of surface moisture status. *Journal of Applied Meteorology* 32: 548-557.

Paruelo, J. M. & Lauenroth, W. K. 1995. Regional patterns of Normalized Difference Vegetation Index in North American shrublands and grasslands. *Ecology* 76: 1888-1898.

Prince, S. D. 2002. Spatial and temporal scales for detection of desertification. In: Reynolds, J. F. & Stafford Smith, D. M. (eds.) *Global desertification, do humans cause deserts?*, pp. 23-40. Dahlem University Press, Berlin.

Sanchez Palomares et al. Modelos y cartografia de estimaciones climaticas para la España peninsular. 2003. MAPA, INITAA, Madrid.

Schmugge, T. 1978. Remote sensing of surface soil moisture. *Journal of Applied Meteorology* 17: 1549-1557.

Sellers, P. J., Berry, J. A., Collatz, G. J., Field, C. B. & Hall, F. G. 1992. Canopy reflectance, photosynthesis, and transpiration. III. A reanalysis using improved leaf models and a new canopy integration scheme. *Remote Sensing of Environment* 42: 187-216.

Wang, C., Qi, J., Moran, S. & Marsett, R. 2004. Soil moisture estimation in a semiarid rangeland using ERS-2 and TM imagery. *Remote Sensing of Environment* 90: 178-189.

The influence of land-use change to soil cover properties and functioning

Kõlli, R.[1] – Lemetti, I. – Penu, P.

Introduction

The transformation of land-use from one mode to another and regulation connected with this carbon cycling are permanently existing world-wide problems (Pulleman *et al.,* 2000; Kimble *et al.,* 2002). In Estonia land-use changes were normally confined to limited areas and were caused by new social-economical situation on the local as well as state level. Drastic changes took place in the nineties of the last century, when because of the economic and social reasons a large part of arable land was set aside. In connection with this, problems regarding soil conservation and assessment of different soil types' environment protection ability in different land-use conditions were aroused. Besides, the land-use changes are by far not only problems of agriculture and environment, moreover, there are clearly visible social, state strategic and ethic aspects. In the evaluation of changes of soil properties and functioning the most important characteristic is soil organic matter (Kern, 1994; Percival *et al.,* 2000; Rusco *et al.,* 2001; West *et al.,* 2002). In this work the land-use changes to soil organic carbon (SOC) and matter (SOM) are treated.

Material and methods

The quantitative characteristics of arable and forest soils originate from soil profile database PEDON, which was formed in the years 1967-85 and updated 1986-95 and 1999-2002. Postlithogenic mineral soils studied in this work form 86% of the total arable land and 61% from forest land. Changing of soil cover properties and functioning as a result of land-use changing may be to a certain extent explained by data of comparative studies of SOC and SOM of natural and cultivated lands formed on the same soil type. The nomenclature and correlation of Estonian postlithogenic mineral soils with WRB used in this work is presented on Figure 1.

The pools of SOC and SOM of different soil types were estimated by two soil layers: (1) in the humus cover and (2) in the soil cover. Humus cover consists of superficial horizons, containing remarkable concentration (>0.6%) SOC. The soil cover or solum depth reaches from the surface to the unchanged parent material, consisting therefore of humus cover and subsoil. The SOC and SOM pools were determined on the basis of soil bulk density. For ANOVA the PC program MS Exel was used. The soil group names and codes are given in the system of WRB (FAO et al., 1998). Presented matrix, which embraces all Estonian postlithogenic mineral soils, was used also for the generalisation of SOM data.

Results and discussion

Land-use change influences first of all the soil humus cover or epipedon, which is as a transition layer between vegetation and soil in natural conditions and is mainly mechanically manipulated and from aside subsidated soil cover part in cultivated areas. Clearly visible differences between forest and arable soils can be seen in epipedon fabric. On forest soils the forest floor is formed, where depending of the concrete pedoecological situation the exogenic soil part of SOC increased. Regularities of these changes in connection with soil types may be well explicated by humus cover types on the background of Estonian postlithogenic mineral soil matrix (Figure 1). Along the vertical scalar (from *Rendzic Leptosols* to *Haplic Podzols*) the endogenic humus covers change step by step by exogenic ones or changes in sequence *mull=>moder=>mor* are followed. Along the horizontal or moisture conditions scalar developed on automorphic soils dry and fresh humus covers are changed by wet and peaty ones on hydromorphic soils (*Epigleyic & Histic Gleysols)* in the sequence *dry=>fresh=>moist=>wet=>peaty.*

On arable mineral soils in conventional soil management conditions the development of exogenic humus covers is prevented due to regular soil tillage. In most cases the thickness of arable humus covers (endogenic) surpasses that of natural areas (Table 1). If we take into account also the epipedon volume weight, which is always higher in arable soils, then it is clear that soil mass of arable soil humus cover overpasses the same of natural ones.

As natural soil humus covers, the ones of arable soils are also developed in concordance with soil type and their correlation may be explicated on the background of mineral soil matrix. It can be concluded that there must also be a good correlation between the classifications of natural and arable soil humus covers. Consequently it is possible to predict probable humus cover type which begins to form after land-use changing. For example, with cultivation of *Calcaric Cambisols* with *fresh mull* humus cover probably *neutral or pebble mild* humus cover is formed, but

[1] Estonian Agricultural University; Kreutzwaldi Str. 64, Tartu 51014, Estonia, Tel.: +3727313536, Fax: +3727313539; E-mail: raimo@eau.ee

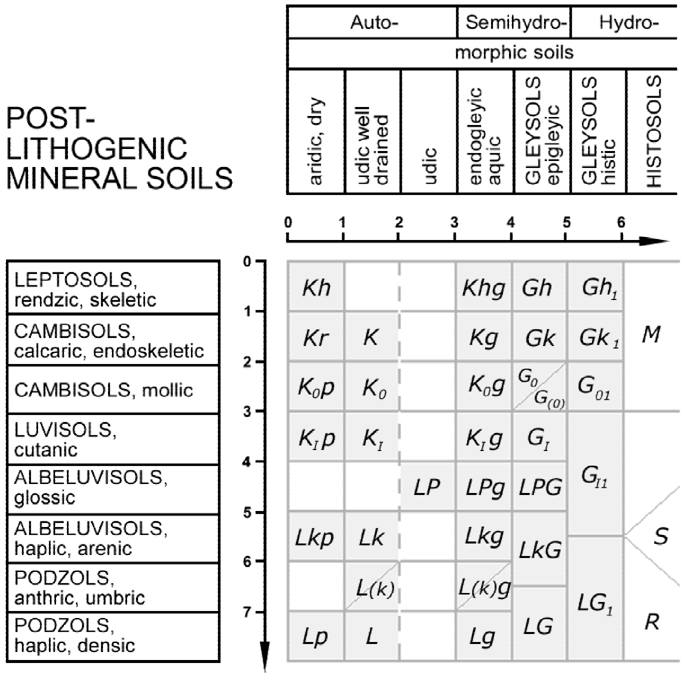


Figure 1. Correlation of Estonian postlithogenic mineral soil codes with WRB soil names.
Kh - *Rendzic Leptosols*, Khg - *Endogleyic Leptosols*, Kr - *Calcari-Skeletic Regosols*, K - *Calcaric Cambisols*, Kg - *Endogleyi-Calcaric Cambisols* Ko - *Mollic Cambisols*, Kog - *Gleyic Cambisols,* KI - *Cutanic Luvisols,* KIg - *Gleyic Luvisols,* LP - *Glossic Albeluvisols,* LPg - *Stagnic Albeluvisols,* Lk - *Haplic Albeluvisols,* Lkg - *Gleyic Albeluvisols* L(k) - *Humic Podzols,* L(k)g - *Gleyi-Humic Podzols,* L - *Haplic Podzols,* Lg - *Gleyic Podzols,* Gh - *Epigleyic Leptosols,* Gk - *Calcari-Skeletic Gleysols,* Go - *Mollic Gleysols,* G(o) - *Calcic Gleysols,* GI - *Dystric Gleysols*, LPG - *Glossic Gleysols*, LkG - *Umbric Gleysol,* LG - *Epigleyic Podzols,* Gh_1 - *Saprihistic Leptosol,* Gk_1 - *Calcari-Histic Regosols,* Go_1 - *Saprihistic Gleysols,* GI_1 - *Dystri-Histic Gleysols,* LG_1 - *Fibrihistic Podzols.*
Remarks: 1) meanings of additional letters in soil codes are: p - aridic; g - endogleyic and $_1$ - histic, 2) the last column (M S R) belongs to *Histosols*.

forestation of *Glossic Albeluvisols* with *acid low or eluvic moder humous* arable humus cover probably the *fresh moder-mor* humus cover type is developed.

For sustainable soil management it is useful to know the best humus cover types from the aspect of biological activity, ecosystem productivity and environment protection ability (substances cycling intensity) for local pedoclimatic conditions. From the agronomic aspect the best humus covers belong to the neutral mild humus cover type, the main constraints of others may be high acidity, low humus content, raw-humous fabric and wet moisture conditions. From the aspect of forest management postlithogenic mineral soils with good edaphic properties are *moist&fresh&wet mull&moder* humus covers. The other main constraints are excess of water (low biological activity, *peaty* types) as well as extremely high acidity or/and poor chemical-mineral composition (*mor* types).

From the material above and data Table 1, it can be revealed that multi-layered humus covers of natural areas are thinner, but arable ones are homogenized and thicker. On arable soils a good characteristic is mean SOC or SOM content (concentration) in arable layer, which at the same time depends on soil calcareousness and soil texture. We must be more attentive only in the case of poorly drained semihydromorphic soils, where raw-humous SOC may be present to a certain extent, the agronomic quality of which is not equal to the automorphic soil. For the characterisation of natural soils it is practically impossible to use humus cover SOC or SOM concentration, as there exists rather the vertical concentration continuum (from 100% to 1% SOM) in different forms of curve. Only in certain cases the weighed (by mass or volume) means of SOM or SOC concentration may be used. The most suitable indicators in comparative analysis of different humus covers are SOC pools (Table 2). As may be seen from this data, in most cases statistically proved differences between humus cover SOC pools in arable and forest soils are absent. At the same time SOC in humus cover has statistically proved differences between certain soil types because the tendencies of their development are the same both in arable and forest soils. Statistically proved differences between natural and arable *Gleysols* SOC pools indicates highly cultivated (well managed) soil where due to artificial drainage the humus content is stabilised according to newly formed situation.

Table 1. Studied soil groups[1] and thickness (M±SD[2], cm) of soil cover layers

Soil or soil association	Soil code by WRB	Forest soils			Arable soils		
		n	**HC[3]**	**SC[4]**	**n**	**HC**	**SC**
Rendzic&Skeletic&Gleyic Leptosols	LP rz sk gl	7	17±5	24±4	12	21±4	22±6
Calcaric&Endoskeletic Cambisols	CM ca skn	5	23±10	56±19	20	27±5	36±11
Mollic&Endogleyic Cambisols	CM mo gln	12	20±9	47±8	26	29±7	56±18
Sceletigleyic Cambisols	CM gls	3	19±8	43±10	0	-	-
Cutanic&Endogleyic Luvisols	LV ct gln	11	24±6	70±19	8	27±5	74±20
Glossic&Gleyiglossic Albeluvisols	AB gs gsg	18	19±5	92±19	13	26±6	93±8
Haplic&Endogleyic Albeluvisols	AB ha gln	26	19±6	75±18	21	25±8	73±15
Haplic& Endogleyic Podzols	PZ ha gln	27	5±2	65±22	-	-	-
Mollic&Calcic&Eutric Gleysols	GL mo cc eu	8	26±5	39±13	6	22±4	38±15
Luvic&Epidystric Gleysols	GL lv dye	16	25±4	55±21	4	26±5	54±22
Spodic&Umbric&Dystric Gleysols	GL sd um dy	8	16±5	70±15	2	23	100
Saprihistic Gleysols	GL his	5	23±5	51±12	1	18	33
Fibrihistic Podzols	PZ hif	13	15±4	76±18	-	-	-

1) Kokk, 1995; 2) M - mean, SD - standard deviation; 3) HC - humus cover, 4) SC - soil cover.

Table 2. SOC pools (Mg ha^{-1}, M±SE[1]) in postlithogenic mineral soils

Soil code by WRB	Forest soils				Arable soils			
	%[2]	n	HC	SC	%[3]	n	HC	SC
LP rz sk gl	0.8	8	82±14	102±15	0.8	12	77±9	78±10
CM ca skn gls	3.2	9	82±18	105±17	11.1	20	59±3	68±4
CM mo gln	3.3	13	49±6	76±5	14.5	26	69±5	101±7
LV ct gln	2.4	12	75±6	95±6	13.5	8	62±7	92±10
AB gs gsg	3.6	19	42±4	64±4	21.3	13	49±4	69±4
AB ha gln	4.3	28	44±4	69±8	5.2	21	49±5	76±8
PZ ha gln	6.0	31	18±2	45±5	0.0	-	-	-
GL mo cc eu	12.1	15	113±15	120±16	10.3	6	74±17	83±18
GL lv dye	8.0	16	118±14	126±13	5.8	4	131±50	144±45
GL sd um dy	9.2	7	39±9	113±16	0.8	2	34	53
GL his	5.3	5	165±42	209±33	2.5	1	189	194
PZ hif	3.1	13	46±5	114±13	0.0	-	-	-

1) M - mean, SE - standard error; 2) % from forest soils, 3) % from arable soils.

It should be noted that in naturally proceeding stabilisation processes the decrease of SOC concentration in topsoil is not always accompanied with the decrease or loss of humus cover SOC pools, as at the same time the depth of humus cover increases (observed effect of dilution) and also the humus binding (stabilising) extent increases. In this context the question of the efficiency of non-tillage management may be arisen. Following natural models or patterns seems optimal to the ameliorative organic residue on the soil surface, with surface density between 3-5 Mg ha^{-1}. The expedient residue's quantity ought to attain nearly 100% of the coverage of soil, contain nutrition elements corresponding to the medium input level and must be equilibrated from the aspect of C:N as well as mutual nutrition elements ratios.

Soil cover thickness is also not so much influenced by land-use, but first of all a peculiarity connected with soil type and local conditions. SOC pools demonstrated an important role of subsoil in carbon sequestration. From this aspect there are also no clearly visible regularities in the differences between arable and forest land soils or the connection with land-use change. More figurative regularities are received by the generalisation of SOM data on Figure 2. The comparison of Figures 2.B. and 2.E. shows that cultivation of *Albeluvisols* and *Podzols* is accompanied by increasing SOM pools in humus cover, as without this the normal plant breading is impossible. The parent material humus covers formed on calcareous soils tend to have the biggest SOM pools under forests. In the forest most calcareous soils have higher SOM pools than it is possible to have under frequent cultivation.

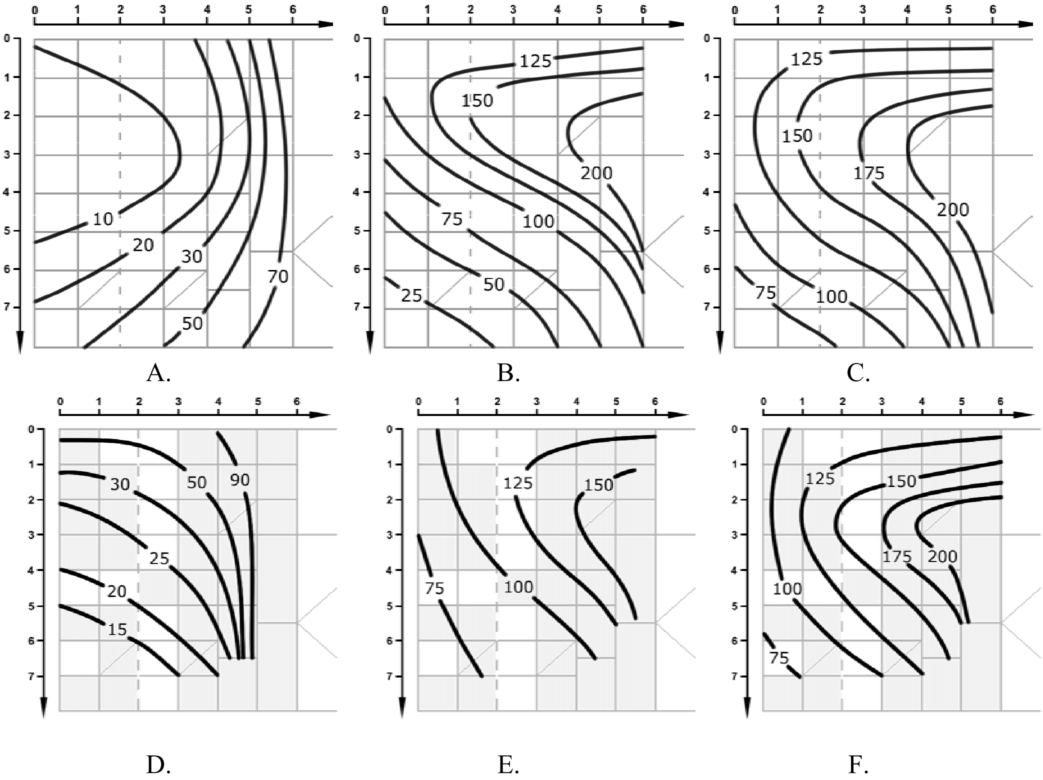


Figure 2. Isolines of generalized SOM contents and pools in postlithogenic mineral soils.

Forest soils: A. SOM pools in forest floor (Mg ha^{-1}); B. SOM pools (Mg ha^{-1}) in humus cover; C. SOM pools (Mg ha^{-1}) in soil cover.
Arable soils: D. SOM content in arable layer (g kg^{-1}); E. SOM pools (Mg ha^{-1}) in humus cover; C. SOM pools (Mg ha^{-1}) in soil cover.

For each soil type SOC (and SOM) retaining capacity is characteristic to a certain extent. Depending on variation of individual site specific soil properties (soil moisture regime as well as different layers carbonate and clay content) the carbon retaining capacity varies to a great extent. Cultivation of soils declines the humus cover toward homogenisation and decreasing of natural diversity.

The correlation between classification units of various soils and humus cover types is substantial, but not absolute due to phenomenon of interference. In spite of this, soil morphometric and humus status characteristics may be successfully used in the determination of soil suitability and in the planning of landscape.

Acknowledgement

Funding for the research was provided by the Estonian Scientific Foundation (grant 4991).

References

FAO, ISRIC & ISSS, 1998. *World Reference Base for Soil Resources*. World Soil Resources Reports 84. Rome.

Kern, J.S. 1994. Spatial patterns of soil organic carbon in the contiguous United States. *Soil Sci. Soc. Am. J.* **58,** 439-455.

Kimble, J.M., Lal, R. & Follett, R.F. (Eds.) 2002. *Agricultural practices and policies for carbon sqeuestration in soil.* CRC Press, Boca Raton, London, New York, Washington.

Kokk, R. 1995. Distribution and properties of soils. In *Estonia. Nature,* (A. Raukas, Ed.) pp. 430-439. Valgus, Tallinn

Percival H.J., Parfitt, R.L. & Scott, N.A. 2000. Factors controlling soil carbon levels in New Zealand grasslands: Is clay content important. *Soil Sci. Soc. Am. J.* **64,** 1623-1630.

Pulleman, M.M., Bouma, J., van Essen, E.A. & Meijles, E.W. 2000. Soil organic matter content as a function of different land use history. *Soil Sci. Soc. Am. J.* **64,** 689-693.

Rusco, E., Jones, R. & Bidoglio, G. 2001. *Organic matter in the soils of Europe: Present status and future trends.* ESB, IES, JRC, Ispra.

West, T.O. & Post, W.M. 2002. Soil organic carbon sequestration rates by tillage and crop rotation: A global data analysis. *Soil Sci. Soc. Am. J.* **66,** 1930-1946.

Land use change and its consequences in southern Thailand

Tanavud, C.[1] – Yongchalermchai, C. – Bennui, A.

Abstract

Using GIS and satellite imagery, this article examines changes in land use and evaluates the environmental consequences of such changes with specific reference to southern Thailand. During 1980-2000, forest resources in southern Thailand were depleted from 2,632,726 hectares to 2,044,023 hectares, equivalent to a decrease of 22.4 %. This observed change was largely attributed to the expansion of rubber cultivation. Indeed, it was evident that during the same period the area under rubber cover increased by a total of 1,591,511 ha, equivalent to an increase of 117.5 %. These inappropriate land use practices disturb the finely tuned equilibrium of the natural ecosystems to such a degree that environmental stability has been compromised. As a result of environmental degradation, southern Thailand has become vulnerable to the occurrence of natural disasters, primarily floods, with consequent impacts on the fragile environment.

Due to population pressure, land use patterns which contribute to the flood disasters are continuing, resulting in further increases in hazard and vulnerability levels. Such hazard events can restrain social and economic development due to the loss of life, the destruction of property and infrastructure and, the degradation of the natural environment that they can cause. To cope with the impact of the flood hazards, areas that are at risk need to be delineated and appropriate risk reduction programmes implemented. In the present study, it was estimated through the use of GIS that 209,100 762,900 and 343,100 ha of land areas in southern Thailand are subjected to low, moderate and high flood risks, respectively. Results also revealed that 143,700 ha of land areas subject to high risk are in Nakhon Si Thammarat Province. Risk reduction programmes are discussed in this paper.

Key words: Land use changes, flood disaster, flood risk area, flood risk reduction programme, Geographic Information Systems, satellite imagery

Background

Situated between latitudes 5 º 35 ´ and 11 º 02 ´ N and longitudes 98 º 12 ´ and 102 º 5 ´ E, southern Thailand covers an area of approximately 7,787,700 ha, equivalent to 13.8 percent of the total area of the country. The southern peninsular experiences higher temperatures and heavier, more frequent precipitation. The average monthly temperature is 27.1 ºC. Annual rainfall across the southern region averages 2,581 mm but is highly seasonal, resulting in floods in the wet season and a pronounced water deficit in the dry season. The population in southern Thailand was 8,066,779, which was about 13.1 percent of the national total. The economy of the region is agricultural in nature. Traditionally, rubber is cultivated in the foothills, fruit trees and mixed orchards on the undulating and rolling, rice on the lowlands and, shrimp farming on the coastal zones. The high slopes on the hills and mountains are covered with forests.

Over the years, in response to necessity and economic opportunity, much of the forest in the upland watershed has been gradually replaced by rubber plantation. The destruction of forests in these environmentally critical areas disturb the finely tuned equilibrium of the natural ecosystem to such a degree that environmental stability has been compromised. As a result of environmental degradation, southern Thailand has become vulnerable to the occurrence of natural disasters, primarily floods. Such hazardous events present a threat to the human environment (human life and socio-economic factors), built environment (property, buildings and infrastructure) and natural environment (geography and physiology). To reduce the negative impacts these hazards have on the vulnerable social and economic development of southern Thailand, areas that are at risk need to be delineated and appropriate risk reduction programmes implemented.

Land use changes

Through the use of GIS and satellite imagery, it was found that, in 1980, forests covered an estimated 2,632,726 hectares, representing the largest land use category in the region (Table 1). Between 1980 and 1990, forest resources were depleted by a total of 253,731 ha, equivalent to an annual loss of 25,373 ha. As a result, by 1990, forest accounted for only 34.0 % of the total land area and had dropped from the largest land use type to the second largest type of land use. During the period from 1990 to 2000, the area under forest cover was further reduced by a total of 334,972 ha, representing an annual decrease through this decade of 33,497 ha. Despite the proclamation of a government decree in 1989, which imposed a ban on commercial logging, the annual average rate of deforestation was actually higher during 1990-2000.

[1] Faculty of Natural Resources, Prince of Songkla University, Hat Yai, Thailand 90112

Over the period of 20 years, from 1980 to 2000, the forest area in southern Thailand declined by a total of 588,703 ha, equivalent to a decrease of 22.4 %, or an annual decrease of 29,435 ha. In contrast, during the same time frame the proportion of rubber plantation areas dramatically expanded from 1,354,653 ha to 2,946,164 ha, reflecting an annual increase of 79,575 ha (Table 1). In southern Thailand, such conversion of natural forest to other uses has been attributed to an expansion of agricultural land, logging and lack of public awareness of the importance and benefits of forests (UNDP, 1994). The dramatic increase in the price of rubber during this time period and the subsidies provided by the Thai Government' Office of Rubber Replanting Aid Fund have been instrumental in promoting land conversion to rubber plantation (Usher, 1994).

Consequences of land use changes

The drastic changes in these forestry and land uses would disturb the finely tuned equilibrium of the natural ecosystems to such a degree that environmental stability is compromised. These changes limit an area's ability to absorb the impact and lower the natural resilience to hazard impact (United Nations, 2002). As a result of environmental degradation, southern Thailand has become highly vulnerable to the occurrence of natural disasters, primarily floods (Ertuna, 1989). Such hazard events claim lives and cause damage to property and infrastructure and, degrade soil and water resources resulting in a disturbance of the equilibrium of the physical, hydrological and biotic environments, as it did in Phipun District in 1988 and in Hat Yai District in 2000. To lessen the negative impacts these hazards have on the vulnerable social and economic development of southern Thailand, areas that are at risk have to be identified and appropriate risk reduction programmes implemented.

Table 1. Land use changes in southern Thailand between 1980, 1990 and 2000.

Land use category	Areas (ha)		
	1980	1990	2000
Forest	2,632,726	2,378,995	2,044,023
Rubber	1,354,653	2,684,188	2,946,164
Rice	1,143,656	779,297	649,335
Fruit trees and mixed orchards	411,628	698,056	829,891
Aquaculture	-	-	84,528
Urban and built up land	15,692	47,640	139,543
Miscellaneous land	1,438,889	409,068	303,760
Total	**6,997,244**	**6,997,244**	**6,997,244**

In this study, flood risk areas in southern Thailand were delineated using GIS together with the weighting and ranking technique of Pachauri and Pant (1992). The method is explained in details by Tanavud et al. (2001). It was estimated that 762,900 and 343,100 ha of land areas in southern Thailand are subjected to moderate and high flood risks, respectively (Table 2). It is worth noting that the 143,700 ha subject to high flood risk, equivalent to 14.4 % of the total land area of southern Thailand, was found in Nakorn Si Thammarat provinces. This signals an urgent need to restore the protective influence of forest cover in this province in order to provide environmental and ecological stability. In addition, appropriate soil and water conservation practices such as contour cultivation and agroforestry should be adopted in rubber plantation areas.

Table 2. Distribution of areas facing flood risk in provinces of southern Thailand.

Province	**Areas (ha)**	**Risk levels (ha)**					
		high		**moderate**		**low**	
		Areas	**%**	**Areas**	**%**	**Areas**	**%**
Nakhon Si Thammarat	996,700	143,700	14.4	165,600	16.6	10,100	1.0
Krabi	485,400	4,000	0.8	65,100	13.4	200	-
Phangnga	394,400	8,100	2.1	74,600	18.9	-	-
Phuket	56,300	1,600	2.8	-	-	-	-
Surat thani	1,312,600	22,500	1.7	90,800	6.9	57,500	4.4
Ranong	319,200	5,300	1.7	32,600	10.2	800	0.3
Chumphon	589,500	12,600	2.1	23,000	3.9	65,300	11.1
Songkhla	789,300	21,400	2.7	36,100	4.6	25,800	3.3
Satun	261,700	10,600	4.1	72,300	27.6	15,000	5.7
Trang	476,100	24,400	5.1	56,400	11.8	3,900	0.8
Phattalung	375,100	18,900	5.0	25,200	6.7	8,500	2.3
Pattani	200,400	26,500	13.2	36,800	18.4	19,400	9.7
Yala	450,000	6,700	1.5	17,800	4.0	2,600	0.6
Narathiwat	447,100	36,800	8.2	66,600	14.9	-	-
Total	**7,138,000**	**343,100**	**4.8**	**762,900**	**10.7**	**209,100**	**2.9**

Risk can be reduced by either decreasing hazard, reducing or eliminating vulnerability of elements at risk, or combination of both actions (DeGraff, 1989). Hazard of flooding in the lowlands is governed in large measure by the condition of upland ecosystems. To decrease flood hazard, the ecological condition of the upland watershed has to be improved through the enrichment of forest cover, the prevention of encroachment by cultivators and, the enhancement of soil and water conservation functions to improve the environmental stability of upland cultivation. In regard to the protected areas, the headwater source areas, national parks and wildlife sanctuaries should be demarcated for further enhancement of the forest environment.

Hazard of flooding is also influenced by the conditions within the lowlands such as hazard or vulnerability levels. Through the use of structural measures such as construction of reservoirs, levees, drainage canal and flood diversion channels, and non-structural measures such as application of land use planning, installing a flood forecasting and warning system, and adopting preparedness measures against flooding, the effect of the hazard on lives, property and crop production can be reduced (Maiklad, 1999). It is anticipated that successful adoption of such risk reduction programmes would improve environmental stability and support sustainable development in southern Thailand

References

DeGraff, J.V. 1989. Landslide activity resulting from the November 1988 storm events in southern Thailand and associated resource recovery needs. p. 1-43. *In* Safeguarding the Future. Restoration and Development in the South of Thailand. NOC and NESDB. Jiramedha Advertising and Printing, Bangkok.

Ertuna, C. 1991. Integrated approach to flood disaster management and rural development. p. 93-110. *In* Disaster management and regional development planning with people's participation. Vol. 2. UNCRD. Dhaka, Bangladesh.

Maiklad, P. 1999. Development and achievements in flood control and management in Thailand. p. 59-111. *In* Regional cooperation in the twenty-first century on flood control and management in Asia and the Pacific. United Nations. New York. 216 pp.

Pachauri, A.K. and Pant, M. 1992. Landslide hazard mapping based on geological attributes. Engineering Geology 32 : 81-100.

Tanavud, C., Yongchalermchai, C., Pramojanee, P., Wangworawut, W., Bennui, A., Sukboon, O. and Pramojanee, P. 2001. Application of GIS and Remote sensing techniques for flood disaster management in Songkla Province. Songklanakarin. J. Sci. Technol. 23 (3) : 425-442.

UNDP. 1994. Strengthening Disaster Management Strategies in Thailand. Asian Institute of Technology. Bangkok. 83 pp.

United Nations. 2002. Living with Risk. Disaster reduction strategy. United Nations, Geneva. 382 pp.

Usher, A.D. 1994. After the Forest. Thai Development Newsletter. 26: 20-32.

Development and Evaluation of Integrated Ecologic-Economic Regional Land Use Model to Study Land Use and Landscape Changes in North East Germany

Ajibefun, I.A.[1] – Wenkel, K-O. – Wieland, R. – Mirschel, W.

Abstract

This paper presents an integrated ecologic-economic land use model formulated and used to study land use and landscape changes in North East region of Germany. Land use studies continue to gain more momentum among researchers and policy makers, given the social, economic and environmental implications of land use and landscape changes. Middle Europe was dominated by forest ecosystems for hundred of years. Agriculture has, however, drastically and extensively changed the original natural landscape resulting in totally new ecosystems, thus making land use and landscape research to draw the attention of researchers and policy makers. Land use and landscape changes are complex, cross sectional and require an inter-disciplinary approach, given the complex interactions between ecologic, social and economic factors. Therefore, land use and landscape studies require integrated approach to be able to explain the consequences of the complex interactions among ecologic and economic factors. While previous research efforts have recognized the need for an integrated modeling approach to study land use and landscape changes, most of these research efforts either treated ecologic models separately or economic models separately. In this study, attempts were made to model land use and landscape changes using integrated economic and ecologic models in a GIS environment. Data on soil properties, crops and the yield, production inputs, input and output prices, value of premium as well as climatic and other spatial data were used to implement the models. Results indicated that the gross margin is greatly influenced by changes in price and premium. Also, different crop management practices determine the erosion potential in the study areas. At the current price and premium levels, projections into year 2030 indicate a wider distribution of crop coverage, with low erosion potential.

Introduction and Problem Statement

The importance of integrated approach to development and management of natural resources has been emphasized in many international fora on sustainable development. The 1992 United Nations Conference on Environment and Development (UNCED) noted that ….“Expanding human requirements and economic activities are placing ever-increasing pressures on land resources, creating competition and conflicts and resulting in sub optimal use of land and land resources”. In order to achieve sustainability, there is need to resolve these conflicts and move towards effective and efficient use of lands and its natural resources. Integrated modeling, involving economic and ecologic models to study landscape and land use, is a practical way to achieve this. By linking economic models with ecologic models in an integrated manner, it is possible to minimize conflicts, to make the most efficient trade-off and to link socio-economic development with sustainable land use, thereby helping to achieve the objective of sustainable development. Understanding the dynamics of land use change is a scientific challenge of considerable importance to humanity. The demands for improved knowledge of environmental processes and the impacts of policy on their dynamics must increase, as population pressures on food supplies and natural resources mount and the publicly held perception of preserving environmental diversity and amenity strengthens. Some of the most profound changes in the landscape have arisen from direct decisions by man concerning land use; from changes in cropping patterns, afforestation and deforestation to modification of water courses. These in turn have affected both the quality of environmental resources and the sustainability of a lasting diversified food chain.

The convergence between economic viability and environmental protection is perceived by both the scientific community and the policy maker as being an important component of land use sustainability. Furthermore, there is going realization that rapid land use change is resulting from policy and economic influences (e.g. CAP reform) as well as changes in the physical environment, such as the climate. Therefore, the integration of biophysical and socioeconomic approaches to land use research underpins the success of the policy-informing process. However, the realization of this perception and its development into a coherent research strategy is not easy. Mainstream research has traditionally adopted approaches only relevant to individual disciplines and the difference in methodologies between disciplines has tended to prelude integration of approaches within single research projects.

This paper presents an integrated biophysical and socioeconomic modeling procedures to evaluate the impact of current land use as well as changes in policy variables on land use and landscape changes in North East Germany. While there has been many land use studies in Germany (Kersebaum, Mirschel and Wenkel, 1995; Zander, 2003; Kaechele and Dabbert, 2002 and Kersebaum, Steidl, Bauer and Piorr, 2003), there has been

---

[1] Institute for Landscape Systems Analysis, Center for Agricultural Landscape and Land Use Research (ZALF), Eberswalder Str. 84 D-15374 Müncheberg, Germany; Tel.: 3343282239; E-mail: Igbekele.Ajibefun@zalf.de

an increasing need for a more concerted effort to use integrated biophysical and economic modeling approach for land use studies. While some of the previous studies have been able to combine economic model with ecologic model, only few of such studies were based on regional level. Our current work involved the integration of economic and ecologic models in a GIS-based environment to study land use at regional level, using the computer software, SAMT (Spatial Analysis and Modelling Tool). SAMT (Wieland, 2004) is a computer software with GIS capability and capability for static and dynamic modeling inherent in land use studies. The next section of this paper presents the modular structure and data requirement, followed by the section on results and discussion. The final section is on summary and conclusion.

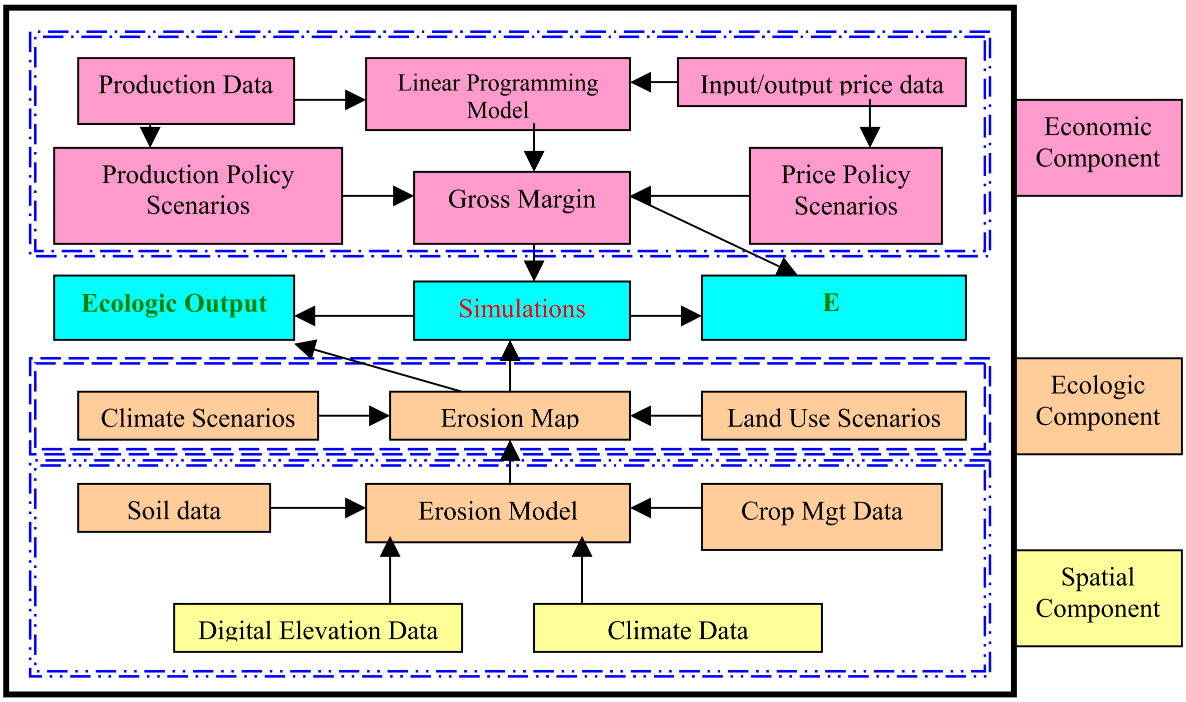
This study makes use of modules, comprising economic, ecologic and spatial modules. The modular structure makes it possible to couple all the components of the integrated model in a GIS environment. The different modules of the integrated models are:

Economic module: This involves linear programming model to describe the economic decision behaviour of farmers.

Ecologic module: This involves modeling the physical environment of agricultural production activities. For this study, it involves erosion model, to represent potential erosion, giving physical and crop management factors.

Yield module: This involves modelling the yield formation of crops, giving biophysical and environmental conditions.

Typology of Integrated Economic-Ecologic Spatial Model in SAMT



The Spatial Analysis and Modelling Tool is a computer software that was used to implement our integrated economic-ecologic model. SAMT is a newly developed computer programme for landscape and land use decision. It has an open source and would soon be made available on the internet for interested researchers on landscape and land use studies. It uses modular approach for integrating economic and ecologic models. It is also flexible to handle different production, policy and ecologic scenarios. SAMT is linked to a large database, which describes the regional agricultural practices in great details. In the database, there is comprehensive description of crop production practices. Hence, it is possible to get information about any specific aspect of farming activities. SAMT is a grid-based system and comprises of the following parts:

(i) A link to a large database, describing the regional agricultural production system. (ii) The economic component, which consists of a linear programming part to model the decision-behaviour of the farmers, with different production and price scenarios. (iii) The ecologic component. Although there are different ecological parameters that could be implemented with SAMT, our current study included only soil erosion model as ecologic parameter. (iv) The spatial component, comprising of digital elevation data and climatic data, as inputs to erosion model. (v) The simulation component, to simulate the output from the economic, ecologic and spatial component.

Study Area and The Data

Our data covered the Quillow catchment area (about 170 square kilometers) located in the North Eastern part of Germany. The catchment is located in the Ückermark region near the town Prenzlau. The area consists of 15 villages and the area is divided into 54,000 grid cells in our analysis. The river Quillow is 27 kilometers long and goes into river Üker. With the use of expert knowledge approach, we were able to implement our model at regional level, using a set of cropping activities, which represent the long-term average. Standard cropping practices were defined for 22 crops according to expert knowledge as well as survey data collected in the area. Yields were estimated as a function of different agricultural cropping areas of the state of Brandenburg, which is a function of standard soil fertility index (Gagern, 2001).

The data in the database are stored in both attribute form and in spatial form. The attribute data are either in actual figure or in coded form. The spatial data is in the form of maps and are in layers, which depict topography, soil types, climate, land use and soil erosion parameters. Crop production activities were specified for four classes of soil quality found in the study region. Map of different parameters are combined to produce land use suitability for crop production and soil erosion. Information on the farm activities is based both on expert knowledge and farm production data. The description of standard and adapted cropping practices is based on expert knowledge from research at the Centre for Agricultural Landscape and Land Use research (ZALF), Germany. The quantitative description of cropping practices allows an assessment of the impact of land use on economic and ecologic parameters. The linear programming model simulates the farm system and allocates production resources in economic way. The system selects production techniques for the specified region and gives recommendations for optimal land use according to objective functions and restrictions. With the introduction of different production possibilities, which are compatible with the ecologic and economic objectives, the model was implemented to provide trade-offs between different ecologic and economic goals. The output from the economic component was combined with output from ecologic component through simulation to produce results for land use in the area.

Results and Discussions

Gross margins were calculated based on inputs and outputs relationship. Prices and subsidies were considered to be at the level of 2002 in the study area. Machinery costs and working hours were calculated according to standard data (KTBL 2002). Cropping activities, as well as the algorithms to calculate gross margins are stored in the database. This allows the implementation and comparison of a large number of cropping systems for different sites.

Our model was implemented with several production and price policy scenarios. Spatial and economic effects of the scenarios were analysed using SAMT in a GIS environment. The economic and ecologic outputs are presented below in GIS-based maps. The simulated scenarios include the following:

Scenarios

A: Base scenario, representing current land use
B: 20% increase in price while premium remains the same
C: 20% increase in premium while price remains the same
D: Projected crop coverage for year 2030
E: Soil erosion under current land use
F: Soil erosion for year 2030

The economic and ecologic evaluations and implications are presented in Table 1 and figures 2 and 3. The economic effects of price and premium changes on gross margin are presented in Table 1. The Table shows the gross margin based on actual farm production, called base scenario, set to 100%. If prices received by farmers go up by 20% while subsidy remains at the same level, gross margin would increase by about 16%. On the other hand, if subsidy received by farmers goes up by 20% while prices remain at the same level, then gross margin would go up by 11%. If however the European Union decides to withdraw farm subsidies in line with pressure from WTO negotiations, then the gross margin derived from farm would decline by 11%. This is an indication that the current subsidy being enjoyed by European farmers has serious impact on their income.

Table 1. Gross Margin Effects of Different Crop production and Price Scenarios

Scenario	**Input and Output Price / subsidy (premium)**	**Gross margin**	**Percentage Change**
1.	Base Scenario (100%)	14,371,060	-
2.	120%/100%	16,675,359	2,304,299 (16.03%)
2.	100 % / 120%	15,959,234	1,588,174 (11.05%)
3.	100% / 0%	1,2764,347	1606713 (-11.18%)

The GIS maps in figure 2 show the effect of different farm production and price conditions on land use changes, while GIS maps of different crop management scenarios (crop coverage) and their effects on soil erosion are shown in figure 3. The GIS-based maps in figure 3 presents the erosion potential of two different crop coverage levels.

Scenarios

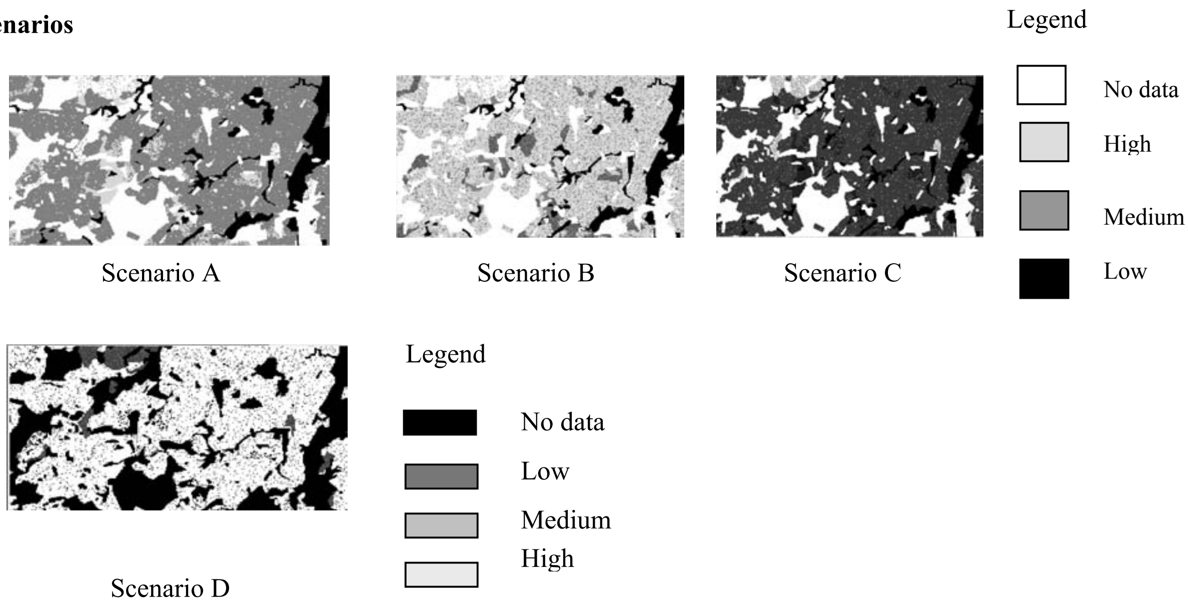


Figure 2. Crop coverage (Figures A,B,C,D,E)

Figure 3: Erosion potential

Acknowledgement

The first Author is a Humboldt Foundation Research Fellow at the Centre for Agricultural Landscape and Land Use Research (ZALF), Muncheberg, Germany. He wishes to thank the Alexander von Humboldt Foundation of Germany for funding his research stay in Germany and for support in attending this conference. The authors also wish to thank Dr. Detlef Deumlich of ZALF for helping with the development of the soil erosion model used in this study.

References

Gagern, W. (2001): "Datensammlung fur die Betriebsplanung und die betriebswirtschaftliche Bewertung landwirtschaftlicher Productionsverfahren im Land Brandenburg", *Landesanstalt fur Landwirtschaft, Germany.*

Kersebaum, K.C.; J. Steidl; O. Bauer and H. Piorr (2003): "Modelling Scenarios to Assess the Effects of Different Agricultural Management and Land Use Options to Reduce Diffuse Nitrogen Pollution into the River Elbe", *Physical and Chemistry of the Earth*, 28, 537-545.

Kersebaum, K.C.; W. Mirschel and K.-O Wenkel (1995): "Estimation of Regional Nitrogen Leaching in the Northern East German Area for Different land Use Scenarios. In: Schoute, J.F.T.; P.A. Finke; F.R. Veeneklaas and H.P. Wolfert (Eds), Scenario studies for the Rural Environment, Kluwer, Dordrecht, Netherlands, pp227-232.

Schuler, J. and H. Kaechele (2003): “Modelling On-farm Costs of Soil Conservation Policies with MODAM”, *Environmental Science and Policy*, 6, 51-55.
United Nations Conference on environment and Development Report, 1992
Wieland, R. (2004) “*Spatial Analysis and Modelling Tool (SAMT)*”, Land use Computer Software, Centre for Agricultural Landscape and Land Use Research, ZALF, Muncheberg, Germany.
Zander, P. (2003): “*Agricultural Land Use and Conservation Options: A Modelling Approach*”, Thesis Landbouwuniversiteit Wageningen, 222 pp.

Land use planning decision support based on land evaluation and Web-GIS modeling: an integrated approach in Hungary

Tóth, G.[1] – Debreczeni, K. – Gaál, Z. – Hermann, T. – Makó, A. – Máté, F. – Vass, J. – Várallyay, Gy.

Abstract

An Internet-based land use and management planning decision support system has been developed in Hungary. The system performs plant production modeling with on-line GIS support, on the basis of land productivity evaluation under different management intensity scenarios. The so-called D-*e*-Meter system, which performs land evaluation for the major cultivated crops separately also calculates productivity indices for three characteristic climatic conditions. With its supporting modules, the information system is able to link the land ownership and land use registries and provides farm data management assisstance for farmers and other linked stakeholders.

Keywords: land evaluation, land use planning, Internet, GIS,

Introduction

Present work illustrates a complex research of land evaluation and IT development, which integrates different requirements (expression of management and climate factors, crop specific evaluation) to a modern land evaluation system.

Main goal of the so-called D-*e*-Meter project was to develop an information system that fulfils the following objectives:

(1) displaying soil quality by means of maps using on-line GIS tools,
(2) plant production modeling on the basis of soil quality and other criteria (e.g. optimal fertilizer use),
(3) assistance for farmers to fulfill their obligations to provide information on the use of arable land, and providing means for direct communication with the administration agencies of the sector.

Thus, the system described above can achieve the following:

(1) The relationship between the yields of the agricultural land use and the natural resources becomes analyzable.
(2) It makes possible to keep up-to-date records of information on plant production and environment management, and the exchange of information between farmers and the administration of the sector becomes simpler and faster.

The information system is based on a land evaluation system that also entails environmental aspects, and which:

(1) determine the production potential of agricultural lands in a quantitative way,
(2) allow evaluations by major cultivated plants or groups of plants,
(3) include the possibility of expressing any decrease in productivity and production risks that originate from climatic effects and are realized through pedological and geological factors (drought, inland water),
(4) describe the conditions of production also on various intensity levels of cultivation.

Land evaluation methods and results

Database requirements of the land evaluation analyses

The basis of the land evaluation work was the soil fertility analysis of the databases available from various sources. The analysis meant statistical processing of pedological, climatic, plant production, soil analysis and fertilizer application data. The following databases were available for this task:

1. National plot-level soil, fertilization and yield databases. 5 years, 80000 cultivated fields each year, containing yield, fertilization and soil information for each plot.
   The data of the database can be classified in three major groups:
   - Basic data (location, size, sloping, exposure, meteorological area etc.)
   - Soil analysis data (SA) (pH, texture, humus, N, P, K)
   - Plot registry data (plant, succession, yields, fertilizer application)
2. Database of National Long Term Field Experiment network. Information on yields of 30 consecutive years, with soil nutrient dynamics and fertilizer response data of 9 field trial station. The experiment

[1] Research Institute of Soil Science and Agricultural Chemistry of the Hungarian Academy of Science, Budapest, Hungary, 1022 Budapest Herman O. u. 15. Tel/fax: 36-1 224-3640 E-mail: gtoth@rissac.hu

network representing differing ecological conditions, in which the fertilizer application experiments are carried out in 9 different geographical regions among differing soil conditions.

3. Database of a 10 sample farms of different characteristic agro-ecologic site, 1-5 thousand hectares area each, containing farming records and soil analysis data as well as a 1:10,000-scale digital genetic soil maps. (These case study areas were also used during the IT development.)

Land evaluation analyses

Land capability indices has been worked out on the basis of soil taxonomic classification, which provides basis for soil mapping information as well. Soil varieties of the classification system are characterized by their relative fertility (related to the fertility of all other soils in the classification system) regarding major cultivated crops, and group of crops. Regional climatic conditions, hydrologic and terrain factors are also taken into account. Meteorological variability and cultivation intensity are also expressed in the land evaluation system.

Above all, the land evaluation work has been based on the computerized statistical processing of available soil and plant cultivation information.

In the first phase of the statistical analyses the fertility limit values of the soil types and sub-types (of soil classification) have been determined, in the context of the water management regime of their units. The effect of the water regime and moisture circulation of the soil have been incorporated to the land evaluation system. In the course of this work the effects of the elements of the soil water balance (precipitation, evaporation, surface runoff, infiltration, fluctuation of inland water etc.) on the production capacity have been examined in interaction with the soil characteristics.

That was followed by exploration of the fertility conditions of soil varieties of the lower taxonomic levels.

The initial phases of the land evaluation work was followed by the definition of the fertilizer responses of the soils. This was meant to explore the causes of changes in the production potential resulting from fertilizer application of various intensities and to express the extent of such changes.

Visualization of the land evaluation model in electronic maps

The creation of GIS databases for the sample areas in the various agro-ecological regions of the country served several goals. The land evaluation model is developed on the basis of archive farming data and the results of experiments was used to calibrate the model also among real conditions of farming. At the same time, sample areas are also needed for the integrated visualization of the land evaluation supported by GIS modeling. The results of the land evaluation research and the information technology development have been united in the sample areas.

IT development methods and results

Planning of the data-model

Database planning has been carried out according to common practice of relational database development, starting from generalized approach to specific solutions, to widen the functionality of the system. As a basis, the system applies large scale (1:10000) digital soil maps, field data on soil nutrient status, vectorized cadastral maps (and includes land evaluation algorithms to asses the production potential of agricultural parcels). Object used in the system:

- Cadastral unit
- Land use unit
- Agricultural field
- Parcel (agricultural plot)
- Soil mapping unit

Calculation of land capability indices (the land evaluation process)

Soil and terrain data and spatial information are used to calculate the land capability index of any given field. Each soil variety (in the corresponding agrometeorological region) is evaluated according to its fertility regarding the given crop. Calculations are carried out both under extensive and intensive cultivation conditions. The land information system stores data on different indices:

- Crop-specific capability index for extensive conditions
- Crop-specific capability index for intensive conditions
- General capability index (index calculated by weighting of crop-specific indices according to crop ratio of the cultivated land)

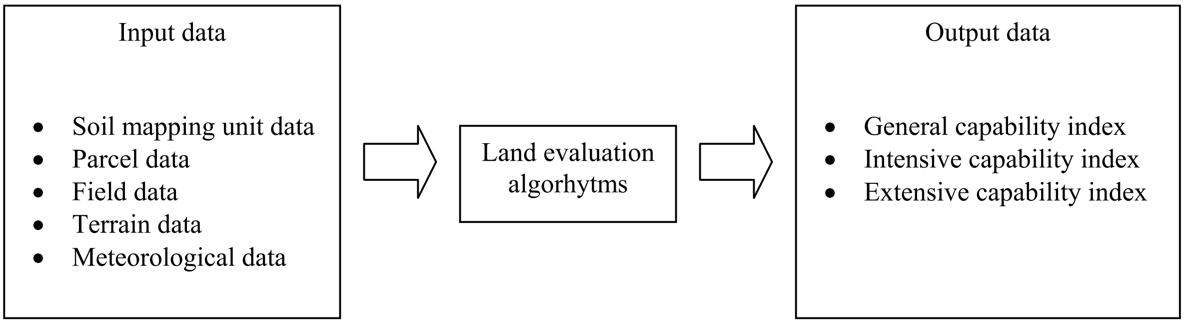


Figure 1. Land evaluation calculation input and output data

Java development environment has been used in order to keep platform independency. To secure the system's accessibility to other information systems, connecting interfaces has been designed by using national and international standards. XML application was applied for system communication, creating specific protocol for the system. Database server and WEB server is operating in different physical locations (giving possibility for regional services in the future).

Interface design and system operation

Since the web-linked monitor is the meeting point of the system and it's user, it was especially important to give clear user-friendly design with full functionality to the interface.

Digital orthophotos assist the users to locate interested areas, where vectorized digital cadastral maps are used for building farm spatial database on-line. Maps of agricultural fields can be created and edited on the selected areas. During land use planning parcels can be delineated by taking land capability into account.

As further function of the land information system, different farming and management data (on cultivation, amelioration, pest management, fertilization , harvest etc.) can be also registered in the system.

Concluding remarks

With the application of the decision support system the relationship between the yields of agricultural land use and natural resources becomes analyzable, thus it can be applicable for land use, land management, energy and crop production related analysis and for supporting decision-making from plot to national levels.

With the help of the D-*e*-METER system, alternatives of land use planning can be applied in an integrated manner for supporting rural development policies. The new land evaluation system that is based on a complex approach of expressing soil quality with the available tools of information technology (Internet, GIS, database managers etc.) offer new possibilities that allow the harmonization of agricultural production and environmental management on a higher level. In this way, decisions can be made on the bases of complex knowledge.

Land use planning can be carried in harmony with local ecological resources and in accordance with the general agro-economic production climate. Therefore the D-*e*-METER project is a truly complex project that is to assist to plan integrative programs for sustainable rural development.

Acknowledgements

The research was conducted with the support of National Research and Development Programs (NKFP 3/004/2001) and with the assistance of the the Research and Development Fund for Higher Education (FKFP – 0060/2001).

References

D-*e*-METER 2001. D-*e*-METER – Developing an Internet-based land evaluation and farm data collection system to integrate environmental resources appraisal and agricultural information management. project homepage.
Available URL: http://www.demeter.vein.hu/indexen.html

Gyuricza C. Role of agroecological factors in crop production. In: Foundations of Arable Land Use. (in Hungarian) Gyuricza C., Ed.; Szent István Egyetem: Gödöllő , 2001; 197pp

Máté F. 1999. Land evaluation based on suitability assessment for breeding of different crops. In Theoretical foundations and options for practical applications of EU-conform land evaluation based on soil quality. (in Hungarian) Stefanovits, P.; Michéli, E., Eds.;. MTA Agrártudományok Osztálya: Budapest, 1999; 100-109.

Sváb, J. Biometric Methods in Agriculture. (in Hungarian) Mezőgazdasági Kiadó: Budapest, 1981; pp 345

Szász, G. Species-specific agro-ecological parameters in Hungary. (in Hungarian) Debreceni Egyetem Agrártudományi Centrum: Debrecen, 2002; pp18 (manuscript)

Tóth, G.; Máté, F. Crop-specific productivity of typical Trans-Danubian soils.(in Hungarian) Agrokémia és Talajtan 1999, 48 (1-2), 172-180.

Várallyay György 2002a. New scientific challenges of a modern land evaluation system (Új tudományos kihívások egy korszerű földminősítési rendszerrel szemben.) Geodézia és Kartográfia 54. évfolyam 7.szám p3-11 (in Hungarian)

Wu, J. T. Concept of soil fertility evaluation based on coefficient-synthesis. Soil and Geology 1993, 269-274 (in Chinese)

Soil erosion measurements at different scales: are they necessary and how should they be made?

Imeson, A.[1]

The topic of this key note "soil erosion measurements at different scales" will consider some of the paradoxes and issues that are challenging current thinking in soil erosion research. It will discuss why and for whom soil erosion measurements are needed, how they were traditionally made and how they might be accomplished in the future. The first question to be asked is if erosion measurements are necessary at all, or if they are what form should they take.

A traditional textbook review of erosion measurements would encompass, open and closed plots, Gerlach traps, sediment discharges and measurements of surface lowering with erosion pins. The arsenal would have included semi-quantitative measurements obtained during repeated surveys, for example of rill or gulley networks and sink and source areas of eroded sediment. In addition, use was frequently made of tracers and of rainfall simulators to study the nature of the erosion processes themselves. None of these measurements could be described as rocket science and soil erosion data were relatively easy to obtain: at least in theory.

In practise the traditional type of measurement was extremely hard to make and the results were extremely sensitive to details of the installation. Maintenance was critical and all too frequently measurement sites often failed to function adequately during extreme events. When visiting or studying other peoples experimental erosion plots it was virtually impossible to find some kind of design fault that would have affected the data. It might be expected that this would not be the case with the standard Wischmeier plot. However, in this case, as will be mentioned later, the whole concept of long-term measurements at one site is perhaps one that should be abandoned.

It is extremely easy to criticise erosion models as unrealistic in terms of how processes are represented. However, in many ways erosion plots measurements have equally bad drawbacks. Both erosion models and erosion measurements suffer from the same objection that they isolate erosion from the ecosystem in which it is occurring. Erosion plots and pins, for example, result in what could be termed ecosystem dysfunction. They totally alter the functioning of the site so that the sediment fluxes that are measured are affected. Unfortunately the conceptual framework in which the measurements are undertaken and models formulated suffer from the same ignorance of the processes that affect erosion. Both erosion measurements and models should then ideally be embedded in the ecosystem.

Before considering ways of overcoming such problems, the reason why erosion measurements are wanted, will be considered.

Why Soil erosion measurements are needed

Soil erosion measurements were traditionally and are still today needed by scientists to test research hypothesis and validate models. Agricultural scientists needed them to compare and demonstrate the effectiveness of different soil conservation treatments and in order to know if erosion was in excess of a critical value (the tolerable rate of erosion. Geomorphologists measured erosion to have information regarding about the nature and rates of processes responsible for the evolution of geomorphologic systems.

In addition to theses scientific needs, today soil erosion is now perceived as a major threat to the policy goal of sustainable land use and management. Recently, the EU Working Group Task Force on Soil erosion concluded that agriculture was the main driver of erosion and that solutions to the problem should be sought in land use and land management. In fact EU Agricultural Policy will probably use cross compliance by farmers as a means of reducing erosion and erosion risk. The ability to measuring and monitoring erosion in a way that would enable the performance of soil conservation efforts to be evaluated would be extremely valuable. Repeated surveys of erosion in Europe, as part of the Lucas programme, are already being made but at the moment these to not include actual measurements.

Soil erosion measurements and conceptual frameworks

Soil erosion measurements are always carried out within a framework of concepts and paradigms that reflect how erosion is seen. Early research measurements reflected more mechanistic paradigms in which it was thought that erosion could be explained in terms of the underlying factors, for example in the USLE. Gradually more organic models of change have been applied and broadened to include socio-economic aspects. When new paradigms are applied (e.g. from dynamic and evolutionary systems, hierarchy theory or adaptive systems, then the limited usefulness of traditional approaches to erosion are evident.

---

[1] IBED Fysiche Geografie, Universiteit van Amsterdam, Nieuwe Achtergracht 166 NL – 1018 WV Amsterdam. Tel.: +31 0205257457; Fax: +31 0205257431; E-mail: a.c.imeson@frw.uva.nl

The adaptive system paradigm can be used as an example. In this paradigm erosion can be understood as a necessary process of release that takes place in an adaptive cycle. It is one of many other processes that can be measured. Equally important as the erosion itself, is the measurement of the critical factors that lead to it taking place. This will be explained further in the full version of the paper.

In other words, the usefulness for traditional types of stand alone erosion measurements is limited to research objectives; for integrated research other approaches are needed that looks at erosion risk in terms of the erosion cycle and the underlying drivers.

Traditional ways of assessing erosion

This section will consider erosion measurements at coarser scales and then gradually zoom in to consider increasingly finer scales. At the global or continental scales there have in fact been very few actual "measurements" of erosion, simply because the concept of "erosion" at this scale is abstract. Reliance has been placed on consultation with experts who are familiar with erosion. This has enabled very effective maps to be produced such as those by Jan de Ploey and co-authors as well as those from the Glassod Project of UNEP. Nevertheless between 1965 and 2000 studies in many countries of the world very many representative or experimental drainage basins were set up enabling continental scale comparisons of erosion rates.

Another approach is to survey the on and off-site effects of erosion. For example, rill and gulley surveys can be made after extreme rainfall events or maps can be made of sediment source and sink areas. These approaches have been found to be very useful as they enable data to be collected over relatively large areas.

At the very finest scales there are very many features of erosion that provides evidence of its occurrence. These cover things such as stone pedestals, splash craters, the accumulation of splashed sand and sediment deposition features, as well as surface seals and crusts.

In a sense sediment yield and model data are also methods that are used to assess soil erosion. Sediment yield data are frequently combined with erosion measurements within the framework of a sediment budget or sediment delivery system.

New ways of measuring erosion

Soil erosion is measured as a soil loss and the notion of the Wischmeier plot provides the norm. In the first instance it would be better if "soil depth" were used instead. In the future changes in soil depth can and will be measured easily using ladar or radar technology. At the moment it is possible to record surface elevation changes with increasing precision. The prospects for doing this have recently been reviewed by several authors. Remotely sensed measurements of ground elevation levels should become the norm. Ground measurements are needed not of soil loss but of the ancillary data needed to interpret surface elevation change.

An alternative approach is to measure indicators that can be used to evaluate if the soil conservation function of the soil is being adequately formed. This can be done by measuring if sediment or runoff are "leaking" from a field or slope. This can be done also by analysing changes in vegetation and soil surface patterns or by using new types of tracers, for example based on very cheap micro-transmitters embedded in sand grains. Technology now used to monitor the flow of goods and banknotes can be used in erosion. Indicators could be measured for all kinds of soil function.

Soil erosion can also be measured using economics, in terms for example of loss of capital or function. It an also be measured in terms of increased costs of risks from for example flooding and contamination. The need for this type of data is frequently expressed because it is a strong motivator of action.

Relationships of measurements of erosion at spatial and temporal scales

This section of the paper will review consider how fine-scale temporal drivers and processes can have an impact at the coarser spatial scales. It will also consider how these can be measured.

In the past soil erosion measurements at different scales have been presented indicating that as the spatial scale increases, so the relevant time scale increases.

Unfortunately, although this idea has some validity, it is too simplistic. For example, very fine scale processes can affect the behaviour of very large areas very rapidly. Large regional scale differences in erosion processes and rates are often the result of micro-scale phenomenon. The same is true of socio-economic drivers of erosion. An intervention applied at the fine scale of the individual farmer can have a regional impact on erosion.

Conclusion

Traditional ways of measuring erosion have proved valuable for providing insight into the underlying processes and for developing models. However they have been less useful for validating models and they are not really sufficient for current soil erosion policy. Different approaches to modelling are needed. New technology can revolutionise soil erosion research and soil conservation.

Cultural practices and risks of runoff and interrill erosion under vineyard (Ardèche, Southern France)

Blavet, D.[1] - De Noni, G. - Roose, E.

Introduction

As they cover poorly the soil surface during the whole year, vineyards involve weeds and erosion problems, particularly on the steep hillslopes of Mediterranean areas of France where rainstorms can be dangerous. This danger is important not only for wine quality but also for landscape evolution and floods over the plains. Last 20 years, many catastrophic floods were observed in southern France.
In Ardèche country, many circumstances increase the erosion risks. The Cevenols rains in autumn may be very intensive (100 mm/hour) and abundant (120 mm/day). Lithosols are poor and superficial on steep slopes (Maillo,1999). Land use has changed last 30 years increasing environmental risks. To improve the wine quality, vineyards have been moved on the hillslopes but soils are compacted by tractors, which can move only up and down, and herbicides degraded the topsoil structure so that runoff increased significantly (Léonard, 2003).

To evaluate the possibility to decrease these runoff and erosion problems, 36 rainfall simulator tests where used to compare the efficiency of six cultural practices on a calcareous Lithosols with 40% of topsoil surface covered by stones on a 12% slope vineyard.

Material and Methods

The experimental vineyard is situated on the old farm of Olivier de Serres, at Pradel (44°35 N, 4° 30 E, 285 m alt.) on a hillslope situated between the Rhone valley and the volcanic Coiron Mountains. The marno-calcareous rocks are covered by 0.4 to 1 m colluvium with a loamy-clay brown soil, 2% of organic matter, and 40% of calcareous and basaltic stones. Rainstorms are particularly aggressive in autumn and spring and attain 1000 mm a year because the proximity of Mediterranean Sea and the Cevennes Mountains. Vineyard (Syrah cepage) is 24 years old and is still well producing: it is planted along the slope each 1 m in the rank and 2.2m between ranks in order to allow the mechanization (Maillo, 1999).

In the spring 1999, four usual cultural practices have been introduced between 3 ranks along the slope:
i) Chemical clean weeding (DCT) corresponding to the presently most frequent practice;
ii) Conventional tillage at 10 cm depth, the preceding system, leaving a soil surface covered by stones at 40% (SARC40); iii) a mulch of 25 t/ha of straw over the tilled surface (PAIL); iv) a graminacea seeding with 30% of Ray-grass (*Lolium perenne*) and 70% of *Festuca rubra*. Locally on 1m² plots, two additional treatments were developed: v) a clean weeding + tilling with manual extraction of stones down to 30% of the surface (SARC 30), vi) after tilling a manual addition of stones up to get 80% of covered surface (SARC 80). These treatments are common on some stony soils of the vineyards in France or in Switzerland (Nachtergaele et al., 1998).

Each cultural practice has been tested by two simulated rains and three repetitions on 1 m² in June 1999: a 30 minutes rain 60 mm/hour on "dry soils" without any natural rain for 5 days at least, and after 15 minutes and the end of the possible runoff, a one hour rainfall of 60 mm/hour "on very wet soils" conditions, similar to the rainstorms falling during the autumn. For each simulation, various parameters were observed in order to explain the differences of runoff and erosion: Hp% = previous soil moisture on 10 cm depth; Pi 1 and 2 = prepounding rain amount (mm), KR 1 and 2= runoff rate (%) for the first and second rains; INF 1 & 2 = final infiltration rate (mm/h) after rains 1 & 2; TURBIM 1 & 2 = Runoff turbidity (g/l) at the end of each rain ; surface status : open surface (%) (aggregates, fauna holes, fissures) and covered surface (%) by litter, stones and weeds (Roose, 1996). They were estimated at 192 points of observation on lines crossing the microplots. Soil samples were collected near the microplots at 0 - 5 cm depth to determine the carbon content, texture and structural stability (Le Bissonnais, 1996). All the variables were analyzed for the second rain but some were not for the first rain because no runoff was observed after 30 minutes. In order to classify the treatments a note was attributed to each treatment in relation to the different parameters from 1 when it is the best to 0 if the worst and 0,5 when intermediate. Statistical analysis (test Newman-Keuls for classification of treatments) was made with the logiciel Statistica V.6 (StatSoft TM).

Results and Discussion

In figure 1 and table I are presented averages and standard deviation of runoff (%) and soils losses (g/m²) of rain simulated in relation of the six treatments and their statistical analysis (test Newman-Keuls). During the first rainstorm, on dry situation (Hp = 4 to 10% in 0 to 5 cm depth), prepounding rain (Pi1) is significantly higher under mulch (Pail) and tilled plots (SARC 80-40-30) than under chemical weeding and grass seeding (DCT and ENH): the runoff % is always higher on those last treatments. During the second rain, on

[1] IRD, BP 64501, F 34394 – Montpellier cedex 5, France, E-mail: Didier.Blavet@mpl.ird.fr

moist soil (Hp = 11 to 20 %), the runoff rate are higher than during the first (KR1= 0 to 27% ; KR2 = 5 to 78%). Mulching (addition of straw or stones on the soil surface) gave better results than the other treatments : highest prepounding rain, (Pi=23 to 35mm), highest infiltration rate (INF = 41 & 55 mm/h instead <39 mm/h), lowest runoff (KR2 = 5 to 12%), lowest turbidity (TURBIM <2.2 g/l instead 5 to 8 g/l for tilled plots) and lowest soil losses (MES = 2 to 12 g/m² while up to 105 and 309 g/m² under chemical weeding and tillage with clearing of stones).

The semi-automatic classification of the six cultural practices allowed getting a general view on the interest of each treatment. After this classification (table 1), with a general note of 0.93, mulching with straw or stones are the best cultural practices. In opposite, tillage with taking stones off the field and chemical weeding got the worse notes (0.29) and accumulated maximal runoff and soil losses inconvenients. We noted that getting grasses was giving relatively poor classification index (0.36 against 0.71 for the conventional mechanical weeding). This was due to high runoff which happens with grasses *Festuca rubra* sewed 3 months before only.

To explain variations of runoff and soil losses observed, we analyzed their relations with parameters depending on local variability (slope, topsoil texture and moisture) and with parameters a priori in relation to cultural practices (soil organic carbon, soil structure stability, soil surface features like % of the surface covered by litter, rocks and weeds, and % of the surface closed by sealing crust, rocks included in the soil or in the crust and compacted areas) (Roose, 1996).

At the 1m² scale there is no relation between slope % (10 to 16%) and erosion or runoff rate (Roose, Cavalié, 1988). We found no correlation between texture (clay, sand %), or soil moisture of the topsoil (0 to 5 or 10 cm) and runoff or erosion parameters, probably because the variations between treatments are not great enough (Blavet et al., 2004; Lelong et al., 1993).

But we found significant correlations (p = 90 %) with the stability of the structure (MWD) and the increase of prepounding rain of 1rst and 2d rain, or the decrease of the runoff rate of each rain and the stable infiltration rate of the second rain (De Noni et al., 2002. There is a good correlation between the carbon rate and the structure stability of the topsoil (Barthès et al., 1998; De Noni et al., 2002). There are also strict correlations between soil losses (Turbim & MES) and the covered surface %. When the topsoil is covered it is protected against the drop energy : here the treatments mulched (with straw or stones) have the best cover % and the worse are tilled with stone clearing (SARC30%)(Gril, 1984; Roose et Cavalié, 1988; Arshad et al., 1999).

Considering all cultural practices, there is no significant correlation between soil covered % and runoff parameters because soil surface could be open or closed on the same level of surface cover. But considering a same surface features (ex tilled weeding) with different cover surfaces, a correlation between various cover % and runoff parameters could appear: so the % of stones can improve the prepounding rate and the final infiltration rate (Poesen, Torri, Bunte, 1994). That means that stones on the open soil surface protect the soil structure against the rainfall energy. But if stones are included in the sealing crust or in the soil, the infiltration rate will decrease. Finally there are interactions between the closed surface and the cover %: the closed surface increased faster if the soil is poorly covered during the rains (r = - 0, 754*).

Thus, considering the treatment classification and the explaining factors, cover % is mainly explaining soil losses and detachment, while closed soil surface % would regulate runoff and final infiltration rate. It appears also that soil structure stability in relation to carbon content of the 10 cm topsoil can influence the runoff rate from the first rain on the dry condition (Barthès et al., 1998).

Conclusion

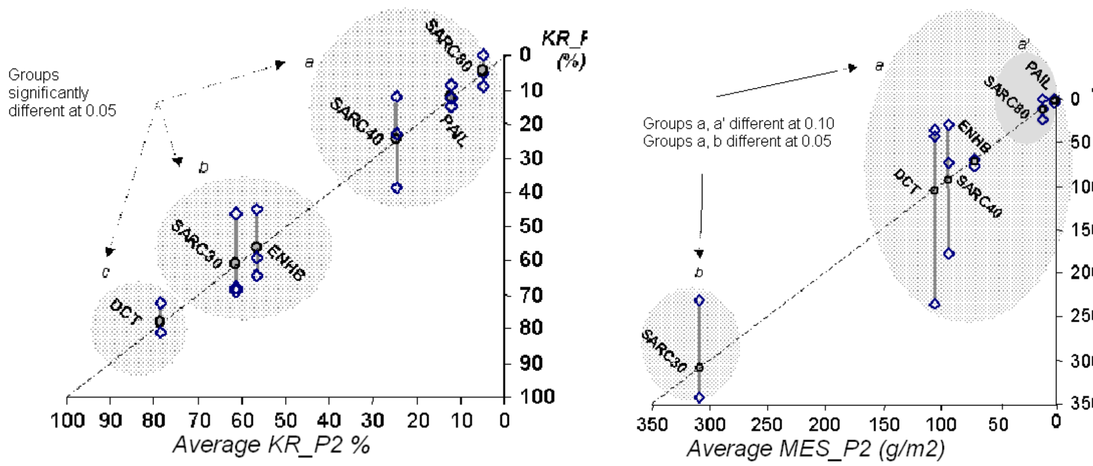
This study shows that mulching with straw (100% surface) and stones (80%) best covering inter rows of vineyard can reduce runoff and erosion significantly because their protection of the open surface against drop and runoff energy, aggregates breaking up and soil porosity closing. The worst cultural techniques are chemical weeding (presently the most frequently used) and tillage weeding with stones clearing (still frequently used). Seeding with grasses practice, not very efficient in our experiments, remains questionable because it was too recently installed (3 months) on previously herbicided soils: it could reduce rapidly soil losses, but more time is necessary to verify it can also reduce runoff.

It seems also useful to verify later the influence of these treatments on the soil properties modifying the soil behavior against erosion. Finally, it appeared that an inquiry must confirm that mulching is acceptable for the winegrowers in term of cost and painful labor.

References

Arshad M., Asseline J., Blavet D., De Noni G., Laurent JY., Leprun JC., 1999. Soil properties as affected by different land use practices in the Languedoc region of southern France. In :J.Bech (ed), Sixth internat. meeting on soils with Mediterranean type of climate. Barcelone university : 618-621.

Barthès B., Albrecht A., Asseline .J, De Noni G., Roose E., Viennot M., 1998. Pratiques culturales et érodibilité du sol dans les Rougiers de Camarès (Aveyron). *Etude et Gestion des sols*, 5,3: 157-170.
De Noni G., Blavet D., Laurent J.Y., Le Bissonnais Y.,Asseline J., 2002.. Proposal of soil indicators for spatial analysis of carbon stocks evolution. « Confronting new realities in the 21st century », 17th World Congress of Soil Science, August 2002, Symposium 05, Bangkok, paper 1783, 13 p.
Gril J.J., 1984. L'érosion dans le vignoble du Beaujolais : étude comparative des techniques culturales sur la commune de Pommiers. *CEMAGREF,* 317: 47-52.
Le Bissonnais Y., 1996. Aggregate stability and assessment of crustability : 1. theory and methodology. *European Journal of Soil Science* ; 47 : 425-437.
Lelong F., Roose E., Darthout R., Trevisan D.,1993. Susceptibilité au ruissellement et à l'érosion de divers types texturaux de sols cultivés ou non cultivés du territoire français. Expérimentation au champ sous pluie simulée. *Science du Sol*; 31, 4 : 251-279.
Léonard M., 2003. L'érosion hydrique des sols cultivés : Analyse systémique et propositions de gestion. Application aux vignobles d'Ardèche méridionale. Thèse de Doctorat de Géographie. Grenoble : Université Joseph Fourier, 545 p. + annexes.
Maillo L., 1999. Influence des pratiques culturales sur le ruissellement et l'érosion sur les coteaux viticoles du Bas-Vivarais (Ardèche). Thèse de Doctorat de Géographie. Grenoble : Université Joseph Fourier; 173 p. + annexes.
Nachtergaele J., Poesen J, Van Wesemael B., 1998. Gravel mulching in vineyards of southern Switzerland. *Soil & Tillage Research,* 46 : 51-59.
Poesen J., Torri D., Bunte K., 1994. Effect of rock fragments on soil erosion by water at different spatial scale : a review. *Catena*, 23: 141-166 .
Roose E., Cavalié F., 1988. New strategy of water management and soil conservation : application in developped and developping countries. In : Rimwanich (ed). *ISCO V Land conservation for future generation.* Bangkok : 913-923.
Roose E., 1996. Méthodes d'estimation des états de surface en relation avec le ruissellement et l'érosion en nappe. *Bull. Réseau Erosion,* 16: 87-97.



1.a.Runoff rate, in % of the rainfall (coefficient KR 2).

1.b.Exported matter in suspension in g/m2 (variable MES 2).

Figure 1. Runoff rate and exported materials by suspension during the second simulated rainfall following the different cultural practices (individual data and means).

Variables of runoff and soil losses	Cultural Practices											
	DCT		SARC30		ENHB		SARC40		SARC80		PAIL	
Pi 1 : Prepounding rain during the first rain (mm)	9,8 ± 3,1 c	0	19,8 ± 4,8 b	0,5	9,3 ± 4,2 c	0	23,8 ± 5,1 a	1	30 ± 0,5 a	1	30 ± 0,8 a	1
KR 1 Runoff rate during the first rain (%)	27,5 ± 7,2 b	0	8,9 ± 7,3 a	1	17,9 ± 8,6 b	0	4,2 ± 5,8 a	1	0 ± 0 a	1	0 ± 0 a	1
Pi 2 : Prepounding rain during the second rain (mm)	1,2 ± 0,4 b	0	1,1 ± 0,6 b	0	1,6 ± 0,2 b	0	4,8 ± 4,0 b	0	35,6 ± 23,1 a	1	22,7 ± 2,2 a	1
KR 2 : runoff rate during the 2d rain (%)	78,2 ± 5,1 c	0	61 ± 12,9 b	0,5	56,4 ± 9,8 b	0,5	24,5 ± 13,3 a	1	4,8 ± 4,6 a	1	12,2 ± 3,1 a	1
INF 2 : stable infiltration at the end of the 2d rain (mm / h)	8,3 ± 3,9 c	0	13,5 ± 8,1 c	0	18,5 ± 5,8 c	0	38,2 ± 8,1 b	0,5	55,3 ± 3,3 a	1	41,8 ± 9,3 b	0,5
TURBIM 2 : Runoff Turbidity a t the end of the 2d rain (g / /L)	2,2 ± 2,3 a	1	8 ± 0,3 c	0	2,1 ± 0,3 a	1	5,6 ± 1,7 b	0,5	5 ± 0,5 b	0,5	0,2 ± 0,3 a	1
MES 2 : Suspension matter during the 2d rain (g/m²)	105,3 ± 113,2 a	1	309,4 ± 67,8 b	0	71,6 ± 4,2 a	1	93 ± 76,0 a	1	12,2 ± 12,0 a	1	1,6 ± 1,9 a	1
Average note for each cultural practice	0,29		0,29		0,36		0,71		0,93		0,93	

Lecture of the table :

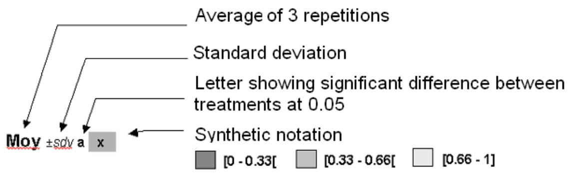


Table 1. Average runoff and soil losses under rainfall simulations, with statistical grouping of means and semi-automatic classification of the cultural practices.

Field variables	Runoff variables					Soil losses variables	
	First rain		Second rain			Second rain	
	Pi 1	KR 1	Pi 2	KR 2	INF 2	TURBIM 2	MES 2
1. MWD µm (0 - 5 cm)	0,82* n=5	-0,81* n=5	0,49 n=5	-0,71 n=5	0,57 n=5	-0,31 n=5	-0,33 n=5
2. SOC g/kg (0 – 5 cm)	0,88** n=5	-0,96*** n=5	0,46 n=5	-0,76 n=5	0,66 n=5	0,27 n=5	-0,06 n=5
3. Soil cover rate on all situations	0,13 n=17	-0,13 n=17	0,43 n=17	-0,40 n=17	0,40 n=17	-0,77** n=17	-0,75** n=17
4. Soil cover rates on tilled situations with stone cover	0,82** n=9	-0,67** n=9	0,63 n=9	-0,72** n=9	0,78** n=9	-0,70** n=9	-0, 82** n=9
5. Initial closing rate at the beginning of the first rain	- 0,55** n=14	0,66** n=14	-0,13 n=14	0,43 n=14	-0,32 n=14	-0,68** n=13	-0,30 n=14
6. Final closing rate at the end of the second rain	- 0,79** n=14	0,79** n=14	-0,74** n=11	0,97*** n=11	-0,94** n=11	-0,22 n=11	0,44 n=11

**Significatives correlations at p > 95 %., ** significative at >99% , n= repetitions number*

Table 2. Linear correlations between i) the Mean Weight Diameter, the Soil Organic Carbon, ii) the soil cover rate and soil surface closing rate and iii) the runoff and soil losses variables.

Conditions for rill initiation on marl soils. A field experiment in South East of Spain

Martínez-Mena, M.[1] – Castillo, V. – Albaladejo, J.

Rills represent the main features through which soil is eroded on slopes. In fact surface runoff reaches its maximum power both as detaching and transporting agent once channelled into rills (Meyer et al., 1975; Poesen, 1987) . Knowledge about the precise conditions leading to rill initiation is incomplete and no widely erosion and transport equations for concentrated overland flow under different soil conditions yet exist. Evaluation of threshold conditions for incipient rilling is very important in order to apply conservation measures able to control soil loss effectively. If the hydraulic characteristics of rill flow can be more accurately defined, upland erosion processes can be better understood and more accurately modeled. In order to get observations and values for rill initiation to validate a process based erosion model (EUROWISE), a set of field experiments were carried out on marl soils in a semiarid Mediterranean area of South East of Spain. Ten runoff simulations involving different inflow discharge (0.81-2.24 l s^{-1}) and local slope (10-20%) conditions were made. Parameters such as runoff, flow velocity (dye tracer), gully wide and depth were measured several times during each run. Characteristics such as profile penetrometric resistance and penetrometric resistance along the walls and on the bed, soil moisture and bulk density along a profile (0-3cm, 3-6cm and 6-9cm) were made before and after simulation.

Better relationships were obtained between mean rill wide, depth and sediment concentration with discharge for slopes higher than 12%. The relations obtained between rill geometry and hydraulic flow characteristics were not as good as those obtained in other studies due to the high penetrometric profile resistance presented by these soils and the high surface roughness induced by the presence of stones. Better relations were, however, obtained between rill width and flow stream power (R^2 = 0.40; $p<0.05$) than between rill width and discharge (R^2 = 0.28; $p<0.05$).

A statistically significant linear correlation (R^2 = 0.54; $p<0.05$) was found between rill sediment concentration and flow shear stress and thus with rill erosion, indicating the dependence of sediment transport on the flow hydraulic characteristics.

[1] Department of Soil and Water Conservation, CEBAS-CSIC. Murcia (Spain). Tel.: 34-968396349; Fax: 34-968396213; E-mail: Mmena@cebas.csic.es

Initial response of recently burned soil to water erosion processes in a Mediterranean environment

Andreu, V.[1] – Rubio, J.L. – Gimeno-García, E. – Gonzalez, O. – Campo, J.

Abstract

In the Mediterranean area, actually, forest fires have been considered as a first order magnitude environmental problem. The increase in its frequency progressively reduces the recovery periods of the ecosystems. This last fact is critical in the Mediterranean countries where the fire season (spring-summer) is usually followed by torrential rains in the fall, favouring the intensification of the erosive processes and the advance of desertification.

In this work, the effect of a repeated fire on soil in its response to water erosion processes is studied, during the critical period of the first 5 months after it. Results are compared with those obtained from a previous fire occurred eight years before. The study has been developed in the Permanent Field Station of La Concordia (Valencia,Spain) where experimental fires, of different intensities, where performed in 1995 and now repeated in 2003. The setup consist in 9 plots (20m long x 4 m wide) of which all runoff generated and sediment produced is collected in each rain event. Three of the plots were burned in 1995 with high fire intensity, other three were burned with moderate intensity and the remainders were used unaltered as control. The plots, in regeneration since the first fire, were burned again in 2003.

Results show the vulnerability of the soil after the repeated fire, with runoff rates that have increased 5 times more than in 1995 and with soil loss which has been almost doubled, mainly in the plots burned with medium intensity fire in 1995. These plots have lost 5 t ha^{-1} during the period of this year of soil in contrast with the 2.31 t ha^{-1} of the same period of 1995.

Introduction

In the last years the incidence of fires in the Mediterranean countries has become from a natural phenomena to a first order of magnitude environmental problem. It has been observed a dual tendency on this phenomenon. By one hand the surface affected by fires has decreased since year 2000 in a continuous way but, by the other hand, the overall tendency for the EU Mediterranean countries is towards increasing number of fires (European Commission, 2002). This is probably due, between other sources, to the extensive use of wildland areas for recreation and the increase in population density in the regions.

This increment in the number of fires means, in many cases, the burnt of areas that have suffered previously the impact of fire and were recovering their natural conditions. This phenomenon clearly implies the impossibility of these ecosystems to reach the adequate resilience time to recover its original state, favouring a progressive degradation and a regression in their evolution. This problem becomes extremely important in the Mediterranean region where the impact of the continuous and repeated fires happens mainly in summer, followed by torrential rains in autumn, which results in the intensification of water erosion processes.

Several studies indicate that the greatest increases in runoff and erosion occur within the first 1 or 2 years after burning (Robichaud and Waldrup, 1994; Inbar *et al*., 1998), although this general pattern depends greatly on the fire intensity and, in the characteristics and distribution of the rainfall events. However, in Mediterranean areas, where the rains are concentrated in the immediate period after the fire season (summer), the 4-6 months after the fire occurrence can be the period of highest susceptibility of soils to water erosion (Andreu et al., 2001).

In this work, the response to water erosion processes of a soil that has suffered a summer fire in 2003, after eight years of recovery from a previous one, has been studied. The incidence of water erosion in the immediate period after the fire (five months) has been monitored and compared with the behaviour of this soil in a similar period after a previous fire occurred in 1995.

Materials and methods

This work was developed in the permanent Experimental Station of La Concordia (Casinos, SPAIN), which is located on a SW-facing midslope between 550 and 575 m a.s.l. with a gradient ranging from 30-40%. It is characterised by shallow soils of Rendzic Leptosol type, according to the F.A.O. classification (FAO-UNESCO, 1988), developed on Jurassic limestone and showing variable depth, but always lower than 50cm. Some physical and chemical characteristics of this soil are shown in Table 1.

[1] Centro de Investigaciones sobre Desertificación-CIDE. Camí de la Marjal, s/n. 46470–Albal (Valencia, SPAIN); Tel.: +34 96 122 05 40; Fax: +34 96 127 09 67; E-mail: vicente.andreu-perez@uv.es

Table 1. Some physical and chemical characteristics of the studied soils in 2003.

	Fire Treatments		
	Control	**Moderate Int.**	**High Int.**
Sand (%)	60.84	-----	-----
Silt (%)	27.88	-----	-----
Clay (%)	7.52	-----	-----
WRC H_2O(%)[a]	30.83	28.54	29.55
Structural Stability (%)	30.41	29.71	34.54
pH	7.6	7.6	7.7
EC ($dS.m^{-1}$)[b]	0.90	0.77	0.73
Total $CO_3^{=}$ (%)[c]	53.65	54.21	54.37
Organic Matter (%)	8.17	7.99	7.66

[a] Water Retention Capacity. [b] Electric Conductivity. [c] Total Carbonate Content

The annual precipitation of the area is around 450 mm, with a maximum in autumn (September to November) and a less intense rainy period in spring. The dry period usually ranges from June to September. The mean annual temperature is 17.2ºC and the mean temperature of the dry period is 34ºC.

The characteristic cover of this area belongs to a Mediterranean shrub land, developed after a fire occurring in 1984. The dominant vegetation type belongs to the *Rosmarino-Ericion* association. The most abundant species include *Rosmarinus officinalis*, *Stipa tenacissima*, *Chamaerops humilis*, *Rhamnus lycioides* and *Pistacia lentiscus*.

The Station consists on a set of nine erosion plots, 4 m wide x 20 m long each, with similar characteristics such as soil morphology, slope gradient, rock outcrops and vegetation cover. The selection of each plot location was made after intensive surveys of the vegetation, soil and the morphology pattern, based on across slope transects every two metres. Plots were oriented parallel to the slope and bounded by bricks. At the foot of each plot a 2 m wide collector ran into a 1500 l tank to record all the runoff and sediment produced during each rainfall event. Inside them there is a 30 l tank to concentrate the sediments produced facilitating its collection.

A random design of three different fire intensity treatments (with three plots each) was used. Two sets of three plots each were burned in June 1995 reaching high (plots 1, 4 and 8) and moderate (plots 2, 6 and 7) fire intensities. It was achieved by addition of different amounts of fuel load to the plots of each treatment, 40 and 20 t ha^{-1}, respectively. The remainder three plots were maintained unburnt to be used as control treatment. The necessary quantity of dry biomass to obtain the two fire intensities was calculated using vegetation (from the surrounding area) similar to that present in the plots. The mean soil surface temperatures were 439ºC for high fire intensity plots and 232ºC for the moderate intensity ones (Gimeno, 2003).

After the 1995 fires, the plots were left untouched allowing the natural regeneration of the vegetation cover, although continuing the monitoring of climatic and erosion parameters. Eight years later, in July 2003, the plots correspondent to the fire treatments were burnt again but, in this case, all the plots in the same conditions. It was done in this way trying to reflect the actual situation of the repeated incidence of fires on zones in recovering from previous ones. Only a constant quantity of biomass (0.25 kg m^{-2}) was added to each one of the plots to obtain continuity on the vegetation mass and thus favour the advance of the fire front. The average of the temperatures obtained in the surface of the plots reached around 160 ºC.

Climatic parameters and the intrinsic characteristics of the different rainfall events were monitored by a logging system of sensors with GSM transmission of data, placed close to the plots. The complete runoff generation and sediment produced in the different plots in each rain event, during the studied periods, were collected.

Samples were taken from the first 5 cm of the studied soils to know some of its physical and chemical characteristics; after that they were air-dried, screened to remove the fraction higher than 2 mm diameter and stored in plastic boxes until their analysis. Standard laboratory analyses were used.

Standard statistical Multiple and linear correlation analyses were applied at 95% of signification level. Analysis of variance and Tukey's test at α=0.05 were computed to detect differences occurring as a result of fire between the treatments and to compare variations between the studied periods.

Results and discussion

Figure 1 shows the rain events occurred, during the five months period after the fires of 1995 and 2003, with runoff generation. Both periods showed similar rain distribution along the year, almost uniformly, with minimums in March/April and, but different behaviour. 1995 received a total of 344.88 mm of rain, corresponding 134.94 mm to the period immediately after the fire (June-November) meanwhile during 2003 the total annual rain was of 464.00 mm, 241.70 mm of which were in the period after the fire (July-December). Both studied periods also show only 8 erosive events with runoff generation Figure 1. In those rain events is where the differences appear. The erosive events of 2003 were higher in rain volume, intensity and duration, being these two last parameters those that mark the most important differences between the two periods. Maximum rain intensities in 1995 and 2003 periods were 26.26 mm h^{-1} and 65.40 mm h^{-1}, respectively, and the average duration of the events were 135' and 327', respectively.

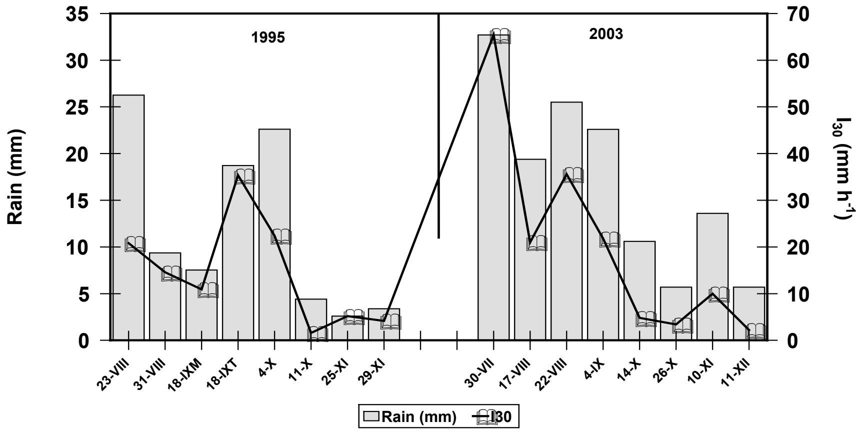


Figure 1. Characteristics of the erosive rain events occurred in the studied post-fire periods of 1995 and 2003.

The almost homogeneous distribution of rain during the year 2003 with the increase of their volume and duration, allowed maintaining a certain degree of soil moisture along the year favouring a faster runoff generation. On the other hand, in 2003 the regeneration of vegetation only reaches the 68 % of the existent vegetation previous to the 1995 fire. These facts were determinant in the soil response to water erosion processes after the repeated fire. In the studied port fire period of 1995 was generated a 65.57% less runoff than in the same period of 2003, with maximum values in 1995 and 2003 of 4.41 L m^{-2} (plot 4, high intensity, 18th September) and 12.48 L m^{-2} (plot 7, moderate intensity, 30th July), respectively (Figure 2A). This great variation is not only due to the different rain characteristics - lower in volume, intensity and duration in 2003 - but also in the fact that the first erosive rain after the fire of 1995 occurred almost 2 months later, allowing the soil some kind of stabilization, while in 2003 the first erosive event was 10 days after fire and shows the highest intensity (65.40 mm h^{-1}). The plots of the fire treatments show similar trend, giving in 1995 period an average of 70.97% less runoff than in 2003. The differences between these burned plots and the control ones, not burned, increase likewise from an average of 85.62 % after the fire in 1995 to 95.27 % in 2003. Although the dissimilarities among plots burned in 1995 with high intensity and those burnt with moderate one have not been statistically significant they increased from 5.22 % in 1995 to 12.74 % in 2003, being higher in this last year the values correspondents to the moderate intensity plots. It has been reflected in the values of infiltration rate that are lower in the moderate intensity plots (average of 9.34 mm $^{h-1}$) than in the others (10.11 mm h^{-1} on the high intensity treatment and 12.23 in the moderate one). Values of runoff coefficient reflected also this tendency, but in this case the differences were still lower.

The evolution observed for the hydrological response in the fire treatments during the studied periods become more evident for soil losses. The greater aggressiveness of rains observed in 2003, together with the earlier incidence of important erosive rains, have been translated in a global soil loss in 2003 almost double (88.56% higher) than in 1995 for the post-fire periods studied (Figure 2B). With maximum values on sediment yield in 1995 and 2003 of 367.019 g m^{-2} (plot 7, 30th July) and 293.51 g m^{-2} (plot 4, 18th September), respectively. Respect to the fire treatments, burnt plots maintain the great differences observed in the post-fire period of 1995, respect to the unburned plots, in the 2003 period giving values around 99% lower in the control plots. However, the differences between treatments of fire have increased and changed the tendency. In 1995, after the fire, plots burnt with high intensity gave values 8.12 % higher than those burnt with moderate intensity, but in 2003 these last plots produce 26.81 % more sediment than the plots of the high intensity treatment. The plots not affected by fire show an important reduction on sediment yield (84.94 %) compared with the values reached in 1995. These data give a clear vision of the importance of the vegetation cover and the maintenance of its natural evolution, against the incidence erosion processes.

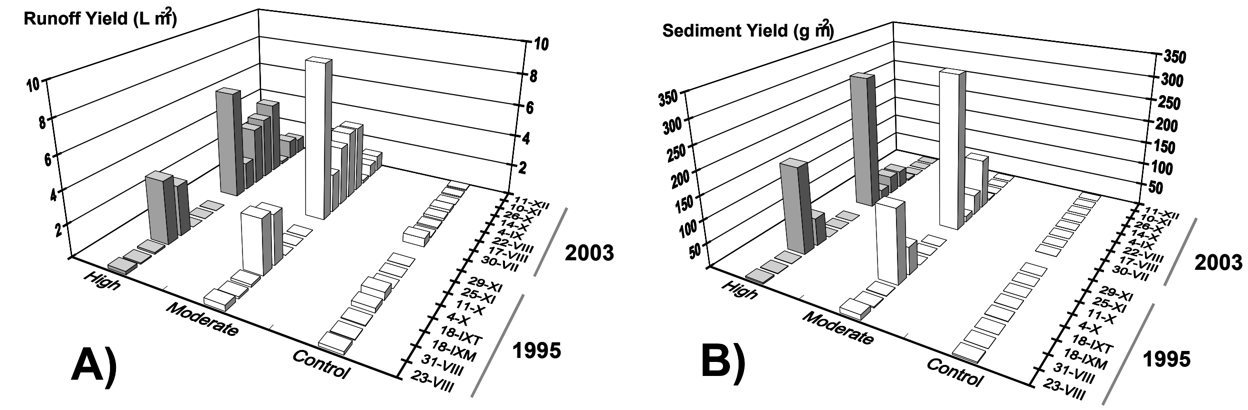


Figure 2. Runoff (A) and sediment yield (B) produced in each rain event for the different fire treatments in the two post-fire periods studied.

The values on soil loss obtained for each treatment for the 2003 period give a vision of the magnitude of soil erosion; it has been a total of 5.14 t ha^{-1} in the moderate intensity plots and 4.05 t ha^{-1} in the high intensity ones, while in the control plots this loss only reached 0.007 t ha^{-1}. These values are critical for Mediterranean soils taken in to account that the established rates of soil formation for them are around 2 t ha^{-1} y^{-1}. This is a clear indication of how important is the incidence of repeated fires, of any intensity, on zones not totally recovered from a previous one. The degree of vegetation recovery and the intensity and readiness of rains after the fire are key factors in the effect on soil of water erosion processes, mainly in fragile ecosystems like those that characterizes the Mediterranean areas.

Conclusions

The repeated incidence of fires on ecosystems previously affected by them can accelerate the degradation processes by enhancing the incidence of water erosion. It has been observed in the data obtained in the plots that suffered fires on 1995 and were burnt again in 2003.

The new impact of fire on the plots in regeneration stage and the occurrence of rains, short time after it, produced an increase in runoff generation and soil loss of almost triple and double, respectively, respect to the values obtained after the previous fire (1995). In contrast, the control plots (not burned) maintain similar values in 2003 than in 1995, although in 2003 the volume and intensity of rains increased. This can be indicative of the improvement on soil hydrological properties that the natural evolution of the vegetation favours, against water erosion. By the other hand, soil loss is magnified after the second fires reaching values for the high and moderate intensity treatments higher than 3 t ha^{-1} in a single rain event (30th July of 2003), overcoming the annual rates of soil generation.

In the Mediterranean countries the phenomenon of increasing the frequency of fires and its repeated incidence in previously affected zones, could broke the possibilities of resilience of the ecosystems favouring its progressive degradation, and the possibilities of soil sustainability, and thus the advance of desertification.

References

Andreu,V., Imeson,A.C. and Rubio,J.L. (2001). Temporal changes in soil aggregates and water erosion after a wildfire in a Mediterranean pine forest. *Catena* 44: 69-84.

European Commission (2002). Forest Fires in Europe: 2001 fire campaign. European Communities, Ispra, 27 pp.

FAO-UNESCO (1988). Soil map of the World 1:5.000.000. Revised legend. World Soil Resources Report. FAO, Rome.

Gimeno-García,E., Andreu,V. and Rubio,J.L. (2000). Changes in soil organic matter, nitrogen, phosphorous and cations in soil as a result of fire ands water erosion in a Mediterranean landscape. *Eur. J. Soil Sci.* 51: 201-210.

Inbar, M., Tamir, M. and Wittenberg, L. (1998). Runoff and erosion processes after a forest fire in Mount Carmel, a Mediterranean area. *Geomorphology,* 24: 17-33.

Robichaud, P.R. and Waldrop, T.A. (1994). A comparison of surface runoff and sediment yields from low-and-high severity site preparation burns. *Water Res. Bull.*, 30: 27-34.

Throughfall Drop Sizes for Mediterranean Vegetation Species

Coutinho, M.A.[1] – Antunes C. R.

Introduction

It was considered necessary to focus attention to the foliage and leaves role in the hydrological behaviour of tree canopies to enable the development of a conceptual model and a computational methodology to analyse the effect of rainfall interception by the vegetation cover on the reduction of rainsplash erosion and runoff (Coutinho and Antunes, 1999, 2000, 2003)

To account on the complexity of the processes, particular emphasis must be given to the leaf behaviour mechanism. The major objective of the study was to measure the retention of water at the surface of the leaves and the characteristic diameters of the drops, falling from the leaves of the most common tree and bush species presented in southern Portugal forest, namely, Cork Oak (*Quercus suber* L.), Evergreen Oak (*Quercus ilex* L. ssp. *rotundifolia* Lam), Wild Oak (*Quercus coccifera* L.), Eucalyptus (*Eucalyptus globulus*), and on orchard species - Olive tree (*Olea europaea* L.) and Orange tree (*Citrus sinensis* O.)

Experimental work was conduced under a rainfall simulator. In that set up the drop diameters falling from the leaves and the retention of water at the surface were measured. The values of drop sizes were measured by integral volumetric methods and the diameters of the drops were also estimated using sensitive paper. Leaves of trees and bushes with different sizes and time of growth have been used.

It was found that the drop sizes do not depend significantly on rainfall intensity. The diameters of the drops are a function of the general geometry of the leaf, the surface roughness, the edge indentation, the shape of the tip and the rate of drops' formation.

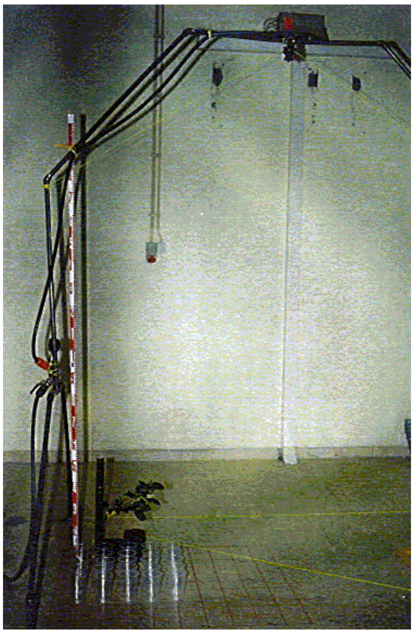
For the most common trees and bush in Mediterranean climates it was verified that the throughfall drop sizes produced by the leaves vary between 3.4 and 6.3 mm. The values of the retention of water at the surface of the leaves were obtained from the measured data, at the beginning of the dripping and at stabilised conditions. Also, the time for the beginning of the dripping, since the start of the simulated rain, was measured.

Experimental set up

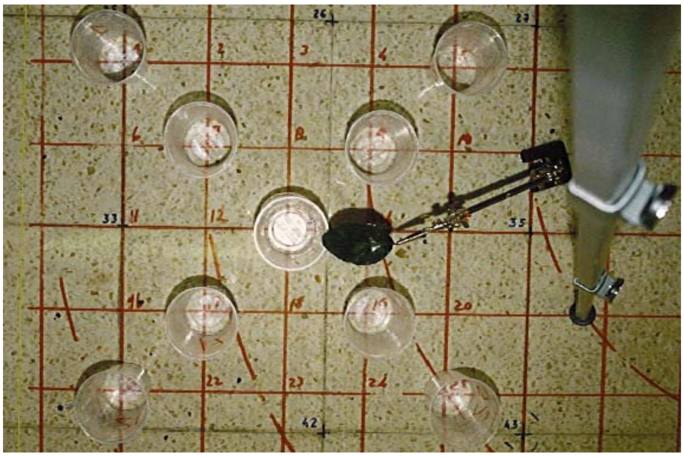
To obtain accurate data to quantify the hydrologic behaviour of trees; some experimental work was done in Instituto Superior Técnico, Portugal, concerning various forest and orchard trees; the leaf retention and the throughfall drops were measured in laboratory conditions. Particular attention has been given to the common species of the Mediterranean zone - namely, Cork Oak (*Quercus suber* L.), Evergreen Oak (*Quercus ilex* L. ssp. *rotundifolia* Lam), Wild Oak (*Quercus coccifera* L.), Eucalyptus (*Eucalyptus globulus*), Olive tree (*Olea europaea* L.) and Orange tree (*Citrus sinensis* O.)

[1] DECivil & Arquitectura, Instituto Superior Técnico, Technical University of Lisbon; University of Évora. Av. Rovisco Pais, 1049-001 Lisboa, Portugal; Tel/fax: (351) 21 8418156; E-mail: macout@civil.ist.utl.pt

The laboratory work and experimental set up are illustrated in Figure 1, a) and b).



a)



b)

Figure 1. a) Rainfall simulator view and the experimental set up. b) Scheme for collecting drops from Cork Oak leaves.

The experimental set up at the laboratory consisted of a very simple rainfall simulator, able to produce different rainfall intensities and rain drops in various diameter ranges' (Antunes, 1995).

Under laboratory conditions the leaves of Cork Oak, Evergreen Oak, Wild Oak; Eucalyptus; Olive tree and Orange tree were submitted to different levels of precipitation intensity. The leaves were positioned with different aspects and the experiments were conducted with single leaves of different sizes and with cascades of overlapping leaves.

For each set up, the following measurements where made: the rainfall distribution under the simulator and the dripping from the leaves (volumes and number of drops).

The values of the retention volumes and characteristic drop sizes were measured by integral volumetric methods and the diameters of the drops were also measured with sensitive paper. Leaves of different sizes and time of growth have been used.

According to the obtained values it was possible to identify the relevant factors for estimating total retention volumes provided by the vegetation canopies and characteristic diameters of the falling drops. Also, the kinetic energy of the drops for different falling heights was computed.

From the obtained data the leaf retention and the throughfall drop sizes values have been computed: In the next chapter a brief description of the findings and of the obtained data is made.

Leaf retention and throughfall data

It was found that the retention volumes depend on the area, texture, roughness and nervures of the surface of the leaves, and on the architecture of the branches and the trunk of the tree.

The drop sizes do not depend significantly from rainfall intensity. They are function of the general geometry of the leaf, the surface roughness, edge indentation and tip shape.

The major results obtained for water retention and drop sizes ranges are summarised in the following table, for different leaf sizes' of the different tree species studied in laboratory.

Table 1. Rainfall retention, throughfall drop sizes' ranges and average size for the dripping of different leaves from tree species

tree species	average water retention (mm)	range of throughfall drop sizes' (mm)	average drop size (mm)
oak species	0.30 to 0.40	4.7 to 6.3	5.3
eucalyptus	0.08 to 0.14	3.4 to 4.8	3.8
olive trees	0.40 to 0.50	3.7 to 4.1	3.9
orange trees	0.45 to 0.55	4.1 to 4.7	4.3

The tree species studied did not present very distinctive drop sizes distributions. It was observed that the drop's size distribution and average drop size for each tree species were a function of the dimensions and general geometry of the leaves.

References

ANTUNES, C.R., 1995 – Coberto vegetal na conservação do solo e da água. Modelação do coberto vegetal para estudo da erosão hídrica. MSc dissertation. Instituto Superior Técnico, Universidade Técnica de Lisboa, Lisboa, Portugal.

ANTUNES, C.R and COUTINHO, M.A.; 2003 - The Montado as a Traditional Sustainable Land Use System and an Efficcient Soil Conservation Measure. International Symposium on the Sustainability of Dehesas, Montados and other Agrosylvopastoral Systems. Caceres, Espanha. 2003.

COUTINHO, M.A. and ANTUNES, C.R., 1999 - Erosion Model For Tree and Bush Canopy Covers. 10th International Soil Conservation Organization Conference (ISCO), Purdue University. West Lafayette, Indiana. USA (oral presentation).

COUTINHO, M.A. and ANTUNES, C.R; 2000 - Leaf Retention and Throughfall Drop Sizes Under Quercus sp. A Contribution for a Conceptual Model of Rainfall Interception for Tree and Bush Canopies. Congresso Mundial do Sobreiro e da Cortiça. Centro Cultural de Belém. Lisboa, Portugal.

HERWITZ, S.R. and SLYE, R.E.; 1995 - Three-dimensional modeling of canopy tree interception of wind-driven rainfall. J. of Hydrology. Vol. 168, Elsevier Science, B.V. Amsterdam, The Netherlands.

Nutrient losses by runoff affected by rainfall characteristics in Mediterranean vineyards

Ramos, M.C.[1] – Martínez-Casasnovas, J.A.

Abstract

The Mediterranean area, characterized by high rainfall variability and frequent heavy intensity rainfall events, is susceptible of suffering high erosion processes which are being accelerated by the elimination of traditional soil conservation measurements and the introduction of new land management practices. The present study makes reference to a new vineyard plantation, prepared for mechanized works, which is representative of the present practices carried out in the Penedès area (Barcelona, Spain). Soils are maintained without any cover during almost all year to avoid the water competition, which favour soil erosion processes. This paper focuses on nutrient concentration in runoff and nutrient losses by runoff associated with events of different erosive potential, quantified by their intensity and kinetic energy. The study was carried out in two vineyard plots: one in which important soil movements were done for field preparation and the another one in a non disturbed soil. In each plot four points along the slope were considered for the evaluations. Runoff samples were collected at each point after the main rainfall events recorded during 2000. Total N and total P were analysed in the runoff samples. Annual rainfall during the analysed period was 518 mm, value close to the annual mean in the area, although about 40% of it fell in one day. Maximum intensities in 30- min periods ranged from 6 to 187 mm h^{-1}, and the kinetic energy of the analysed rainfall ranged from 2787 to 135611 MJ ha^{-1}. Total N and total P concentrations were, on average, lesser in the disturbed than in the non disturbed plot (0.76 g kg^{-1} vs. 1.03 g kg^{-1} for N, and 627 mg kg^{-1} vs.775 mg kg^{-1} for P). However, in the non disturbed soil there was a small enrichment ratio in the sediments related to the soil content, while in the disturbed soil, the concentrations were lower in the sediment, whatever the rainfall characteristics. Nitrogen concentrations were similar at the different locations of the plot. However, P concentrations were higher in the points located at the top of the plots and decreased along the slope (ranging between 894 to 393 mg kg^{-1} in the disturbed plot and between 967 to 533 mg kg^{-1} in the non disturbed soils). There was not a clear relationship between the erosive character of the rainfalls and nutrient concentrations, although the pattern was the same in both plots, with higher values for lower rainfall intensities.

Introduction

The Mediterranean climate is characterised by a complex pattern of spatial and seasonal variability, with wide and unpredictable rainfall fluctuations from year to year and with frequent heavy intensity rainfall events (Ramos, 2002). This climate feature contributes to generate erosion processes, which also depend on soil management practices and crop types. Vineyards are one of the lands that incur the highest runoff and soil losses: 47-70 Mg ha^{-1} yr^{-1} in NW Italy (Tropeano, 1983), 35 Mg ha^{-1} yr^{-1} in the Mid Aisne region (France) (Wicherek, 1991), 22 Mg ha^{-1} yr^{-1} in the Penedès – Anoia region (NE Spain) (Usón, 1998), and even higher soil losses have been associated with extreme rainfall events: 34 Mg ha^{-1} in an only extreme rainfall in the SE France (Wainwright, 1996) or 207 Mg ha^{-1} (Martínez-Casasnovas et al., 2002).

These erosion processes are being accelerated by changes in land use and in the cropping patterns adapted for field mechanisation. The traditional free growing vines planted following contour lines and in bench terraces are being change to trained vines, with vine rows perpendicular to the maximum slope gradient in most cases. Land preparation for mechanisation has required important soil movements, removing surface soil from some places and filling other sites, which has generated important changes on soil physical and chemical characteristics. Soils are now low in organic matter content and have weak structure, leading to land degradation processes. The Anoia-Alt Penedès region, located in the Mediterranean NE Spain, is a clear example of this situation.

The aim of this paper focus on nutrient concentration in runoff and nutrient losses by runoff associated with events of different erosive potential, quantified by their intensity and kinetic energy**.**

Material and methods

Study area

The study was conducted in a commercial vineyard located in the Anoia region (X: 400300; Y: 4592700). The area has a Mediterranean climate with an annual average temperature about 15ºC and an annual rainfall about 550 mm, mainly in autumn and spring. The soil moisture regime is xeric and the soil temperature regime is thermic and according to Keys of Soil Taxonomy (Soil Survey Staff, 1998) they are classified as *Typic Xerorthents* and *Typic Calcixerepts*.

[1] Department of Environment and Soil Science. University of Lleida. Alcalde Rovira Roure 191, E25198. Lleida. Spain. Tel.: 34 973702092; Fax: 34 973702613; E-mail: cramos@macs.udl.es

Vineyards are maintained with bare soil during all the year, by continuous tillage. Composted cattle manure was applied in this field one year prior this study at a rate of 50 Mg ha^{-1} wet weight in alternate rows. This compost carried in his matrix N and P at concentrations of 22.6 ± 0.6 mg g^{-1} and 1411±11 mg kg^{-1}, respectively.

Sample collection and analysis

Soil samples from the top 0-20 cm were collected in 8 points along the slope in two plots. one plot in which soil surface had been removed in the upper part (up to 3m) and filled in the lower part (points Di), and one plot without changes in the landform (points Ui). Particle size distribution without extraction of carbonates, organic matter content were analysed in each sample (Porta et al., 1986).

Sediment and runoff collectors, Gerlach type, which allowed separation of sediment and runoff samples, were installed at the same points. Runoff samples were collected after the main rainfall events occurred during the year 2000. The collected runoff samples were filtered and air dried. Total phosphorus (Olsen and Sommers, 1982) and total nitrogen (Bremner and Mulvaney, 1982) were analysed in the sediments collected at each point and in the soil samples collected at the same slope positions. Enrichment ratios were calculated by dividing the nutrient content of the sediment by the nutrient content on the soil surface.

Rainfall data

Rainfall was recorded at 1-min intervals at the same field using a tipping-bucket pluviometre connected to data-logger. Intensity and kinetic energy of each storm was calculated using the relationship obtained for the area (Ramos, 1999).

Results and discussion

Rainfall characteristics and runoff generation

Total precipitation recorded during 2000 at the study area was 518mm, very irregular distributed along the year. A total of 26 rainfall days were recorded through the year although only 10 of them registered more than 13 mm/storm (value given by Wischmeier and Smith (1978) as the erosive threshold). The most relevant one was an extreme event recorded in June, which had a return period of 105 years. It supposed 37% of annual rainfall in a single event. This storm had an intensity in a 30-minute period of 172 mm h^{-1} with a maximum intensity of 212 mm h^{-1} in 1-minute intervals and an erosive potential (R factor = KE*I30) 10 times higher that the annual for this area (Ramos and Porta, 1994), which determined most of the soil erosion produced during the study year. The rest of the storms had 30-minute intensity ranging from 15 to 37.5 mm h^{-1}.

In some cases, due to the low intensities, the rainfall recorded in one single rainfall did not cause runoff. Runoff samples were collected after eight rainfall intervals: the second interval includes 2 rainfall events of 12 mm each, and the sixth interval includes several low depth of rainfall (< 10mm), all of them of low intensity. Table 1 shows total rainfall (P) recorded during the whole period and the rainfall causing erosion, maximum intensity in a 30-minute period (I30), kinetic energy, rainfall erosivity (R), runoff ratio (runoff/rainfall) and sediment concentration for each analysed rainfall period.

Soil characteristics

The soils have relatively high silt and fine sand contents (> 50%) and very low organic matter content (1.6-5.3 g kg^{-1} in disturbed soils and 6.9-14.9 g kg^{-1} in disturbed soils). Calcium carbonate content ranges from 300-410 g kg^{-1}, and pH varies between 7.9 and 8.9. Total N ranged from 0.6 to 1.8 g kg^{-1} in the original soil and P ranged from 600 to 1700 mg kg^{-1}. The high variability on nutrient content level is due to the effect of some organic residua previously applied in the plots, which was not homogeneously distributed. The average concentrations in the sediments collected after the each rainfall periods in both disturbed and undisturbed plots are shown in Fig. 1 and 2.

Table 1. Accumulated rainfall (mm), rainfall events causing runoff (mm), total rainfall duration (min), maximum 30-minute intensities (mm h^{-1}), total kinetic energy (KE) of the rainfall (mmh^{-1}), rainfall erosivity: RE=KE*I30 ($MJha^{-1}mmh^{-1}$), runoff ratio (%) and soil concentration in runoff (gL^{-1}) during 2000.

	20/3 -10/4	10/4 -3/5	3/5 -24/5	24/5 -14/6	14/6 -4/10	4/10 -18/10	18/10 -3/11	3/11 -4/12
P(mm)	44.8	49	41.4	237.2	46.4	57.9	28.2	17.6
Erosive rainfall (mm)	14.2	12+ 12.8	22.4	216.2	40.6	9.6+9.6 +8.8+ 8.8+8.4	12.4	14.2
Duration (min)	2081	757	597	716	227	551	1295	764
Max I30 (mm h^{-1})	15.4	16.7	20.8	172.5	37.5	25.6	29.9	20.9
KE (MJ ha^{-1})	24.9	361.0	314.2	7374.2	428.3	271.4	110.6	130.9
RE ($MJha^{-1}mmh^{-1}$)	255.1	4778	12178	1356111	11022	3946	2788	2620
Runoff ratio (%)	8.8	3.5	1.7	75.0	8.0	9.3	6.6	4.6
Soil conc (gL^{-1})	25.5	12.1	20.7	41.3	8.1	4.9	21.8	4.1

Nutrient concentrations

Total N and total P concentrations were, on average, lesser in the disturbed than in the non disturbed plot (0.76 $g.kg^{-1}$ vs. 1.03 g kg^{-1} for N and 627mg kg^{-1} vs. 775 mg kg^{-1} for P) (Fig 1 and 2). For nitrogen, concentrations in the sediments were higher than in the soils (enrichment ratio (1.1 <ER < 1.2), in both disturbed and undisturbed, but for phosphorous, concentrations were lower in the sediment than in the soil in the disturbed plot (ER = 0.5) and higher in the (ER = 1.2), whatever the rainfall characteristics were. Nitrogen concentrations were similar at the different locations of the plot. However, average P concentrations were lower at the top of the plot increasing along the slope (ranging between 894 to 393 mg kg^{-1} in the disturbed plot and between 967 to 533 mg kg^{-1} in the non disturbed soils), particularly when high erosive rainfalls were recorded. Most is fixed on the surface and detached and transported by runoff, but part of it is sedimented inside the plot.

These concentrations in the sediments imply nutrient losses ranging from 0.2 to 1.2 kg ha^{-1} of N except for the extreme event, in which the nutrient losses were higher than 100 kg ha^{-1}. Phosphorous losses associated with sediment transported by runoff ranged from 0.2 to 0.6 kg in ha^{-1}, and during the extreme event they were higher than 50 kg ha^{-1}. Additional phosphorous is lost dissolved in water. Phosphorous concentration in water ranged form 0.37 to 0.87 mg L^{-1}.

Total nutrient losses are higher than those reported by Douglas et al. (1998), who showed annual losses ranging from 20-100 kg ha^{-1} yr^{-1} and P losses ranging form 8 to 48 kg ha^{-1} yr^{-1} in plots under continuous fallow. Figures are also higher than those found for P by Schlesinger et al. (2000) in shrubland (0.33 kg ha^{-1} yr^{-1}) and grasslands (0.15 kg ha yr^{-1}), areas in which the coefficient runoff was always less than 25%. Except for the extreme event, an inverse relationship between nutrient concentration in the sediment and kinetic energy and the R factor (KE.I30) is observed with the higher values for the lower intensities.

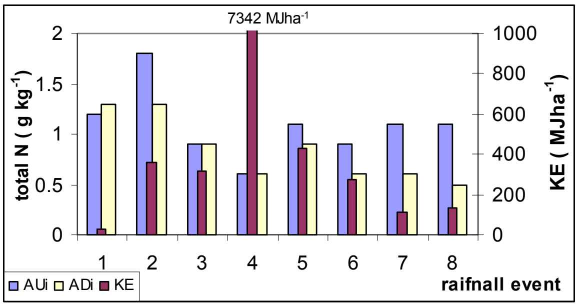


Fig.1 Average total N in the sediment for each rainfall period in disturbed and undisturbed plot and kinetic energy of the corresponding period

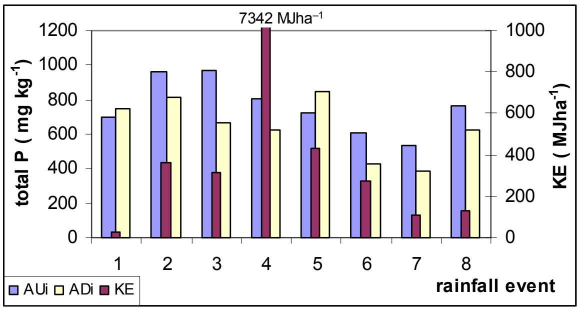


Fig.2 Average total P in the sediment for each rainfall period in disturbed and unidsturbed plot and kinetic energy of the corresponding period

Conclusions

Total N and total P concentration is, on average, lesser in the disturbed than in the non disturbed plot. However, in the non disturbed soil there was a small enrichment ratio in the sediments related to the soil content, while in the disturbed soil, the concentrations are lower in the sediment, whatever the rainfall characteristics. Nitrogen concentrations were similar at the different locations of the plot. However, P concentrations were higher in the points located at the top of the plots and decrease along the slope. There was not a clear relationship between the erosive character of the rainfalls and nutrient concentrations, although the pattern was the same in both plots, with the higher values for the lower intensities.

References

Bremner, J.M.and C.S. Mulvaney., 1982. Nitrogen-Total. pp 1149-1176. *In*. A.L. Page et al. (ed). Methods of soil analysis. Part 2. Chemical and microbiological properties. 2nd ed. Agron. Mongr. 9. ASA and SSSA, Madison, WI.

Douglas, C.L, K.A., King, and J.F., Zuzel, 1998. Nitrogen and phosphorous in surface runoff and sediment from a wheat-pea rotation in Northeastern Oregon. J. Environ. Qual. 27: 1170-1177.

Olsen, S.R. and L.E. Sommers. 1982. Phosphorous pp. 403-430. *In.* A.L. Page et al. (ed). Methods of soil analysis. Part 2. Chemical and microbiological properties. 2nd ed. Agron. Mongr. 9. ASA and SSSA, Madison, WI.

Martínez-Casasnovas, J.A., M.C., Ramos, and M., Ribes-Dasi. 2002. Soil erosion caused by extreme rainfall events: Mapping and quantification in agricultural plots from very detailed digital elevation models. Geoderma 105: 125-140.

Ramos M.C. 1999. Rainfall intensity-kinetic energy relationship for NE Spain. Il Nuovo Cimento, 1999, 22: 675-68.

Ramos, M.C. 2002. Differences on the characteristics of the storms recorded along the year in a Mediterranean climate. Intensity and kinetic energy. pp 431-440. *In*: A., Mugnai, F., Guzzetti, and G. Roth, (eds). Mediterranean Storms. 2nd Plinius Conference European Geophysical Society. Publi GNDCI nº 2547.

Ramos, M.C. and J. Porta. 1994. Rainfall intensity and erosive potentiality in the NE Spain Mediterranean area: results on sustainability of vineyards. Il Nuovo Cimento 17: 291-299.

Schlesinger, W.H., T.J., Ward, and J. Anderson, 2000. Nutrient losses in runoff grassland and shrubland habitats in Southern New Mexico: II. Field plots. Biochemistry 49: 69-86.

Soil Survey Staff (SSS). 1998. Keys to Soil Taxonomy, 8th edition. U.S. Department of Agriculture, Natural Resources Conservation Service, Washington, D.C.

Tropeano, D., 1983. Soil erosion on vineyards in the Tertiary Piedmontese basin (northwestern Italy): studies on experimental areas. Catena Supplement 4:115-127.

Usón, A., 1998. Medidas de control de la erosión en suelos de viña de las comarcas Anoia – Alt Penedès (Barcelona): Efectividad y viabilidad. Ph.D. Thesis, University of Lleida, Lleida. pp: 260

Wainwright, J., 1996. Infiltration, runoff and erosion characteristics of agricultural land in extreme storm events, SE France. Catena 26: 24-47.

Wicherek, S., 1991. Viticulture and soil erosion in the North of Parisian Basin. Example: The Mid Aisne Region. Z. Geomorph. N.F., Suppl.-Bd. 83: 115-126.

Wischmeier, W.H., and D.D., Smith, 1978. Predicting rainfall erosion losses. A guide to conservation planning. USDA Agricultural Handbook No. 537, Washington, D.C.

Soil Erosion and Carbon Dynamics in Agricultural Landscapes

Van Oost, K.[1] – Van Muysen, W. – Govers, G. – Heckrath, G.

Abstract

The influence of erosion and redistribution of soil within the landscape on the global terrestrial C budget is poorly understood. This is due to the lack of detailed information on SOC (soil organic carbon) storage in terrestrial ecosystems and of simulation models that allow to track the fate of the eroded sediment. In this paper, perform a spatial analysis of sediment and carbon fate during erosion, transport and deposition by water and tillage erosion. We combine detailed measurements of ^{137}Cs, used as an erosion tracer, with SOC data for 4 agricultural fields in Europe. The results indicate that soil erosion substantially contributes to the spatial variation in SOC at the field scale. Tillage erosion is the dominant soil redistribution process leading to the burial of substantial amounts of SOC in concave landscape positions. In contrast to earlier estimates, we conclude that soil erosion may lead to substantial carbon uptake in agricultural soils.

Key words: Soil erosion, tillage erosion, water erosion, SOC, carbon sequestration, caesium-137

Introduction

At present, there exist two opposing hypothesis concerning the role of soil erosion on carbon dynamics. (i) Soil erosion creates an atmospheric sink for CO_2. This is based on the assumption that carbon in eroded sediment will decay more rapidly than in undisturbed soil as a large part of the eroded carbon is decomposed during aggregate breakdown (Lal, 2003). (ii) Soil erosion and deposition may create an atmospheric sink for CO_2 if considerable storage of sediment takes place between the site of erosion and the fluvial system (Stallard, 1998). This redistribution leads to burial of carbon and such storage zones may reduce decay. In this paper, we address this issue in a spatial analysis of sediment and carbon fate during erosion, transport and deposition by water and tillage erosion. We combine detailed measurements of ^{137}Cs, used as an erosion tracer, with SOC data for 4 agricultural fields in Europe. The objective of this study is to improve our understanding of the impact of soil erosion on the redistribution of SOC within the landscape and soil erosion induced carbon fluxes between soil and atmosphere.

Study area

For this study, 4 agricultural fields were selected in the Mediterranean. A first study site was selected in Spain ca. 25 km southeast of Cordoba. The south oriented 1.35 ha field site is part of the Alcaparro catchment that drains to a alluvial plain near the Guadajoz river and consists of clay soils, developed in marine deposits. Landuse in the area consists of dryland cropping of cereals and sunflower, although considerable parts of the area are more recently used for olive and almond plantations. This site will be referred to as the Alcaparro site. Average annual precipitation in the area is 606 mm while temperature is 17.5 °C. A second study site was selected in the Alentejo region of Portugal. It is located in a region of intensive dryland agiculture with a cropping history of winter cereals and, more recently, the introduction of sunflower cropping in a rotation with set-aside fallow. Soils are classified as Chromic Luvisols or Cambisols. Annual precipation is 580 mm while average annual temperature is 15.6 °C. The south-facing ca. 2 ha study field is part of a 24 ha catchment, bordered by a road/track at the northern side. The Thives site is located ca. 100 km north-west of Athens (Greece). The field covers an area of ca. 3.5 ha and is mainly cultivated with rainfed cereals. Soils are classified as Typic Xerochrept or Typic Rhodoxeralfs and are shallow to moderately deep with a rock fragment content ranging from 44 to 72 %. Annual precipitation is ca. 490 mm and average annual temperature is 17.0 °C. The Vicarello site (2 ha) was selected near Florence (Italy). Soils in the study area are Calcaric Regosols. Annual rainfall is 678 mm, while the average temperature is 12.7 °C. Fields are cropped with a rotation or durum wheat, barley, and oats. For each study site, a detailed topographical survey (with elevation measurements taken along a 10*10 m grid) was carried out using an automatic theodolite to construct a digital elevation model.

Materials and methods

Sampling for ^{137}Cs inventory assessment was carried out in 1996 – 1997. The sampling procedure described in Van Oost et al. (2003) was applied. Bulk samples were taken using a cylindrical tube with an

[1] Laboratory for Experimental Geomorphology, KU Leuven, Redingenstraat 16b, 3000 Leuven, Belgium; Tel.: +003216326407; Fax: ++003216326400; E-mail: Kristof.vanoost@geo.kuleuven.ac.be

internal diameter of 7.6 cm. For the Vicarello and Alcaparro site, the tube was drilled into the soil using a percussion-coring device until a depth of 0.6 m was reached. For the other sites, however, the presence of bedrock at shallow depth prevented to reach this depth at several locations. In those cases, samples were taken to the bedrock or the weathered subsoil. Reference samples were taken on non-eroding sites. In addition to this, the organic matter content was determined on the ^{137}Cs samples using the Walkley-Black method.

Results and discussion

The relative contribution of water and tillage erosion

All sites show large variation in ^{137}Cs inventories with differences up to 100% (Figure 1). This indicates that substantial erosion and deposition has taken place. Due to the high rock fragment content of the soils, ^{137}Cs measurements are associated with a high uncertainty. Consequently, a ^{137}Cs conversion model cannot be used to derive quantitative estimates of soil redistribution by water and tillage. The relative importance of tillage and water erosion is therefore assessed by considering the very distinct spatial pattern of both processes. While tillage will result in soil erosion on convexities and deposition in concave slope positions, water erosion will be highest on steep slopes and/or on slope positions characterised by a relatively large contributing area. In this perspective, a qualitative evaluation of the relative importance of diffusive and fluvial erosion processes can be made by investigating the relationship between the spatial pattern of measured ^{137}Cs inventories and basic topographical characteristics, such as slope gradient, contributing drainage area and slope curvature.
Multiple regression analysis has been applied to relate the ^{137}Cs inventory to topographical parameters following the general regression equation:

$$^{137}Cs_m = a + bS + c(Log\_A_s) + dC_u$$

where *a*, *b*, *c* and *d* are regression parameters, *S* is the slope gradient (m m^{-1}), *As* is the unit contributing area (m) en *Cu* is the total curvature ((m m^{-1})/m). Results show that in all cases ^{137}Cs inventories are significantly related to the curvature while (Table 1). In contrast, parameters that are indicative for water erosion are not significantly related. The strong correlation with curvature points to the importance of tillage erosion in explaining the higher ^{137}Cs inventories in concave and lower in convex landscape positions. This result agrees with earlier studies in Mediterranean agricultural environments indicating that tillage is the dominant soil redistribution process on sloping agricultural land (e.g. Kostas et al. 2001, Gerontidis et al. 2001, Tsara et al., 2001).

Table 1. Results of the multiple regression analysis. Values in italic indicate the significance.

site	*a*	*b*	*c*	*d*	R^2
Alcaparro	2527	-1881	-82	45611	0.44
	0.0001	*0.1223*	*0.4438*	*0.0001*	
Santa Susana	1731	-1402	-39	30086	0.33
	0.0001	*0.4784*	*0.6017*	*0.0001*	
Thives	7446	-1720	-197	161129	0.21
	0.0001	*0.6570*	*0.4749*	*0.0059*	
Vicarello	11183	-3133	580	77339	0.36
	0.0001	*0.4137*	*0.0734*	*0.0001*	

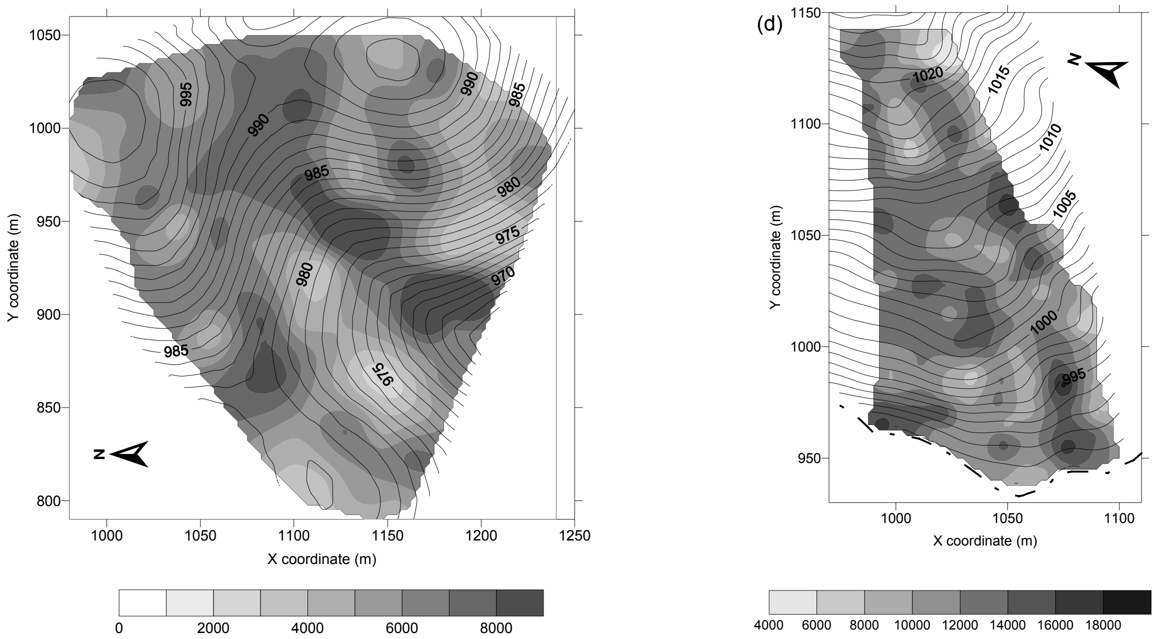


Figure 1. Spatial variation in measured ^{137}Cs inventories (Bq m^{-2}) at the Thives (left) and Vicarello (right) sites.

Patterns of SOC

The above analysis, although qualitative of nature, shows that total soil redistribution is mainly controlled by tillage erosion. This dominance is not only reflected in the spatial variation in observed ^{137}Cs inventories. A strong positive relation between SOC inventory and ^{137}Cs inventory is found for all study sites (Table 2). This strongly suggests that tillage erosion significantly contributes to the spatial variation and burial of SOC on sloping agricultural land. Tillage erodes SOC from convex landscape positions and transports this to concave landscape positions where deep soils, rich in SOC develop. This is further supported by the significant correlations between ^{137}Cs inventories and Ap-depths (depth of the soil A-horizon) (Alcaparro r = 0.59, p<0.001; Santa Susanna r = 0.40, p<0.001).

Table 2. Pearson correlation coefficients (*r*) of SOC inventories and ^{137}Cs inventories.

	r
Alcaparro	0.688^{***} (n=37)
Santa Susana	0.524^{***} (n=42)
Thives	0.478^{***} (n=44)
Vicarello	0.381^{***} (n=53)

Conclusions

In this study, ^{137}Cs measurements were used to study soil redistribution patterns and rates on 4 study sites throughout Mediterranean Europe (Spain, Italy, Greece and Portugal). The observed spatial pattern of ^{137}Cs inventory indicates that tillage erosion is the predominant soil erosion process on these study sites. This results agrees with earlier studies reporting the dominance of tillage erosion in the total soil redistribution on sloping agricultural land (e.g. Govers et al., 1994, Govers et al., 1999). Significant correlations between ^{137}Cs and SOC inventories suggest that tillage substantially contributes to the removal of SOC at convex landscape positions while soil and associated SOC is buried in concavities.

Until now, soil erosion carbon dynamic-studies focus on the process of water erosion (Lal, 2003, Stallard, 1998) but the role of water erosion in the global carbon budget is highly uncertain. Our results indicate that tillage erosion leads to substantial redistribution of SOC in agricultural landscapes. This mechanism may lead to significant C sequestration by fixating atmospheric C at eroding sites while the eroded C is efficiently stored in the subsoil at depositional sites. However, a quantification of the water- and tillage induced carbon fluxes between soil and atmosphere requires the integration of carbon and spatially distributed water and tillage erosion models.

References

Govers, G., Lobb, D.A., Quine, T.A., 1999. Tillage erosion and translocation: emergence of a new paradigm in soil erosion research. Soil and Tillage Research 51, 167-174.

Govers, G., Van Daele, K., Desmet, P., Poesen, J., Bunte, K., 1994. The role of soil tillage in soil redistribution on hillslopes. European Journal of Soil Science 45, 469-478.

Lal, R., 2003. Soil Erosion and the global carbon budget. Environment International 29, 437-450.

Stallard, R.F., 1998. Terrestrial sedimentation and the carbon cycle: Coupling weathering and erosion to carbon burial. Global Biogeochemical Cycles 12, 231-257.

Kosmas, C., Gerontidis, S., Marathianou, M., Detsis, B., Zafiriou, T., Muysen, W.N., Govers, G., Quine, T., Vanoost, K., 2001. The effects of tillage displaced soil on soil properties and wheat biomass. Soil & Tillage research 58, 31-44.

St Gerontidis, D.V., Kosmas, C., Detsis, B., Marathianou, M., Zafirious, T., Tsara, M., 2001. The effect of moldboard plow on tillage erosion along a hillslope. Journal of Soil and Water Conservation 56 (2), 147-152.

Tsara, M., Gerontidis, S., Marathianou, M., Kosmas, C., 2001. The long-term effect of tillage on soil displacement of hilly areas used for growing wheat in Greece. Soil Use And Management 17 (2), 113-120.

Van Oost, K., Govers, G., Van Muysen, W. A process-based conversion model for caesium-137 derived erosion rates on agricultural land: An integrated spatial approach. Earth Surface Processes And Landforms 28 (2), 187-207.

Erosion potential of organic and conventional farming – validation of large scale modelling by results of a long term field study

Auerswald, K.[1] – Kainz, M. – Fiener, P.

Abstract

Modelling erosion potential of organic (OA) vs. conventional agriculture (CA) on the scale of Bavaria, Germany, resulted in 15% less erosion potential for OF (Kainz et al., this volume). For validation, erosion was measured over 8 years in 10 sub-watersheds (287 erosive events)on two neighbouring OA and CA farms using best management practices.

In general all important findings from the country-scale study could be verified on the farm scale: The bare fallow soil losses were close to the averages in Bavaria. Slopes were shorter and steeper, soils shallower and less erodible, and land-use was less erosive under OA on both scales. Finally erosion was less under OA on both scales. On the farm scale this was true for the predicted and for the measured soil loss, indicating that the major findings of the country-scale modelling are valid.

Differences between both scales were detected in three important aspects: (1) Rain and rain erosivity was identical for both neighbouring farms, while a large difference between OA and CA occurs on a country scale. (2) The measured and the predicted soil losses were much lower in both systems as compared to the average in Bavaria due to the best-management practices.(3) The difference in soil loss between OA and CA was larger for the measurement (-86%) than for the prediction (-33%). This may indicate an additional effect of OA in reducing erosion which is not understood, quantified and taken into account in present models.

Introduction

Soil erosion by water is regarded as being one of the most serious environmental problems associated with land use (Morgan 1996). Organic agriculture aims to be in closer alignment with natural cycles and processes than CA. Hence OA should also cause less erosion than CA. Although this is claimed sometimes, proof is still missing. To our knowledge, there is only one study which compares soil loss on a conventional and on an organic farm, and which demonstrates a smaller soil truncation for OA (Reganold et al. 1987) based on the unproven assumption that soil depth prior to different farming were identical. Furthermore, there are some studies comparing soil properties which influence erosion like infiltrability, aggregate stability or earthworm abundance (Mulla et al. 1992; Scullion et al. 2002; Mäder et al. 2002). However, these studies allow no quantitative conclusion on soil erosion and they do not take the various interactions between different factors governing erosion into account. Hence Kainz et al. (this volume) evaluated on a country-wide scale the erosion potential of organic and conventional faming following a modelling approach. We will try to validate their conclusions by evaluation long-term measurements from two neighbouring farms. An extended version of this contribution may be found in Auerswald et al. (2003).

Material and Methods

On two neighbouring farms, one conventional (68 ha) the other organic (43 ha), soil loss was continuously measured on a field to sub-watershed scale for 8 years in 10 small sub-watersheds ranging in size from 0.5 to 16 ha. The sub-watersheds consisted of less than one field to a few fields because no artificial borders are allowed at this scale. The 10 sub-watersheds were selected out of 16 to have identical soil use except for the type of farming with 83.7 / 83.1% arable land, 10.3 / 10.8% grassland and permanent set-aside, 4.6 / 5.0% field borders, and 1.4 / 1.1% farm roads in the conventionally and the organically farmed watersheds, respectively. Runoff and soil loss were measured on an event base by sampling 0.5% of the runoff with Coshocton-type runoff samplers where runoff was concentrated by topography and/or field borders. For details of the measurement and validation of the measuring system see Fiener & Auerswald (2003 a). Soil loss was modelled with high resolution using the dUSLE (average polygon size: 13 m^2; Fiener & Auerswald 2003 a). Best management practices were applied appropriate to the individual farming systems (i.e. optimised field layout with field borders acting as runoff barriers, use of ultra-wide tyres, reduction of field passes, use of intercropping, catch crops and residue management to increase surface cover, use of grassed waterways). For details of management see Auerswald et al. (2000) and Fiener & Auerswald (2003 a, b).

The USLE (Wischmeier & Smith, 1978) predicts soil loss by multiplying six more complex terms:

$$A = R\ K\ L\ S\ C\ P$$

where A is the long-term average annual soil loss (t ha^{-1} yr^{-1}), R is the rainfall and runoff erosivity (N hr^{-1} yr^{-1}), K is the soil erodibility (t hr ha^{-1} N^{-1}), L and S are dimensionless topography factors quantifying the influences of

[1] Lehrstuhl für Grünlandlehre, Wissenschaftszentrum Weihenstephan, D-Freising, Tel.: ++ 49 8161 71 3965; Fax: ++ 49 8161 71 3243; E-mail: auerswald@wzw.tum.de

the watershed area and watershed curvature, C and P are dimensionless factors quantifying the influence of the cropping system and the influence of permanent erosion control measures like terracing. The C factor can be estimated from the combination of the so-called soil loss ratio SLR with the erosivity index EI (Wischmeier & Smith 1978). The EI quantifies the seasonal distribution of rainfall erosivity. The SLR quantifies the susceptibility of the soil surface relative to the conditions of a freshly prepared seedbed, which is thus considered a standard. The SLR mainly depends on tillage and soil cover. It can be determined experimentally, e.g., by rainfall simulator experiments, or by calculation from sub-models. We calculated "measured" C factors from the measured soil loss and the predicted bare fallow soil loss RKLSP of the instrumented watersheds after adjusting the measured soil loss for the effects of the grassed waterways and the retention ponds at field borders as quantified by Fiener & Auerswald (2003 a). "Predicted" C factors for the specific rotations of both farms were derived from soil cover (plants, residues, stones) measured bi-weekly in 15 fields at three geodetically defined locations over four years (for examples of data see Auerswald et al. 2000). The soil loss ratios were calculated from soil cover using the equation determined by Kainz (1989) with rainfall simulator experiments under similar conditions. The C factors were then computed from daily soil loss ratios and the annual distribution of the erosivity index taken from Rogler & Schwertmann (1981). The carry-over effect after inversion of ley on the organic farm was taken from Wischmeier & Smith (1978).

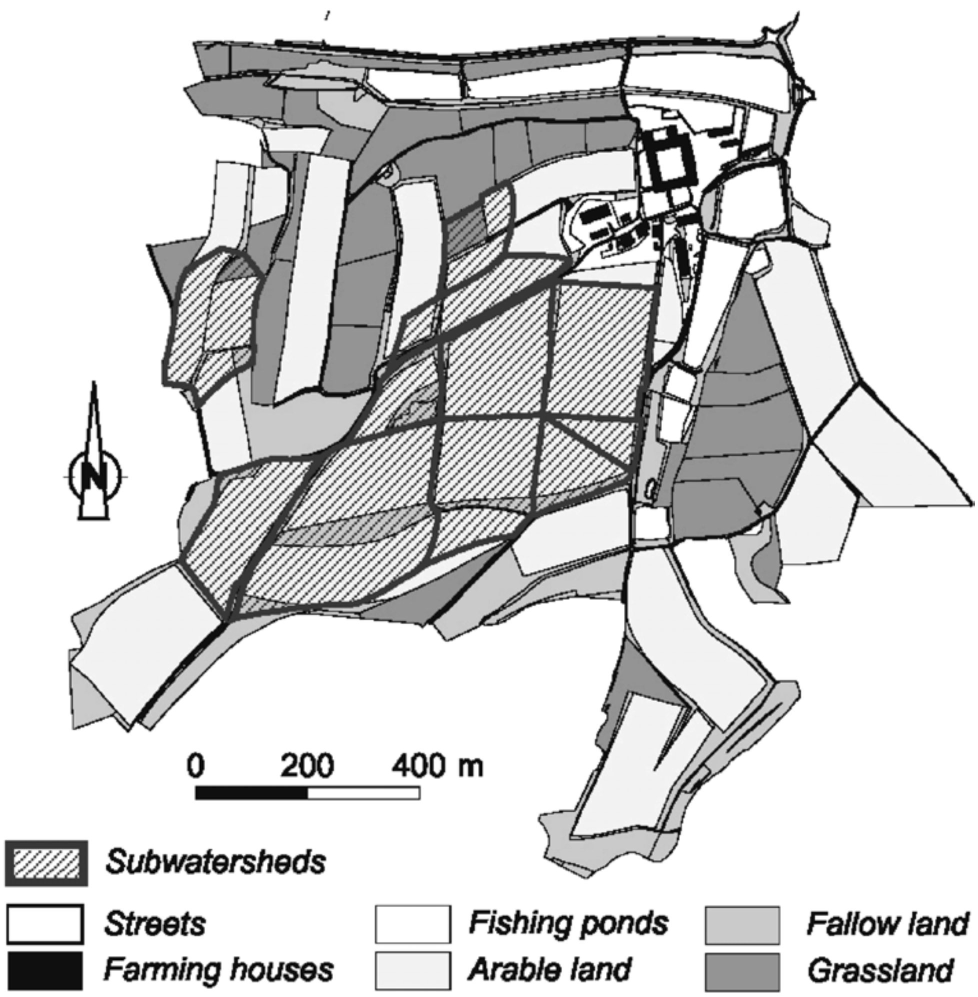


Figure 1. Layout of fields, grassland and set-aside areas on both experimental farms. The gauged watersheds used for this study are enclosed by bold lines and hatched. The farm road running from the SW corner diagonally to the farmstead in the NE corner separates the organic from the conventional farm. The four watersheds north of the farm road are organically farmed, those south of the road are conventional

Results and Discussion

During the 8-yr measuring period 287 events induced runoff and soil loss in at least one of the 10 sub-watersheds. The data set, however, represents a unique situation and thus the absolute values of the different parameters for both farms differ from the country averages. Nevertheless, the relative differences between OA and CA in this data set confirm the results from the country statistics (Table 1). The organic farm had more leys at the expense of row crops, which was similar to the countrywide averages. The site conditions exhibited similar differences as the country average except for long-term average precipitation and the R factor which are considered identical for two farms separated only by a farm road. The organic farm had soils with a smaller K factor. It was situated on steeper land and the S factor was larger, the field size and the L factor were smaller. The bare fallow soil loss (RKLSP) of the organic farm in the validation study was, however, about 17% smaller due to the identical R factor. Finally, the measured soil loss from the organic farm was much less than the difference in RKLSP (86% vs. 17%) proving the lower erosion risk of a land use, which incorporates leys.

Table 1. Average cropping conditions and erosion parameters on arable land (AL) of the conventional and the organic farm (high-resolution erosion modelling with a total of 52894 cells; measured soil loss is based on 2296 watershed events) as compared to the Bavarian average taken from Kainz et al. (this volume).

Variable	Unit	Conventional farm	Organic farm	Difference between OA and CA	
		Validation		Validation	Bavaria
Small grain	% of AL	50.0	42.9	-7%	-1%
Row crops	% of AL	50.0	20.8	-29%	-14%
Ley	% of AL	0.0	22.3	+22%	+14%
Precipitation	mm yr^{-1}	804	804	0%	+28%
R factor	N hr^{-1} yr^{-1}	69	69	0%	+27%
K factor	t hr ha^{-1} N^{-1}	0.42	0.32	-24%	-14%
Number of fields	-	7	14	+100%	n.d.
Field size	ha	4.3	2.2	-49%	n.d.
Slope length	m	159	112	-30%	-19%
L factor	-	2.69	2.25	-16%	-4%
Slope gradient	%	8.9	10.4	+16%	+16%
S factor	-	1.04	1.36	+32%	+17%
RKLSP	t ha^{-1} yr^{-1}	68.9	57.4	-17%	+14%
Measured soil loss	t ha^{-1} yr^{-1}	2.5	0.2	-92%	n.d.
Measured soil delivery	t ha^{-1} yr^{-1}	0.29	0.04	-86%	n.d.

On the conventional farm the C factor determined from measured soil loss was 0.036, which matches the C factor predicted from soil cover measurement (0.040; range 0.028–0.049). On the organic farm the measured soil loss gave a much lower C (0.004), while from soil cover alone a higher C factor than on the conventional farm was obtained (0.049) because more frequent tillage reduced soil cover. Including the carry-over effect into the prediction yielded a lower C factor than on the conventional farm (0.032), but it was still considerably higher than that derived from the measured soil loss. This could be the result of an additional effect of organic farming due to the absence of mineral N fertilizers and synthetic pesticides, which until now has not been quantified.

The measured soil losses on both farms were much smaller than what could be expected on average for all conventional or organic farms (Table 1). This was due to the adoption of best-management practices on both farms (Auerswald et al. 2000; Fiener & Auerswald 2003 b), which have considerably lowered soil loss. This can also be shown by comparing soil loss measured be for and after the implementation of erosion control strategies: For one field, which now belongs to the organic farm, Schimmack et al. (2002) quantified the soil loss by using atomic-weapon fallout plutonium. Soil loss by sheet and rill erosion (not including tillage erosion) was more than two orders of magnitude greater than after the best-management practices were introduced. Averaged over a 23 yr period the rate of soil loss was 14 t ha^{-1} yr^{-1} compared with substantially less than 1 t ha^{-1} yr^{-1} after the land-use change.

The measured soil delivery (soil loss leaving the agricultural land) was even lower by an order of magnitude than the measured soil loss due to the installation of retention structures like grassed waterways and retention ponds (Fiener & Auerswald 2003 a, b). This demonstrates that soil loss and off-site damages could be greatly lowered with both farming systems without significant change in the acreage of different crops. In consequence, on-site and off-site protection can be achieved without economical drawback (Fiener & Auerswald 2001, 2003 b).

Conclusions

In general all important findings from the country-scale study could be verified on the farm scale: The bare fallow soil losses were close to the averages in Bavaria. With OA slopes were shorter and steeper, soils shallower and less erodible, and land-use was less erosive than with CA on both scales. Finally erosion was less under OA on both scales. On the farm scale this was true for the predicted and for the measured soil loss, indicating that the major findings of the country-scale modelling by Kainz et al. (this volume) are valid.

Differences between both scales were detected in three important aspects: (1) Rain and rain erosivity was identical for both neighbouring farms, while a large difference between OA and CA occurs on a country scale. (2) The measured and the predicted soil losses were much lower in both systems as compared to the average in Bavaria due to the best-management practices. Retention structures allowed to reduce off-site damages even more. Present agriculture does not reduce soil loss to a degree, which could be achieved without economic restrictions. This is true for both, CA and OA. (3) The difference in soil loss between OA and CA was larger for the measurement (-86%) than for the prediction (-33%). This may indicate an additional effect of OA in reducing erosion which is not understood, quantified and taken into account in present models.

Acknowledgements

The scientific activities of the research network "Forschungsverbund Agrarökosysteme München" (FAM) were financially supported by the German Federal Ministry of Education and Research (BMBF 0339370). Overhead costs of the research station of Scheyern were funded by the Bavarian State Ministry for Science, Research and Arts. Many persons, namely Stephan Weigand and Richard Wenzel, helped during the 10 year of data acquisition and evaluation.

References

Auerswald K Albrecht H Kainz M & Pfadenhauer J 2000. Principles of sustainable land-use systems developed and evaluated by the Munich Research Alliance on agro-ecosystems (FAM). Petermanns Geographische Mitteilungen 144, 16-25.

Auerswald K Kainz M & Fiener P 2003. Erosion potential of organic versus conventional farming evaluated by USLE modelling of cropping statistics for agricultural districs in Bavaria. Soil Use Mangem. 19: 305-311.

Fiener P & Auerswald K 2001. Eight years of economical and ecological experience with soil-conserving land use. In: Helming K (Editor) Multidisciplinary approaches to soil conservation strategies. ZALF, Müncheberg, Germany, 121-126.

Fiener P & Auerswald K 2003 a. Effectiveness of grassed waterways in reducing runoff and sediment delivery from agricultural watersheds. Journal of Environmental Quality 32, 927-936.

Fiener P & Auerswald K 2003 b. Concept and effects of a multi-purpose grassed waterway. Soil Use and Management 19, 65-72.

Kainz M 1989. Runoff, erosion and sugar beet yields in conventional and mulched cultivation. Results of the 1988 experiment. Soil Technolology Series 1, 103-114.

Kainz M Fiener P & Auerswald K, this volume. Erosion potential of organic and conventional farming – results of a country-scale modelling the situation in Bavaria.

Mäder P Fließbach A Dubois D Gunst L Fried P & Niggli U 2002. Soil fertility and biodiversity in organic farming. Science 296, 1694-1697.

Morgan RPC 1996. Soil erosion and conservation. Addison-Wesley Pub. Co.

Mulla DJ Huyck LM & Reganold JP 1992. Temporal variation in aggregate stability on conventional and alternative farms. Soil Sciences of America Journal 56, 1620-1624.

Reganold JP Elliott LF & Unger YL 1987. Long-term effects of organic and conventional farming on soil erosion. Nature 330, 370-372.

Rogler H & Schwertmann U 1981. Erosivität der Niederschläge und Isoerodentkarte Bayerns. Zeitschrift für Kulturtechnik und Flurbereinigung 22, 99-112.

Schimmack W Auerswald K & Bunzl K 2002. Estimation of soil erosion and deposition rates at an agricultural site in Bavaria, Germany, as derived from fallout radiocesium and plutonium as tracers. Naturwissenschaften 89, 43-46.

Scullion J Neale S & Philipps L 2002. Comparisons of earthworm populations and cast properties in conventional and organic arable rotations. Soil Use and Management 18, 293-300.

Wischmeier WH & Smith DD 1978. Predicting rainfall erosion losses - a guide to conservation planning. U.S. Department of Agriculture, Agricultural Handbook 537.

Development of a field-scale erosion model

Antal, S.[1] – Máté, F. – Sisák, I.[2]

Plot-sized rainfall simulation experiments have been carried out and development of a new, field-scale erosion model has been started, in which sheet and rill erosion should be modelled as two stages of the same process.

Basic idea of the model development was that one cannot know the surface and soil properties in full detail so stochastic methods should be used. The simulated area is divided into pixels. The elevation of pixels is known (***H***), but it is randomly diverted from the original value with the surface roughness between plus and minus ***Z***. ***H*** is function of the slope angle yet (α), but digital elevation model may be used later.

The velocity of rainfall considered to be 9 $m.s^{-1}$. The initial velocity of water on the surface is the component of rainfall velocity in the direction of slope. The water volume in a pixel is the area multiplied by the height of water column. The water velocities into direction *x* and *y* are stored in a matrix, too. The water moves with some degree of randomness toward the neighbours. The unified water masses move together and cannot be split again. Their velocities are calculated from the summed impulses. The acceleration of the water masses had to be also calculated from gravitation and friction (***S***).

A fraction of water infiltrates into the soil. The speed of infiltration depends on the initial infiltration capacity and on the volume of water stored in the profile. Steady state infiltration depends on the seepage and assumed to be constant. Three variable describe the process: initial infiltration into the dry soil ($\boldsymbol{K_0}$), storage capacity (***C***) and equilibrium hydraulic conductivity ($\boldsymbol{K_e}$). The process can be described by first order inhomogenous differential equation. The soil has average surface storage capacity (***F***) which randomly varies between zero and 2***F***. There is no surface runoff until the capacity of surface storage not filled by the rainfall or by the runoff from other pixels. The infiltration reduces the amount of water stored on the surface or, if that is not enough, reduces the surface runoff.

The mass of soil eroded by water is proportional to the impulse of water and erodibility of soil (***E***). The volume of suspended solid increases the volume of water. The erosion is assumed to happen from the whole pixel therefore the removed soil mass is proportional to the deepening of surface. The deepening can be considered as rill below a given depth but there is no theoretical difference between the deepening and rill formation so we call it rill. The erosion effects changes in the ***H*** matrix. This has the hydraulic consequence that water can quit rills only if its impulse increases the limit caused by the barriers in the neighbourhood.

Part of the suspended solids settles back on the soil surface. The velocity of settling calculated from the Stokes-formula, but average diameter of the settling particles (***d***) and their average bulk density ($\boldsymbol{\rho}$) must be estimated. Complete mixing has been assumed so the average distance of an average particle from the soil surface is half of the water column. The distance of settling during one time step is calculated from the Stokes-formula and the ratio of this distance to the height of water column gives the rate of settling. The settled particles fill the rills and it is recorded in the ***H*** matrix, too. The settled particles may be eroded again as described above.

The rainfall is homogenous in space and time yet but temporal variability will be incorporated later. The parameters of the rainfall are the intensity (***I***) and duration (***t***).

The model has been tested and parameterized with data from small plot erosion experiments with simulated rainfall at Somogybabod where soil properties and slope result in strong rill erosion.

Special experiments will be designed to measure unconventional parameters (e.g. ***S***), investigations will be carried out to estimate ***d*** and $\boldsymbol{\rho}$ from usual soil physical data and further experiments will be carried out to estimate the other parameters, too.

This work was carried out with support of the DESPRAL (EVK1-CT-1999-00007) and 3/024/2001 NKFP projects.

[1] Pictron Ltd. Bartók Béla St. 3, H-1114 Budapest, Hungary. Tel.: 36-1 381-0776; Fax: 36-1 381-0777; E-mail: antisamu.pictron@axelero.hu

[2] University of Veszprém, Georgikon Faculty for Agriculture, Department of Soil Science and Agrochemistry, Deák F. St. 16, H-8360 Keszthely, Hungary; E-mail: talajtan@georgikon.hu

Erosion potential of organic and conventional farming – results of a country-scale modelling the situation in Bavaria

Kainz, M.[1] – Fiener, P. – Auerswald, K.

Abstract

Organic agriculture (OA) aims to identify a production regime which causes less environmental problems than conventional agriculture (CA). We examined whether both differ in susceptibility to soil erosion by water. To account for the large heterogeneity within the rotations practiced on different farms, we chose a statistical evaluation and modelled erosion from the cropping statistics for 2056 districts in Bavaria (70547 km^2; 29.8% arable). Physical conditions of erosion were determined in a rectangular grid yielding 13125 grid cells of ca. 5 km^2 covering the whole area of Bavaria. On average, about 15% less erosion on arable land was predicted for OA than for CA due to the higher percentage of leys in the rotations, although OA more often than CA occupies areas, which are susceptible to erosion. On the country scale cropping did not change adequately with sites conditions favouring erosion. The need for erosion control seems not to influence crop rotations on erosion-prone sites.

Introduction

Soil erosion by water is regarded as being one of the most serious environmental problems associated with land use (Morgan 1996). It is highly variable in time and space, which makes it difficult to base an assessment on measurements over short time periods only, e.g., several years, or on small spatial segments, e.g., plots. To overcome this problem many soil erosion models have been developed and are accepted tools for studying soil erosion. The Universal Soil Loss Equation USLE (Wischmeier & Smith 1978) is one of the oldest models, which is still frequently used. It has a large experimental background, has been adapted to many areas in the world and is still among the best tools for long-term assessment of soil erosion by water (Nearing 1998). It was extensively customized over 20 years in the research area using data of about 1000 rainfall simulations and 500 plot years under natural rain (summarized in Schwertmann et al. 1987).

Organic agriculture aims to be a production system in closer alignment with natural cycles and processes than CA. Hence OA should also be less conducive to erosion than CA, although proof is still missing. To our knowledge, there is only one study which compares soil loss on a conventional and on an organic farm, and which demonstrates a smaller soil loss for OA (Reganold et al. 1987) and there are some studies comparing soil properties which influence erosion like infiltrability, aggregate stability or earthworm abundance (e.g., Siegrist et al. 1998; Pulleman et al. 2003). However, these attempts may be insufficient to draw firm conclusions for two reasons. First, a quantitative comparison requires that the two farms differ only in respect to the farming system while all other parameters match. This condition cannot be met and proven for large landscape elements like fields or farms. This is especially true for soil erosion, which depends on many site properties like soil erodibility, topography and rain erosivity, all known to change over short distances. Secondly, a quantitative comparison requires that the farming systems under consideration can be clearly defined, which is not the case in practical agriculture, where every farm has to be regarded individually. “Organic farming” can only be evaluated by taking into account all organic farms. Hence, in this study we compare the degree of erosion on all organic farms in Bavaria to that of all conventional farms there. This comparison is based on modelling, which allows us to specify site influences on erosion when comparing the influence of farming systems. The results will be validated by Auerswald et al. (this volume) by using long-term measured data from two farms. An extended version of this contribution may be found in Auerswald et al. (2003).

Material and Methods

The USLE predicts soil loss by multiplying six more complex terms:

$$A = R\ K\ L\ S\ C\ P$$

where A is the long-term average annual soil loss (t ha^{-1} yr^{-1}), R is the rainfall and runoff erosivity (N hr^{-1} yr^{-1}), K is the soil erodibility (t hr ha^{-1} N^{-1}), L and S are dimensionless topography factors quantifying the influences of the watershed area and watershed curvature, C and P are dimensionless factors quantifying the influence of the cropping system and the influence of permanent erosion control measures like terracing.

The long-term average C factor can only be computed for complete rotations for two reasons. First between two main crops there is a period, sometimes of some months duration, in which considerable erosion may occur but cannot be assigned either to the previous or to the following crop. Second carry-over effects exist by which the preceding crop influences the extent of erosion during following years. This is especially true in

[1] Lehrstuhl für Ökologischen Landbau, Wissenschaftszentrum Weihenstephan, D-Freising. Tel.: + 49 8161 71 3034; Fax: ++ 49 8161 71 3031; E-mail: kainz@wzw.tum.de

ley-based rotations. Sod-forming crops like clover-grass are known to stabilize the soil. This decreases soil loss up to two years after the sod has been ploughed as compared to an otherwise identical system without sod (Wischmeier & Smith 1978). These carry-over effects of leys are also identified in other models like the "prior land use factor" in EPIC (Sharpley & Williams 1990). In EUROSEM (Morgan et al. 1998) or WEPP (Lane & Nearing 1989) the higher organic matter content, the higher aggregate stability, more earthworm channels and lower erodibility (Siegrist et al. 1998, Pulleman et al. 2003) after inversion of leys would cause a similar effect.

Data on crop rotations are not available, however, for larger areas because to our knowledge no statistical inventory of rotations exists. This is true for CA and OA. Therefore, C factors assumed in this study have to be computed on the basis of cropping statistics based on a transfer function developed by Auerswald (2002). The mean absolute error between this estimation and the average from the accurately determined C factors of rotations was 0.016 only. The C factor is estimated from rather simple parameters with one equation being valid for both farming systems:

$$C = \{[830 - 15.8\,(G + M + S) + 0.082\,(G + M + S)^2]\,(1\text{-}0.03\,S) + 0.1\,S - 0.5\,M + 27\}/1000$$

where G, M and S are the percentages of small grain (including oil seeds), row crops planted in mulch tillage and the percentage of sod-forming crops, respectively. Mulch tillage is the planting of row crops into a mulch cover created by the cultivation of cover crops which are either frozen down during winter or chemically killed prior to row crop sowing or planting (Kainz 1989). In cases where C factors of less than 0.01 are predicted the C factor has to be set to 0.01 and where it exceeds 0.45 it has to be set to 0.45 (Auerswald 2002).

Study area

Bavaria is a 70547 km^2 large state in southern Germany, comprising 29.8% arable land, 16.7% grassland and 34.6% forest. It is characterized by a comparatively wide range of site conditions. This allows extrapolation of findings in a study such as this to other German states or to neighbouring countries like Austria and Switzerland (Auerswald 2002). Bavaria is divided into 2050 districts. For each of these districts average cropping records exist from the INVEKOS inventory (INtegriertes VErwaltungs- und KOntrollSystem zur Kontrolle von flächengestützten Förderanträgen; integrated administration and control system for European Community aid schemes). The INVEKOS inventory covers about 97% percent of the agricultural area and thus provides accurate information about cropping. The INVEKOS data were separated into organic and conventional farms and the average C factor was computed for each district from the respective inventory data. We used only data from rotations but not from permanent crops like hops, grapes or asparagus and we did not compare the percentage of grassland because erosion on productive grassland can be regarded close to zero in either case.

The C factor alone may be insufficient to compare the erosion risk of two farming systems, when accumulations of organic farms in certain regions occur, which may be characterized by non-average erosion conditions. The C factors hence have to be combined with the other factors of the USLE to yield soil loss. To guarantee a sufficiently high resolution, Bavaria was divided into a rectangular grid of 13125 cells, each about 5 km^2 in size. For each grid cell the necessary information to calculate the R, K, L, S and P factor were determined. Details on data acquisition and interpretation are given by Auerswald & Schmidt (1986). By multiplying the product RKLSP with the respective C factors of OA or CA of each grid cell we are able to predict regional and general differences in soil loss between OA and CA systems. The average cropping conditions on either organic or conventional arable land were computed by weighting each grid cell according to the proportion of respective arable land.

Results & Discussion

OA occupies less favourable arable sites than CA. On average the arable OA sites receive more precipitation and have soils, which are less deep, and slopes, which have steeper gradients (Table 1). The higher annual precipitation corresponds to a greater erosivity R, and the steeper slopes to a greater S factor. The shallower soils of OA are also stonier, sandier or clayier and hence have a 14% lower erodibility K. This difference in K , however, is too small to compensate for the 27% greater R and 15% greater S.

Table 1. Average site conditions on arable land of conventional and organic farms (computed from 13125 grid cells weighted according to their percentage of conventional or organic arable land)

Variable	Unit	Average CA	Average OA	Difference OA - CA
Precipitation	mm yr^{-1}	767	981	+28%
R factor	N hr^{-1} yr^{-1}	65.4	83.2	+27%
Soil depth	m	0.68	0.64	-6%
K factor	t hr ha^{-1} N^{-1}	0.37	0.32	-14%
Slope length	m	185	150	-19%
L factor	-	2.41	2.30	-4%
Slope gradient	%	7.5	8.7	+16%
S factor	-	0.87	1.02	+17%
RKLSP	t ha^{-1} yr^{-1}	46.9	53.4	+14%

Land use accounts for these more unfavourable conditions by smaller fields leading to 19% shorter erosive slope lengths. The effect on the L factor, however, is only 4%, due to the low sensitivity of the L factor to length changes in this range of slope length and the largest differences occurring in flat landscapes. Consequently, it does not compensate for the effect of the other site specific properties. Hence the bare fallow soil loss (RKLSP) is about 14% greater on organic arable land than on conventional (Table 1).

Among all 2050 districts, 85 had no arable area and will not be considered further. OA contributed between 0% and 100% to the arable area. On average it covered 3.6% of the arable land (Table 2). Hence, it has a negligible influence on the district-wide average soil loss. The distribution between districts is very uneven, which is demonstrated by the 25% quartile being equal to 0% and the 75% quartile being equal to the mean because the mean is largely influenced by a few districts with exceptionally high percentages of OA.

Table 2. Comparison of organic and conventional agriculture based on district records for 2001 (2050 districts in Bavaria, 1965 with total arable land >0.00% of agricultural land; 1081 with organic arable land >0.00% of agricultural land, 1956 with conventional arable land >0.00%; AL is arable land, RKLSP quantifies the site-specific soil erosion potential exclusive of the influence of cropping).

		Organic Farms	Conventional Farms
Total arable land (% of AL)	25% quartile	0.0	96.4
	average	3.6	96.4
	75% quartile	3.6	100.0
Small grain (% of AL)	25% quartile	45.4	48.4
	average	56.9	57.6
	75% quartile	73.7	70.7
Row crops (% of AL)	25% quartile	7.0	23.1
	average	20.8	34.5
	75% quartile	27.4	43.0
Grass/legume ley (% of AL)	25% quartile	1.6	1.6
	average	22.3	7.9
	75% quartile	32.2	10.1
C factor (% of RKLSP)	25% quartile	3.3	10.1
	average	9.9	13.3
	75% quartile	11.9	15.9

The percentage of small grain on arable land is similar for CA and OA. Distinct differences occur in the percentages of row crop and sod-forming crops between the systems. Predominantly, OA is characterized by a large percentage of grass/legume ley which is about three times greater than that for CA. This is mainly at the expense of row crops. This difference results from the need to use symbiotic N fixation of legumes as a source of nitrogen, in place of mineral N fertilizers, and to control weeds with repeated mowing.

From the wide range in crop areas, a wide range in C factors followed. The C factors in both systems ranged from 0.01 to 0.45. The low values are restricted to regions of more than 1000 mm annual precipitation growing almost entirely grass. C factors of 0.45 indicate maize monocultures, which are restricted to the same regions because the maize serves to supplement the fodder from grassland. In both cases, the respective districts can be regarded as unimportant outliers in respect to the amount of arable land. The 25% and 75% quartiles (Table 2) provide a more realistic picture of the range.

The comparison of the mean C factors (Table 2) predicts that OA reduces soil loss by about 24% as compared to CA under identical site conditions. Due to the more erosive site conditions of OA, the soil loss is only 15% less for OA than for CA. A regression between the C factors of OA and CA, however, only yields $r^2 = 0.128$ (for n = 1072 districts) indicating that the rotations and thus the C factors of both systems are governed by different influences. Due to the large variability of both systems and the low correlation, we should not conclude that OA decreases soil erosion, although this was true for the majority of districts. For 255 out of 1072 districts the C factor of OA was larger than that of CA. The large scatters shows that for both systems the C factor, and thus soil loss, can be decreased. In both cases, the expansion of grass/legume leys would decrease soil loss far more than changing from row crop to small grain. Opportunities to increase the percentage of grass/legume leys should hence be explored in both systems.

For both systems, the average C factor decreases with increasing site specific erosion potential, which is quantified by RKLS:

$$C_{OA} = 13.7 - 1.1\ \ln(RKLS) \qquad r^2 = 0.020\ \ n = 6879$$

$$C_{CA} = 17.1 - 1.0\ \ln(RKLS) \qquad r^2 = 0.043\ \ n = 10070$$

These relationships are very weak, however. The C factor decreases only as logarithm of RKLS whereas a linear decrease would be necessary to compensate for the effect of RKLS on soil loss. Slight changes in cropping can thus not compensate for the large differences in site specific erosion potential. This is true for both farming systems. Neither OA nor CA adequately take into account the site specific erosion potential in their cropping decisions.

The equation used to estimate the C factor accounts for the effects created by the rotation. Organic farming differs not only in rotation but also in the use of agrochemicals. In addition to the rotation effect absence of pesticides are sometimes claimed, which may additionally influence the C factor. These effects on erosion are, however, not quantified and thus have not been considered.

Conclusions

In Bavaria organic farms tend to occupy the more unfavourable arable sites, which are also more at risk of erosion. The estimated site specific bare-fallow soil loss is hence 14% greater for OA than for CA. The district average in the proportion of row crops, small grains and grass/legume leys differed greatly between OA and CA indicating that natural site properties have little influence on rotations.

On average, OA will cause about 24% less erosion then CA under otherwise identical site conditions. This can be attributed to the larger area of grass/legume ley and their extraordinary potential to reduce erosion even two years after inversion. The lower C factors more than compensate for the unfavourable site conditions. Hence, the average soil loss is about 15% less for OA than for CA.

There are large deviations on both sides of the average C factor indicating that erosion in both farming systems could be reduced considerably. Erosion control does not seem to influence management decisions on crop rotation in either farming type. The lower erosion in OA on average has hence to be regarded as accidental. It is a consequence of the shortage of N supply and the need for weed control which are partly met by a greater proportion of grass/legume leys in organic rotations. The large effect of the best-management practice on the soil loss in the validation study (Auerswald et al., this volume) also demonstrates, that both farming systems have a large opportunity to reduce soil losses.

References

Auerswald K 2002. Schätzung des C-Faktors aus Fruchtartenstatistiken für Ackerflächen in Gebieten mit subkontinentalem bis subatlantischem Klima nördlich der Alpen. Landnutzung und Landentwicklung 43, 269-273.

Auerswald K & Schmidt F 1986. Atlas der Erosionsgefährdung in Bayern - Karten zum flächenhaften Bodenabtrag durch Regen. GLA-Fachberichte 1, Geologisches Landesamt, München, 64 pp.

Auerswald K Kainz M & Fiener P 2003. Erosion potential of organic versus conventional farming evaluated by USLE modelling of cropping statistics for agricultural districs in Bavaria. Soil Use Mangem. 19: 305-311.

Auerswald K Fiener P & Kainz M, this volume. Erosion potential of organic and conventional farming – validation of large scale modelling by results of a long term field study.

Kainz M 1989. Runoff, erosion and sugar beet yields in conventional and mulched cultivation. Results of the 1988 experiment. Soil Technolology Series 1, 103-114.

Lane LJ & Nearing MA 1989. USDA-Water Erosion Predicting Project: Hillslope profile model documentation. NSERL Report 2, West Lafayette.

Morgan RPC 1996. Soil erosion and conservation. Addison-Wesley Pub. Co.

Morgan RPC Quinton JN Smith RE Govers G Poesen JWA Auerswald K Chisci G Torri D & Styczen ME 1998. The European soil erosion model (EUROSEM): A dynamic approach for predicting sediment transport from fields and small catchments. Earth Surface Processes Landforms 23, 527-544.

Nearing MA 1998. Why soil erosion models over-predict small soil losses and under-predict large soil losses. Catena 32, 15-22.

Pulleman M Jongmans A Marinissen J & Bouma J 2003. Effects of organic versus conventional arable farming on soil structure and organic matter dynamics in a marine loam in the Netherlands. Soil Use and Management 19, 157-165.

Reganold JP Elliott LF & Unger YL 1987. Long-term effects of organic and conventional farming on soil erosion. Nature 330, 370-372.

Schwertmann U Vogl W & Kainz M 1987. Bodenerosion durch Wasser - Vorhersage des Abtrags und Bewertung von Gegenmaßnahmen. Ulmer Verlag, Stuttgart, 67 pp.

Siegrist S Schaub D Pfiffner L & Mader P 1998. Does organic agriculture reduce soil erodibility? The results of a long-term field study on loess in Switzerland. Agriculture Ecosystems & Environment 69, 253-264.

Wischmeier WH & Smith DD 1978. Predicting rainfall erosion losses - a guide to conservation planning. U.S. Department of Agriculture, Agricultural Handbook 537.

Modelling soil erosion at the regional scale using LANDSAT TM and RADARSAT data

Cerdan, O.[1] – King, C. – Baghdadi, N. – Desprats, J-F. – Le Bissonnais, Y. – Couturier, A.

Introduction

Soil erosion of cropland constitutes a major environmental issue (CCE, 2002 http://europa.eu.int /comm/environment/agriculture/soil_protection.htm). Besides the loss of soils and the flooding of urban areas, the main costs are attributable to the pollution of drinking water sources both by sediments and agricultural chemicals. The generation of runoff depends on rainfall, infiltration, interception and storage in surface depressions (Govers et al., 2000). The degradation of soil surfaces decreases both infiltration rates and the storage capacity of shallow surface depressions. In the Loess belt of northwestern Europe, the silty soils, which are susceptible to crusting, show a high risk of runoff and erosion. Moreover, changing trends in agricultural practices (increase of spring crops, decrease of permanent pastures, increase of field size) have increased the occurrence of erosion and mud flows over the past few decades (Souchere et al., 2003). To confront this issue, a runoff and erosion model —STREAM (Sealing and Transfer by Runoff and Erosion related to Agricultural Management), which operates at the rainfall event and catchment scales, has been developed to simulate the influence of conservation measures, such as introducing vegetated filter strips (Souchère et al., 1998; Cerdan et al., 2002a; 2002b). A particular feature of the model is that it takes into account crusting processes when calculating infiltration rates, and the influence of agricultural features (e.g. ditches, furrows…) when computing the runoff circulation network. STREAM is based on an expert-system approach that focuses on the dominant processes whilst requiring only a few input parameters. Input nevertheless requires field observations, costly in terms of time and money, thus restricting application of the model to small catchments.

Satellite data covering large areas with consistent precision can therefore be considered as a promising alternative input for any runoff and erosion model where surface characteristics constitute the key parameters. Previous work has shown that optical remote-sensing images, such as SPOT and LANDSAT TM, as well as radar images, such as RADARSAT, could provide a significant contribution (Leek, 1992; Pillesjö, 1992; Arrouays et al., 1996; Rémond, 1996; Zhangshi and Lee, 1997).

Optical satellite images can provide a specific characterization of the different land-use components, e.g. soils that are agriculturally bare or have only a thin vegetation cover during periods of highest rainfall (Mathieu et al., 1996). Furthermore, remote sensing also enables the study of temporal variations and, in certain cases, changes that affect the hydrological behaviour of catchments, such as the size and spatial distribution of individual fields (Blanchard et al., 1999). Soil-infiltration capacity is also directly related to surface roughness (Papy and Douyer, 1991), the quantification of which thus constitutes another pertinent indication of potential runoff risk. We have already demonstrated (Baghdadi et al., 2002) that surface roughness can be retrieved using a backscattering coefficient derived from high-incidence SAR radar images (RADARSAT 47°). This parameter, called the root mean square of random roughness, can also be used in satellite-based runoff models.

The objectives of the present study were to assess whether remote-sensing data can constitute an efficient input for the STREAM model by adapting it accordingly and comparing the results obtained using the new version of the model (STREAM-TED) with those based on ground data gathered during the winter of 1998 for a catchment in Normandy.

Study site and field data

The study site, the Bourville catchment in the Pays de Caux region (long. 0°50' and lat. 49°47'N), consists mainly of agricultural fields on a low-relief plateau (62 % of the area is below 2 % slope and 11 % above 5 % slope) with homogeneous soil cover. The soils are Typic Hapludalf with a texture composed of about 67% silt, 13% clay and 20% sand. They are representative of the extensive belt of silty soils in northwestern Europe.

The catchment outlet is equipped with a calibrated flume and an automatic water sampler. In addition to monitoring rainfall and runoff, three parameters were measured semi-quantitatively within each plot of the catchment on 19 February 1998: 1) surface roughness, 2) soil-crusting stages and 3) vegetation coverage were assessed. Five roughness classes were distinguished: 0-1 cm, 1-2 cm, 2-5 cm, 5-10 cm, >10 cm. Four stages of soil-crusting were identified: unsealed - initial fragmentary state where all clods are clearly distinguishable; structurally sealed - altered fragmentary state with a local structural seal; transitionally sealed - generalised structural seal with the local appearance of a sedimentary seal; sedimentary sealed: generalised depositional seal. Three classes of vegetation coverage were adopted: 0-20%, 21-60% and 61-100%.

[1] BRGM ARN, 3 Av. Claude Guillemin - 45 060 Orléans Cedex France; Tel.: +33 238 64 31 55; Fax: +33 238 64 33 61; E-mail: o.cerdan@brgm.fr

Twenty-five rainfall events, including eight producing runoff, were identified during the three months around the date of field observation, i.e. from January to March 1998.

Satellite data and classification

This study uses LANDSAT TM and RADARSAT data gathered during the winter of 1998 at the same period as the field survey.

After georeferencing the LANDSAT TM image, a classification according to the maximum likelihood method allowed us to specify 13 different radiometric classes. From these radiometric classes, 8 land-use classes were distinguished with, in certain cases, the identification of sub-classes or 'clusters' according to radiometric criteria and regrouped after classification: 1) bare soils (3 clusters), 2) sparse vegetation cover, 3) moderate vegetation cover, 4) pasture, 5) woodland (3 clusters), 6) industrial, 7) water (2 clusters), and 8) cloud.

For the bare soils and sparse vegetation cover (classes 1 and 2) selected using LANDSAT TM, roughness was extracted from the RADARSAT image after it had been georeferenced. The testing of three configurations of radar incidence (23°, 39°, 47°) by Baghdadi et al. (2002) has shown that the optimal configuration for discriminating soil roughness is 47°. This configuration allows three classes of surface roughness (rms) to be distinguished (0-1 cm, 1-2 cm, >2 cm) and provides an overall classification accuracy of 85.3%.

STREAM: original structure and adaptation for the input of remote-sensing data

STREAM is a runoff and erosion model developed on the basis of field experiments and knowledge concerning crusting and agricultural practices (Cerdan et al., 2002a; 2002b). The model is designed to calculate total-runoff and erosion volumes at any point in a catchment for a single rainfall event. Input data for STREAM are: 1) ploughing direction, 2) slope and orientation, 3) agricultural aspects, 4) soil-surface state, 5) oriented and random roughness, 6) vegetation cover, and 7) antecedent rainfall; 1-3 are used for determining the runoff circulation network, and 4-7 for computing infiltration rates.

The adaptation of STREAM to accept satellite data as input necessitates certain modifications. The resulting STREAM-TED model requires fewer input variables: 1) slope and orientation, 2) land-use classification from optical remote-sensing data, 3) surface roughness indices from RADARSAT, and 4) antecedent rainfall. Ploughing direction and oriented roughness are no longer considered. Although the degradation of soil-surface states is not considered directly, this is incorporated indirectly through the land-use and roughness data supplied by remote sensing.

The influence of the modifications was analysed by simulating the selected rainfall events on the Bourville catchment using STREAM and STREAM-TED.

Results

A range of statistical indices was calculated to evaluate model performances (Table 1). The performance of the different versions of the model proves relatively similar for the studied rainfall events. All four versions provided simulated runoff volumes that are fairly consistent when compared to measured runoff ($R^2 > 0.9$). The original STREAM model based on field data underestimates runoff volume at the catchment outlet by about 110 m3 and has a mean precision of approximately 1300 m3 for values ranging from 0 to 21,000 m3.

Table 1. Performance of STREAM and STREAM-TED with different input data compared to measured runoff (8 events).

Model	Input data	R²	ME (m³)	RMSE (m³)	AUE (%)	EF
STREAM	Ground	0.94	111	1271	34.3	0.90
STREAM-TED	Remote sensing	0.94	-217	1028	45.7	0.93

R²: coefficient of determination, *ME:* Mean Error, *RMSE:* Root Mean Square Error,
AUE: Average Unsigned Error, *EF:* Modelling efficiency.

The STREAM-TED model based on remote-sensing overestimates runoff volume by about 220 m3 on average. To analyse why, we simulated 24 additional standard rainfall events ranging from 10 to 50 mm over 2 to 5 hours with differing previous rainfall amounts. The trend of STREAM-TED overestimating runoff volume was confirmed. This difference can be attributed to changes in field conditions between field observation and remote-sensing data acquisition, and may suggest the presence of additional fields generating runoff in the STREAM-TED version (Fig. 1). The date of measured runoff covers January, and the radar and optical data were acquired at the beginning of February; the soil surfaces could have degraded during this interval and cause local changes in the state of surfaces favouring runoff.

Globally, prediction performance does not decrease with the STREAM-TED version. The average unsigned error (AUE), around 45%, is satisfactory, as is modelling efficiency (EF).

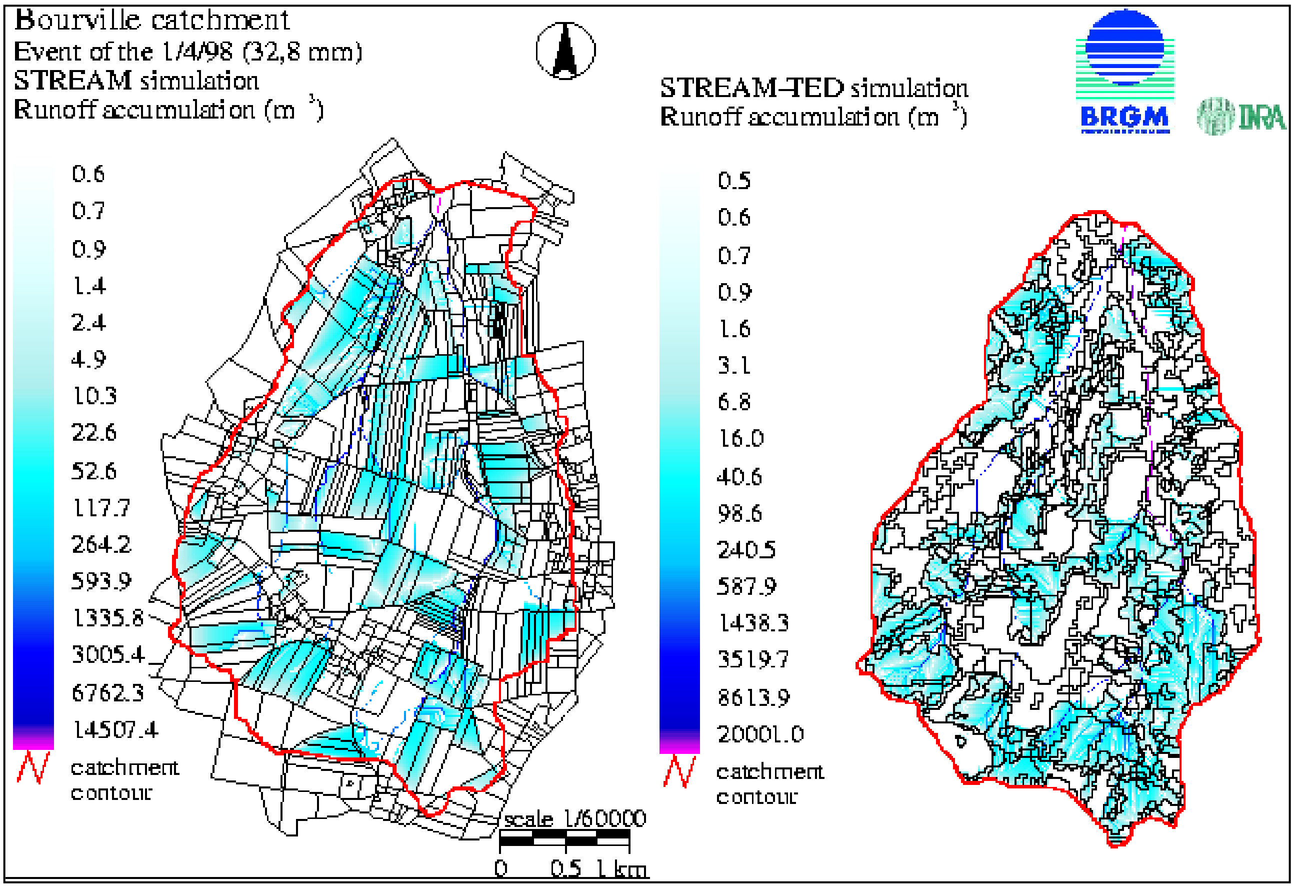


Figure 1. Maps of simulated runoff accumulation by the STREAM and STREAM-TED models

Conclusion

Progression from the original STREAM model to the STREAM-TED version involves significant modifications, in particular, the loss of information on agricultural features, which can have an influence on the runoff circulation network, and the reduction (from 31 to 9) in the number of combinations of soil-surface characteristics, and their matching with infiltration classes. Nevertheless, these simplifications do not significantly affect STREAM-TED performance compared to the original overland flow model, which suggests major prospects for its regional use with remote-sensing data. In particular, it enables catchment surveys to be carried out and the creation of overland flow hazard maps according to various scenarios of rain event and land-use distribution. These are vital tools in land-use management where the aim is to reduce runoff and erosion risk.

References

Arrouays, D., King, C., Vion, I. and Le Bissonnais, Y., 1996. Detection of soil crusting risks related to low soil organic carbon content by using discriminant analysis on the Thematic Mapper data. Geocarto International, 11 (4): 11-16.

Baghdadi N., King C., Bourguignon A., and Remond A., 2002. Potential of ERS and RADARSAT data for surface roughness monitoring over bare agricultural fields : application to catchments in Northern France. International Journal of Remote Sensing 23 (17) 3427-3442.

Blanchard, E., King, C., Le Bissonnais, Y., Bourguignon, A., Desprats, J-F., Maurizot, P. and Souchère, V., 1999. Paramétrisation du potentiel de ruissellement des bassins versants au moyen de la Télédétection et des Systèmes d'Informations Géographiques : Application à des bassins versants du Pays de Caux. EGS Etude et Gestion des Sols 6, 3, pp. 181-199.

Cerdan, O., Souchère, V., Lecomte, V., Couturier, A. and Le Bissonnais, Y., 2002a. Incorporating soil surface crusting processes in an expert-based runoff model STREAM. Catena 46, 189-205.

Cerdan O., Le Bissonnais Y., Couturier A., Saby N. 2002b. Modelling interrill erosion in small cultivated catchments. Hydrological Processes 16 (16), 3215-3226.

Govers, G., Takken, I. and Helming, K., 2000. Soil roughness and overland flow. Agronomie 20, 131-146.

Leek, R., 1992. Using remote sensing for terrestrial monitoring and prediction of sediments yield to rivers. Doctoral Thesis, University of Oslo, Nijos.

Mathieu, R., King, C. and Le Bissonnais, Y., 1996. Contribution of multitemporal SPOT Data to the mapping of a soil erosion index. Soil Technology, 10, pp. 99-110

Papy, F. and Douyer, C., 1991. Influence des états de surface du territoire agricole sur le déclenchement des inondations catastrophiques. Agronomie, 11, pp. 201-215.

Pillesjö, P., 1992. GIS and remote sensing for soil erosion studies in semi-arid environments: estimation of soil erosion parameters at different scales. Lund Univ. ISSN 0346-6787.

Rémond, A., Beaudoin, A. and King, C., 1999. SAR Imagery to estimating roughness parameters then modeling runoff risk. Int Journal of Remote Sensing, vol. 20, n°13, pp 2613-2625.

Souchère, V., King, D., Daroussin, J., Papy, F. and Capillon, A., 1998. Effects of tillage on runoff direction: consequences on runoff contributing area within agricultural catchments, Journal of hydrology, 206, 256-267.

Souchère V., King C., Dubreuil N., Lecomte-Morel V., Le Bissonnais Y., Chalat M., 2003. Grassland and crop trends: role of the European Union Common Agricultural Policy and consequences for runoff and soil erosion. Environmental Science & Policy, 6(1): 7-16.

Zhangshi, Y. and Lee, W., 1997. Obtaining spatial & temporal vegetation data from Landsat MSS & AVHRR/NOAA satellite images for a hydrological model. Photo. Eng. & Remote Sensing, vol. 63, pp 69-77.

Modelling potential risk of water erosion on a national scale in Denmark based on the Revised Soil Loss Equation

Olsen, P.[1] – Bøcher, P.K. – Greve, B.H.

Introduction

In Denmark, efforts to secure a good environmental quality of the aquatic environment have been going on for the last 16 years. The actions taken have focused on losses of nitrogen and phosphorus. Phosphorus has always been the limiting nutrient in Danish lakes. In addition, phosphorous has during the recent 10 years become the prime nutrient, when it comes to the reduction of algal growth in Danish fjords and coastal waters (*Kronvang et al., 2001*).

Loads of P from point sources has now been significantly reduced due to treatment of industrial and household wastewater. A further reduction on point source loading will eventually be extremely costly.
At present, point source loads make up much less then half the total phosphorus loading in many catchments. The diffuse loss of P from agriculture has thereby increased its relative importance. In order to achieve a good ecological status within the Danish aquatic environment, focus on diffuse losses is imperative.
In Denmark soil erosion normally occurs in connection with inexpedient use and cultivation of slopping areas having soil properties supporting the process. Whether erosion takes place will depend on the climatic conditions. Since the mid-eighties erosion on the cultivated fields apparently has increased in concurrence with the intensified soil tillage as well as the increased winter cereal cultivation. To the farmers per se the soil loss has no economic importance. What concerns about erosion in Denmark is the associated loss of P to the aquatic environment.

Besides direct action against the general P surplus in the Danish agricultural sector in general, a reduction of diffuse P loss will call for targeted initiatives in local areas having a potentially high risk of loosing P to the aquatics. Such critical source areas for P loss (*Heathwaite et al., 2000*) are to be found where an effective transport process links a P-rich area with a sensitive recipient. The GIS-based tool, presented in this manuscript, was based on this concept, focusing on water erosion as one of the potential transport processes.

Materials and methods

A simplified version (A=KLS) of the Revised Soil Loss Equation (A=RKLSCP) (*Renard et al. 1997*) was used, taking in to account only the factors that are considered invariable over time, i.e. K (soil erodibility), L (slope length) and S (slope steepness). The calculated A was assumed to describe the potential risk of water erosion.

As the basis for calculating the K-factors of Denmark we used the Danish Soil Classification, containing measurements of soil-texture of the plough layer on about 44.000 locations (*Larsen & Sørensen, 1995*). The transition from point- to surface coverage was carried out by dividing the country into 9 geo-regions, established on the basis of geological settings as well as the basic maps of the Danish Soil Classification. In the resulting map of K-values each of six soil classes within each of the nine geo-regions was assigned a K value.

The LS factor was calculated using the LS equation from RUSLE operated in ArcInfo (*Van Remortel et al. 2001*) This part of the modelling made use of a digital elevation model covering the area of Denmark with a resolution of 25-by-25 meter grid-cells.

Combining the K-factor with the LS-factor produced a KLS map, Figure 1.

[1] Danish Institute of Agricultural Sciences, Department of Agroecology, Research Centre Foulum, P.O. Box 50, DK-8830 Tjele; Tel.: +45-89-991-900; Fax: +45-89-991-819; E-mail: Preben.Olsen@agrsci.dk

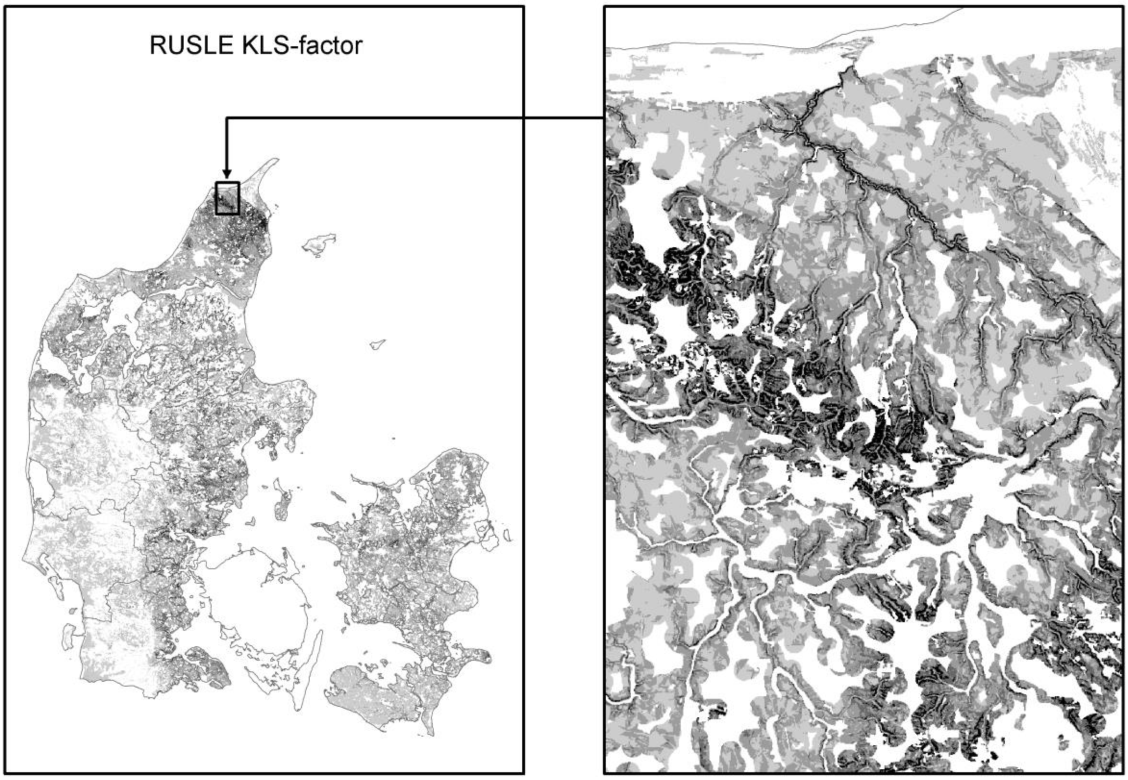


Figure 1. The map shows the variation in KLS in Denmark; the darker the tone, the higher is the KLS-value. The resolution is 25-by-25 meters.

In 1992-1997 a nation wide study on soil loss by rill erosion was conducted on approximately 190 arable fields. The summarised results given in Figure 1 show that the amounts of soil being lost were generally low. As an average of the 6 years 33% of the fields were eroded. Of the fields being eroded the average rill erosion ranged between 0.5 and 3.5 m^3/ha

Table 1. Overview of soil lost by rill erosion for all crops and for those fields where rill erosion were observed. Measurements were done in spring and represent the period since the last soil tillage operation, maximal one-year back.

	All crops[1]				Only eroded[2] fields			
	Average m³/ha	Number of fields	Number of fields eroded	Percentage of fields eroded, %	Average m³/ha	Median m³/ha	Min m³/ha	Max m³/ha
1994	1,65	67	32	48	3,46	1,9	0,02	14,82
1995	0,42	61	16	26	1,58	0,93	0,2	4,02
1996	0,15	70	20	29	0,54	0,21	0,03	3,25
1997	0,76	72	35	49	1,56	0,55	0,01	28,35
1998	0,13	131	26	20	0,65	0,44	0,08	1,83
1999	0,19	123	32	26	0,73	0,26	0,02	5,39
Average[3]	-	-	-	33	1,42	0,72	-	-

[1] Grass/clover grass, stubble, cereals/rape, Christmas trees, ploughed, stubble cultivated
[2] Cereals/rape, Christmas trees, ploughed, stubble cultivated
[3] Average of years

The data in Table 1 was used for, so to say, draw the line between high and low erosion risk areas shown in Figure 2, and to check that we did not pinpointing areas as being of low potential risk of erosion, where measurements in the field study did show high erosion. The other way round, was not as critical since our method did not involve the influence of climatic factors but only the conservative.

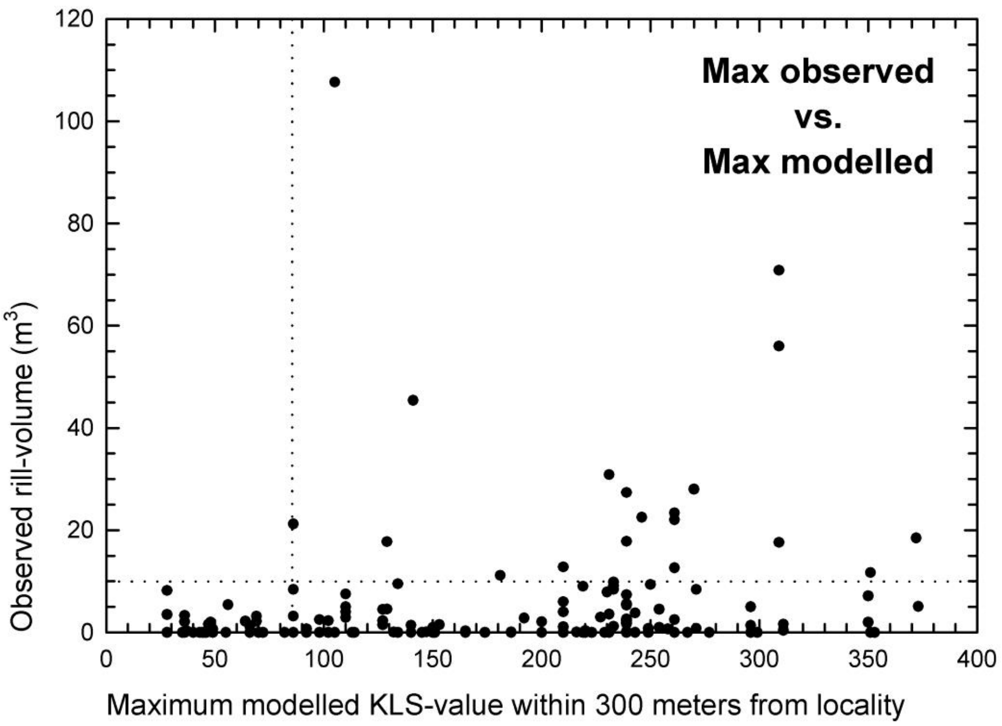


Figure 2. Comparison of observed rill-volumes in fields versus maximum modelled KLS-values for the same fields detected over a buffer zone of 300 meters to compensate for positional errors in the model.

Discussion and conclusion

Though being a coarse tool we find that the KLS method together with a GIS theme on lakes and streams can be used in the initial screening of areas that may potentially pose a risk of P loss to the aquatic environment. This first pointing out must however be accompanied by a field inspection on site before any actions can be taken restricting the use of that particular location. Additional information needs to be included e.g. phosphorus status of the soil, past cropping history, presence of buffer strips hedge rows and specific local circumstances.

The method is only considering the surface runoff and erosion. Before we can use the tool in pointing out all potential risk areas other transport processes needs to be considered e.g. ditching, artificial drainage, interflow and preferential flow paths, all of which may cause loss of phosphorous.

References

Heathwaite, L., Sharpley, A. and Gburek, W. (2000: *A conceptual approach for integrating phosphorus and nitrogen management at watershed scale*. J. Environ, Qual. 29(1), 158-166.

Kronvang, B., Iversen, H.L., Jørgensen, J.O., Paulsen, I., Jensen, J.P., Conley, D., Ellermann, T., Laursen, K.D., Wiggers, L., Flindt Jørgensen, L. & Stockmarr, J. (2001): *Fosfor i jord og vand. Udvikling, status og perspektiver*. Faglig rapport fra DMU 380. (In Danish)

Larsen, P. & Sørensen, M.B. (1996): *Geografiske data hos Afd. for Arealanvendelse*. SP rapport nr. 6. 73 pp. (In Danish).

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder (1997). Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). *Agriculture Handbook No. 703. U.S. Department of Agriculture, Agricultural Research Service, Washington, District of Columbia, USA. 404 pp*

Van Remortel, R.D., Hamilton, M.E. and Hickey, R.J. (2001) *Estimating the LS Factor For RUSLE Through Iterative Slope Length Processing of Digital Elevation Data Within ArcInfo GRID*, Cartography, Vol. 30, No. 1.

Soil texture versus soil structure in the evaluation of erodibility in sandy soil

Casermeiro, M.A.[1] – de la Cruz Caravaca, M.T. – Hernando, M.I. – Molina, J.A.

Introduction

In the Mediterranean region, soil conservation is paramount in order to adequately develop agriculture and optimise the use of available land. Water erosion processes in this zone are of particular importance given the irregular distribution of rainfall, alternating between summer drought and high-energy downpours. Therefore, it is most necessary to understand the vulnerability of soils to these physical processes. As Lal (1988) states, the erodibility of soil depends on the sum of the overall processes that affect how well the soil can retain rainwater and resist liberating its particles. Sandy soils, with little colloidal content, usually display a poorly developed structure, with highly unstable structural aggregates, which make them very susceptible to the processes of hydric erosion. This type of soil is very frequent in many parts of the Mediterranean area.

In the evaluation of soil erodibility, soil texture plays a major role for most authors. Thus in some models of soil erosion, such as USLE, RUSLE or WEPP, one of the most important pieces of soil data is texture. With respect to the movement of water in the soil profile, soil structure is one of the main edaphic features involved, especially in relation with other properties such as porosity and water storage capacity. The structure of the soil is the result of a wide variety of physical-chemical and biological processes which together create a soil aggregate.

In some circumstances, texture seems to be a good indicator for soil erosion in sandy soils, while other authors (Le Bissonais, 1996 and Amezketa et al., 1996) have instead proposed structure as one of the more important indicators of soil erosion. In some sandy soils, hydric erosion processes are more moderate, probably due to their high hydraulic conductivity, a property that is closely linked to texture and structure.

The objective of this study is to check the validity of these concepts, texture and structure, in regard to sandy soils.

Materials and methods

The study area encompasses, on one hand, the southern projection of the Sierra de Guadarrama, whose base material is made up of crystalline massif of granite nature (IGME, 1980). Also selected were soils over Miocene continental deposits composed of arkosic sands of the Madrid facies that originate from granites and gneiss from the Sierra de Guadarrama. 11 soil samples were collected in steel cores in the catchments of del Monte River, Madrid (Soto de Viñuelas), with different types of vegetation, and 12 soil samples were collected from the Rio Alberche. Both belong to the Tajo River basin in the Comunidad de Madrid (Spain). Climate is Mediterranean pluviseasonal oceanic (Rivas-Martínez, 1997) with an annual average precipitation of 498 mm. Agriculture and cattle herding are the main land uses. All samples were taken from significantly eroded areas, and there was evidence of rill erosion.

The methods employed in the determination of pH, texture and organic carbon level followed the procedures of ISRIC 1993. Soil macroaggregates (diameter 3-5 mm) were isolated and their structural stability measured using the methodology proposed by Le Bissonais 1996. Statgraphics Plus 5.1 and SPSS 11.0 were used for statistical analysis.

Results and discussion

The samples were collected at very similar altitudes, between 670 and 730 m, and were all taken from moderately sloping hillsides whose vegetation cover was a variety of pasture, cultivated land, denuded ground or fallow ground in the Monte River basin (Soto de Viñuelas) and consisted of scrub brush in the Alberche basin. The soil types belonged for the most part to the Arenosols group (FAO 1998) in Soto de Viñuelas and to the Leptosols in the Alberche (FAO 1998).

[1] Soil Science Department. Universidad Complutense de Madrid. Pz/Ramón y Cajal s/n.28040 Madrid. Tel.: +34913942088; Fax: +34913941759; E-mail: caserme@farm.ucm.es

Table 1. Soil features: pH, organic carbon and texture

SAMPLES	pH	% Organic Carbon (OC)	% Coarse Sand (CS)	% F ine Sand (FS)	% Silt	% Clay	TEXTURE
1	6,30	0,76	69,23	13,07	4,20	13,50	LOAMYSAND
2	5,32	0,16	76,61	9,46	3,19	10,74	LOAMYSAND
3	5,47	1,73	61,09	15,31	4,83	18,77	SANDYLOAM
4	6,74	1,56	69,26	16,40	3,46	10,88	LOAMYSAND
5	5,70	0,19	49,36	34,33	10,44	5,87	SAND
6	6,19	0,58	74,15	15,69	4,29	5,88	SAND
7	6,25	0,59	81,50	7,30	6,30	4,90	SAND
8	5,08	0,21	78,39	12,40	3,01	6,20	SAND
9	5,77	0,21	63,85	16,71	8,46	10,98	LOAMYSAND
10	5,86	0,49	70,44	18,83	6,41	4,31	SAND
11	6,49	0,92	70,26	14,61	8,21	6,92	SAND
12	5,84	0,91	65,88	22,33	7,43	4,46	SAND
13	5,74	0,86	66,00	24,63	5,15	4,22	SAND
14	5,89	0,85	63,27	26,85	5,53	4,35	SAND
15	5,93	0,73	66,53	22,95	7,10	3,42	SAND
16	6,44	2,24	53,93	32,21	8,93	4,93	LOAMYSAND
17	6,34	1,00	63,64	27,07	4,95	4,34	SAND
18	6,29	1,32	59,47	28,00	6,58	5,95	LOAMYSAND
19	6,57	0,70	75,29	17,38	2,18	5,15	LOAMYSAND
20	6,45	1,08	64,24	22,73	4,66	4,24	LOAMYSAND
21	5,96	0,42	74,97	18,47	2,17	4,39	SAND
22	6,07	1,63	53,28	31,74	9,89	5,09	LOAMYSAND
23	6,33	1,95	60,81	26,89	8,15	4,15	SAND

Table 2. Structural stability and aggregates distribution

SAMPLES	MWD	% > 2 mm (AG2)	% 2-1mm (AG2-1)	% 1-0,5 mm (AG1-05)	% 0,5-0,2mm (AG05-02)	% 0,2-0,1 mm (AG02-01)	% 0,1-0,05 mm (AG01-005)	% < 0,05mm (AG005)
1	1,22	49,2	12,8	13,6	15,0	3,8	1,0	4,6
2	0,86	28,2	15,8	16,8	18,2	9,2	6,2	5,6
3	1,15	44,0	16,6	13,6	16,0	3,6	2,0	4,2
4	1,15	45,6	13,4	14,0	15,6	4,0	1,4	6,0
5	0,69	23,0	9,0	14,8	23,4	8,8	12,0	9,0
6	1,75	82,2	7,0	4,8	4,2	0,8	0,6	0,4
7	1,30	53,6	14,0	10,6	12,4	3,8	1,8	3,8
8	0,75	24,4	12,4	15,8	21,0	7,8	6,6	12,0
9	1,16	45,0	15,0	14,8	14,6	4,2	3,0	3,4
10	1,12	42,4	16,9	14,5	11,7	4,5	3,1	6,9
11	1,06	37,8	18,6	14,2	17,2	6,8	5,4	0
12	0,73	23,41	9,26	23,86	19,59	11,46	5,64	6,77
13	0,61	14,75	13,30	27,37	20,00	11,16	5,67	7,75
14	0,78	24,75	12,10	22,94	20,29	9,57	3,69	6,67
15	1,01	38,16	11,00	19,81	17,04	7,15	3,04	3,80
16	1,26	54,09	8,26	14,75	10,62	6,22	2,78	3,28
17	1,04	41,91	8,77	15,24	17,42	9,63	2,83	4,19
18	1,59	75,42	4,38	7,25	6,11	3,41	1,48	1,94
19	1,67	77,03	9,06	6,81	3,97	2,15	0,56	0,41
20	1,16	48,02	8,86	15,99	13,19	7,49	2,83	3,63
21	1,10	39,72	17,79	19,37	12,35	6,23	1,95	2,60
22	1,90	94,22	0,36	1,67	1,68	1,05	0,38	0,63
23	1,63	75,93	4,58	7,86	6,34	2,70	0,69	1,90

The analytic results correspond to the soils' surface horizon. The shaded samples correspond to Soto (1-11) and the unshaded samples to the Alberche (12-23). The pH was moderately acidic as one would expect from soils that evolve from naturally acidic materials. Although all the soils showed very coarse textures (sandy and fine sand) the soils that evolved from arkose (1-11) showed slightly higher clay values (Table 1). In Table 2, the index is shown for the structural stability (MWD) and the percentages of the different sizes of the aggregates. Differences appeared between the different zones for structural stability, which was slightly higher in the Alberche soils (12-23). This could be related to their organic carbon content (Table 1). Organic carbon content depends on the type of vegetation, and generally soils under scrub brush show a slight increase in carbon content, which translates into a slight increase in the stability of the larger sized aggregates (Casermeiro et al. 2002). The statistical analysis confirms the importance of organic material in the structural stability index, as a positive correlation exists between the two (R^2=0,43, $p<0.05$). Furthermore, there exists a highly significant relationship between MWD and aggregates larger than 2 mm (R^2=0,99, $p<0.01$), and between these aggregates and organic carbon (R^2=0,44, $p<0.05$).

To confirm the relationship between structural stability and the rest of the variables a multivariance analysis was done, transforming the values of those variables that did not fall into the normal distribution (Box and Cox 1964). The results are shown in Table 3 and Figure 1, where it is observed that the first three axes account for 83% of the variance. Axis 1 compares the indicator of structural stability of the aggregates larger than 2mm with that of the rest of the aggregates. Axis 2 compares the organic carbon levels of clay to those of fine sand and silt. These results confirm that structure is more important than texture, even in soils with low levels of organic material and clay, like those in this study (Barthes and Roose, 2002; Casermeiro et al 2004). Figure 1 shows the close relationship between MWD and both the larger sized aggregates and organic carbon.

Table 3. Result of principal components analyses in selected variables

Component number	Eigenvalue	Percent of Variance	Cumulative percentage
1	6,5950	50,73	50,73
2	3,0828	23,71	74,44
3	1,2252	9,42	83,87
4	0,7763	5.97	89,84

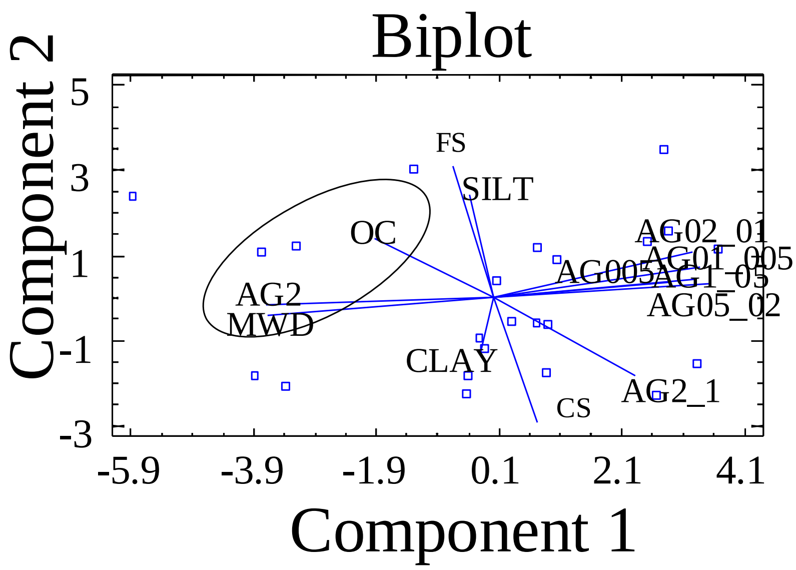


Figure 1. Principal Component Analysis biplot. Component 1 and 2.

Conclusions

In texturally sandy soils, structural stability is a good indicator for determining the susceptibility of soils to erosion processes.

The formation of structural aggregates is favoured by organic carbon content, and no statistically significant relationship is found with clay content, in spite of this being the soil colloid that should favour aggregation.

Acknowledgement

This paper is partially granted by 07M/0006/2002 of the Comunidad de Madrid.

References

Amezketa, E.; Singer, M.J. and L. Bissonais, Y. 1996. Testing a new procedure for measure wate-stable aggregation. Soil Science American journal 60 (3):888-894.

Barthes B. And Roose, E. 2002. Aggregate stability as indicator of soil suceptability to runoff and erosion: validation and several levels. Catena 47:133-149.

Box GEP, Cox D.R. 1964 Analysis of transformation. JR Stat Soc Ser B.26:211-252.

Casermeiro M.A., De La Cruz, M.T., Hernando,J., Hernando,I, Molina,J.A.& Sanchez,P. 2002 El papel de los tomillares *(Thymus vulgaris L)* en la protección de la erosión del suelo. Anales de Biología Facultad de Biología. Universidad de Murcia. Vol 24: 81-87.

M. A. Casermeiro, J. A. Molina, M. T. de la Cruz Caravaca, J. Hernando Costa, M. I. Hernando Massanet and P. S. Moreno 2004. Influence of scrubs on runoff and sediment loss in soils of Mediterranean climate**,** Catena. In Press.

FAO 1998. World Reference Base for Soil Resources. In: World Soils Resources Report,84. ISII-AISS-IBG.ISRIC 88 pp

IGME, 1980 Mapa Geológico de España a Escala 1:200.000, nº 45 Madrid. Instituto Geológico y Minero.

I.S.R.I.C., 1993. Procedures for soil analisys. 4 ed. Iternational Soil Reference and Information Center, Wageninngen. The Netherland.

Lal R.1988. Erodibility and Erosivity. In: LAL, R. (Ed) Soil Erosion research methods.

Le Bissonais, Y 1996 Aggregate Stability and assement of soil crustability and erodibility; Theory and Methodology. European Journal of Soil Science, 47:425-437

Rivas-Martínez, S 1997. Memorias del mapa de vegetación potencial de España en Rivas-Martínez S. (Ed). ICONA Madrid.

Heavy metals in the soil-plant system

Németh, T.[1] – Kádár, I.

Introduction

All of the trace elements and heavy metals can be found in all of the spheres and in different ecosystems under natural conditions, as well.

Since the industrial revolution and especially from the middle of the 20th century, energy generation, industrial production and increase of transportation have caused serious heavy metal loads on environment, and contamination of the environment (soils, plant communities, surface and subsurface waters and air) by trace elements. The rate of contamination can vary in place and in time, as a function of sources, source densities and intensities of trace element flux, meteoroligical condition and duration of the hazardous activities. The origin of the contamination can be characterized as point source or non-point source pollution. Point sources are: densely populated urban areas, surrandings of industry, sewage sludge and waste deposit sites, while the non-point sources are the dispersed ones (aerosol particles containing trace elements can be transported far away from their sources by advection before being deposited). Atmospheric dry and wet deposition also transports heavy metals to the environment.

Industrial activities have influenced the natural biogeochemical cycles of trace elements, heavy metals and other elements, which are relatively low concentrations in eco- and agroeco-systems as well as the spheres excluding litosphere. For example, worldwide annual release of Cd to the atmosphere - during the mid 1980s - has been estimated to be $7.6x10^9$ kg yr^{-1}, compared to $1.4x10^9$ kg yr^{-1} from natural sources (NRIAGU and PACYNA, 1988, NRIAGU, 1989). Cumulative all time emission of Cd to the atmosphere estimated to be $376x10^9$ kg (NRIAGU, 1994). There are significant regional differences in atmospheric Cd load because of the location of emitting sources, in the northern hemisphere the industrial inputs exceed the background fluxes by several fold. Furthermore large quantities of Cd are applied to agricultural lands worldwide with phosphate (especially phosphate rock) fertilizers, animal manures, and sewage sludge and waste waters.

The trace elements in different spheres can also be originated from natural sources (like minerals and rocks) or from human activities.

The soil–plant system is an open system subject to inputs, such as contaminants, fertilisers and pesticides, and to losses, such as the removal of metals in harvested plant material, losses by leaching, erosion and volatilisation. Heavy metal contamination potentially endanger soil, air and water, thus plants and, especially animal and human health.

On the field of fate, behaviour and effects of metals in the soil-plant system different experimental techniques are available, i.e.,pot experiments, larger (undisturbed) soil columns or lysimeters and field experiments.

Undisturbed soil column experiments

In a series of long-term laboratory experiments with large, cropped, undisturbed soil monoliths, overloading with heavy metal nitrates was studied in the presence or absence of sewage sludge. One of the objectives of the research was to determine the total potentially available and plant-available metal fractions, and to compare these to the measured plant uptake of the metals.

Multicomponent (Cd, Cr, Ni, Pb and Zn) solutions of metal nitrates (M) or communal sewage sludge (S) enriched with them (MS) were mixed into the top 10 cm layer of 40 cm diameter, 100 cm long columns of a humous sandy soil (NÉMETH et al., 1993a, 1993b, NÉMETH et al., 1999). The final metal loading rates in the soil were equivalent to 10, 30 and 100 times the permitted loading limits. Corn was grown as test plant on the monoliths. Sprinkler irrigation was applied at the soil surface. After harvesting the mature corn plants (no plants were growing at the maximal load), the upper parts of the columns were cut into 5 cm or 10 cm consecutive soil layers. Soil pH and *total potentially available* metal concentrations (c_T) were measured in air-dried soil samples (2 mol/L HNO_3 at 100 C° at 1:20 soil:extractant ratio). *Plant-available* concentrations (c_s) were determined in the soil solution obtained by centrifugation of the field-moist soil samples.

Migration and plant-availability (Table 1)

In the upper layers of the columns the total potentially available amounts of Cd reflected the application rates. Even at the highest contamination level (100M) only a slight downward movement was observed below the application zone. The migration and the plant availability is shown by the example of Cd. Though Cd and other metals were originally mixed into the 0-10 cm soil layer, their concentrations were generally higher in the

[1] Research Institute for Soil Science and Agricultural Chemistry, H-1022 Budapest, Herman Ottó u. 15. Tel/Fax: 36-1-3654-682, E-mail: nemeth@rissac.hu

0-5 cm layer than in the 5-10 cm layer due to upward movement of the elements caused probably by evaporation. The differences between the two upper layers, at equal loading rate, were lower when sludge was present. Plant-availability of Cd was calculated from the soil solution concentration ($SA_S = c_s / c_T$). The SA_S value was much lower when sewage sludge (MS) was present.

Table 1. Amounts of extractable Cd in the upper 30 cm of the soil columns (mg/kg soil)
* under detection limit

Treatment	Depth (cm)>	0-5 cm	5-10 cm	10-15 cm	15-20 cm	20-30 cm
10M	soil solution	0,056	0,012	0,003	*	*
	2M HNO_3	1,441	1,406	0,881	0,556	0,61
100M	soil solution	11,804	2,076	0,755	0,048	*
	2M HNO_3	13,43	3,842	3,159	1,306	0,906
30MS	soil solution	0,055	0,017	0,004	*	*
	2M HNO_3	3,609	3,979	0,765	0,712	0,642
100MS	soil solution	1,932	0,251	0,009	0,002	*
	2M HNO_3	9,534	7,870	0,851	0,744	0,658

Plant uptake (Table 2)
Concentrations in the shoot reflected both the loading in the soil and the order of mobility of the metals applied (Zn=Cd=Ni>Pb=Cr). Cadmium as an example: Cd concentration in the root was higher than in the shoot. Transfer factors showed that bioaccumulation of Cd (similarly to other heavy metals) was smaller when sewage sludge was present. The ratio of amounts of metals taken up by the various plant parts depended more on the type of heavy metal, than on the loading. Translocation percentage values of 87% (10M) and 90% (30MS) indicated, that most part of the total amount of Cd taken up by the plant (root+shoot) had accumulated in the shoot.

Table 2. Concentrations in the plant parts and bioaccumulation of heavy metals

Element	in shoot		in root	
	10M	30MS	10M	30MS
	µg/g dry matter			
Cd	3.5	4.69	7.17	12.1
Cr	1.24	2.48	10.5	203
Ni	25.4	17.4	168	127
Pb	6.87	11.7	104	280
Zn	839	495	1990	759
TF_t Cd	2.4	1.2	4.8	3.1

transfer factor$_t$ (TF_t) = $c_{plant\ part} / c_{soil,\ total\ potentially\ available}$

Heavy metal-load long-term field experiments

It is well known that movement of anions and negatively charged ions is the most expressed in the soil, because the soil-colloids bind them only slightly on their negatively charged surface. Linkage of metals and kations is stronger on the specific binding places, but at a bigger load these places are saturated and the more mobile fractions become conspicuous. Behaviour of metals is similar to kation-exchange. The decreasing stability order of the celates of different metals can be the following: Hg, Cu, Ni, Pb, Co, Zn, Cd, Fe, Mn, Mg, Ca. (LISK 1972, BOUWER et al. 1974, FILEP 1988, CSATHÓ 1994).

The heavy metal-load long-term field experimental series started between 1991 and 1995 with the support of Ministry of Environmental Protection. The experiments were started on calcareous chernozem soil in the spring of 1991 (Nagyhörcsök, Mezőföld), on calcareous sandy soil (Őrbottyán) and on acid brown forest soil in 1995 (Tass-puszta, Mátraalja).

In the following the results of the oldest long-term experiment set up in Mezőföld will be discussed. In this area the calcareous chernozem soil was formed on loess, and it contains averagely 5% CaCO3 and 3% humus in the ploughed layer. Concerning to its mechanical composition, it is loam with 20% clay and 40% fine-fraction. Nearly half of their clay minerals is illite**,** the third part is chlorite and a smaller part is smectite. The water table c be found at the depth of 13-15 meters, its contamination is practically excluded with surface leaching. The climate of the settlement is dry and similar to Great Hungarian Plain and it is amenable to drought. In the ploughed layer $pH_{(KCl)}$ is 7.3, and Al-P2O5 shows 80-100, Al-K2O 140-160, KCl-Mg 150-180, KCl-soluble EDTA Mn 80-150, Cu 2-3, Zn 1-2 mg kg^{-1} values, respectively. On the basis of methods and limit values initiated by MÉM NAK (1979) these values mean that the soil is well-supplied with Mn, sufficiently-supplied with Mg and Cu, medium-supplied with N and K, and weakly-supplied with P and Zn.

Salts of the 13 examined microelements and heavy metals were applied once on 4-4 levels in the spring of 1991, maize was the test crop in the first year (The investigated treatments embody soil-contamination relations that occur nowadays or also can occur in the future in the polluted environment of industrial establishments, highways, settlements and – unfortunately - in city-gardens.) The 13x4 =52 treatments were arranged in split-plot design altogether in 104 plots with 2 replications. The loading stages means 0, 90, 270, 810 kg/ha quantity per element in the form of AlCl3, NaAsO2, BaCl2, CdSO4, K2CrO4, CuSO4, HgCl2, (NH4)6Mo7O24, NiSO4, Pb(NO3)2, Na2SeO3, SrSO4, ZnSO4. The basis fertilising was done yearly with 100-100-100kg/ha N, P2O5 and K2O active agent with ammonnitrate, superfosfate, potash artificial fertilizer. It was only one application for the elements in 1991, from that time only the residual effects of the different treatments are investigated, without any new salt application.

Deep drilling was carried out four times from the begining of the experiment. The first sampling happened just before the start. The maximal depth of sampling was 60 centimeters in 1993, 90 centimeters in 1996 and 290 centimeters in 2000 (in 30 centimeter intervals). In 1993 13 treatments x 2 replications were sampled, so drilling was carried out on 26 plots, and considering the 2 soil layers, 52 samples were analysed. In 1996 12 treatments x 3 replications were done in 3 layers, so 108 samples were analysed. In 2000, the most mobile Cr, Mo, Se elements were sampled in 9 layers, while the other treatments were analysed only in the upper 3 layers. 108 average samples were made from 12 treatments x 2 replications = 24 plots. (The number of part-samples were 540) In the case of dry soil surface, the environment of drilling-hole was watered and the thinnest drill-series was used to avoid soil contamination between the layers. Sampling was done after harvesting. The 5-5 drilling-holes settled in one quadrate meter inside the plot, let 1m from the edge. In Table 3. contains the resilts of the upper part 0-90 cm soil layer.

The soil analysis data of Table 3 show that 3-10% of the Cr, 10-20% of the Al and AS, 20-40% of the Ba, Mo, Ni, Se and Sr, 40-50% of the Zn, Pb, Cu and 100% of the Cd applied, remained in the first year as ammonium-acetate+EDTA soluble form in the ploughed layer.

These results can be considered as first and orientated information. On the other hand, however the standard deviation and mistake of examinations can not be correctly estimated, on the basis of trends the vertical movement of some elements can be judged. Because leaching is a slow process and it is differs element by element, practical to repeat the deep-drilling from time to time. On the basis of the repeated results of deep drillings, which become wider in space and in time, our conclusions become more reliable. Leaching will be predictable and modelable more accurately and in the case of the necessary soil-protection the intervention can be planned more precisely and can be cheaper.

Table 3. Vertical distribution of heavy metals at the time of the beginning of the experiment (1992) and the sampling years (1993, 1996, 2000)

	Zn mg/kg				**Cu mg/kg**			
Sampling depth (cm)	**1992**	**1993**	**1996**	**2000**	**1992**	**1993**	**1996**	**2000**
0-30	1.3	213.0	96.0	93.5	3.4	270.5	108.1	98.2
30-60	.4	4.5	1.8	23.1	1.6	6.9	2.9	2.4
60-90	.6	x	.9	.6	1.1	x	1.2	1.4
	Ni mg/kg				**Pb mg/kg**			
Sampling depth (cm)	**1992**	**1993**	**1996**	**2000**	**1992**	**1993**	**1996**	**2000**
0-30	3.7	223.5	45.6	52.7	3.9	280.5	121.0	112.0
30-60	1.1	4.4	.8	.9	1.6	23.2	2.5	2.1
60-90	.5	x	.5	.6	1.5	x	1.6	1.8
	Ba mg/kg				**Sr mg/kg**			
Sampling depth (cm)	**1992**	**1993**	**1996**	**2000**	**1992**	**1993**	**1996**	**2000**
0-30	17	285	60	61	36	257	142	131
30-60	22	44	22	24	42	51	36	54
60-90	21	x	20	20	55	x	48	62
	Mo mg/kg				**Cr mg/kg**			
Sampling depth (cm)	**1992***	**1993**	**1996**	**2000**	**1992**	**1993**	**1996**	**2000**
0-30	-	43.3	13.6	11.3	.1	7.2	2.4	1.8
30-60	-	2.0	1.9	1.0	.2	14.3	1.4	1.0
60-90	-	x	1.3	1.3	.2	x	2.0	1.0
	Se mg/kg				**As mg/kg**			
Sampling depth (cm)	**1992**	**1993**	**1996**	**2000**	**1992**	**1993**	**1996**	**2000**
0-30	.3	81.0	45.5	17.2	-	92.6	44.6	34.4
30-60	.2	1.1	6.2	13.4	-	-	2.5	.4
60-90	.1	x	1.0	12.5	-	x	-	-
	Hg mg/kg				**Cd mg/kg**			
Sampling depth (cm)	**1992***	**1993**	**1996**	**2000**	**1992**	**1993**	**1996**	**2000**
0-30	-	60.9	12.8	10.0	.2	227.5	141.0	118.0
30-60	-	.4	2.0	.1	.1	6.6	.3	2.9
60-90	-	x	.1	-	.1	x	.1	.3

* In 1992 Mo and Hg was not measured

Conclusions

For the purpose of follow the fate and behaviour of trace elements and heavy metals it is essential to know the change and movement of these elements among the various compartments of the environment. The accumulation of these elements by plants depends on their mobility in soils but is highly determined by plant physiological and biochemical characteristics.

The experiments with large ***undisturbed soil columns*** are necessary to follow the vertical movement of the applied metals under environmentally controlled conditions in time and in space, the ***long-term field experiments*** – they are extremely rare, because of safety futures – can help to follow the transport of metals not only in the soil-plant relationship, but also further in the food chain in many of years (as long as the experiment exist).

References

Bouwer, H., Lance, J.C. and Riggs, M.S. 1974. High-rate land treatment II. Water quality and economic aspects of the Flushing Meadows project. *J. Water Poll. Control Fe*. 46:844-849.

Csathó, P. 1994. A környezet nehézfém szennyezettsége és az agrártermelés. Tematikus szakirodalmi szemle. MTA TAKI. Budapest. (in Hungarian)

Filep, Gy. 1988. Talajkémia. Akadémiai Kiadó. Budapest.

Kádár I. és Németh T. (2003): Mikroelem-szennyezők kimosódásának vizsgálata szabadföldi terheléses tartamkísérletben. *Agrokémia és Talajtan*. 52:315-330.

Lisk, D.J. 1972. Trace metals in soils, plants and animals. Adv. Agron., 24:267-325.

Németh T., Molnár E., Csillag J., Bujtás K., Lukács A., and Pártay G. 1993a. Fate and plant uptake of heavy metals in soil-plant systems studied on soil monoliths. Agrokémia és Talajtan 42:195-206.

Németh, T., Molnár E., Csillag, J,, Bujtás, K., Lukács, A., Pártay, G., Fehér, J. and Van Genuchten, Th. 1993b. Mobility of some heavy metals in soil-plant system studied on soil monoliths. Water Sci. Tech., 28:389-398.

Németh, T., Bujtás, K., Csillag, J., Pártay, G., Lukács, A. and van Genuchten, M. Th. 1999. Distribution of ecologically significant fractions of selected heavy metals in the soil profile. In: Fate and transport of heavy metals in the vadose zone. (Eds.: Selim, H.M. and Iskandar, I.K.) Chapter 12. pp. 251-271. Lewis Publ., CRC Press LRC, Boca Raton, US.

Nriagu, J.O. 1994. Worldwide contamination of the atmosphere with toxic metals. Nature 338:47-49.

Nriagu, J.O. 2001. Global change and the cycling of cadmium. In: Environmental cadmium in the food chain: sources, pathways, and risks. J.K. Syers and M. Gochfeld (eds.) Proc. of the SCOPE Workshop, Belgian Academy of Sciences, pp. 27-33.

Nriagu, J.O. and Pacyna, J.M. 1988. Quantitave assessment of worldwide contamination of the air, water and soils with trace metals. Nature 333:134-139.

Heavy metal availability in Hungarian Alluvial Soils

Szalai, Z.[1] – Varga, I. – Németh, T. – Jakab, G. – Madarász, B. – Tóth, M.

Introduction

The environmental and social importance of floodplains is increasing continuously since the last two decades. From the social viewpoint these areas are and can be the main recreational areas in the flatlands, and these areas also have agricultural relevance as well. From the environmental viewpoint the floodplains are multifunctional wetlands, which have green-corridor and refuge area function and this areas serves as an important filter. The water quality deterioration (and partly the air pollution) causes hidden hazards for using these riparian environments. The increased heavy metal content of the suspended sediments (mainly during the pollution waves) increased the heavy metal content of the alluvial soils and parallel with this process the canopy of the riparian forests also can be effective filter for the airborne particles. These adsorbed particles also load to topsoil. The main direct human hazard is caused by the agricultural landuse (orchards and arable lands), because the heavy metal content of this livestock can be elevated. The main ecological hazard is also caused by the heavy metal uptake. In this case the increased heavy metal content is caused low quality for species of riparian green corridors. The heavy metal content and availability of the alluvial sediments is not homogenous. It is affected by micro-topography, sediment quality, vegetation pattern and quality, etc. Present paper tries to show some local and regional differences of these processes in the riparian zone of River Danube, and the River Tisza.

Keywords: heavy metal, groundwater, alluvial sediment, Danube, Urtica dioica

Materials and methods

Study areas

The study was conducted along the Hungarian section of River Danube (three sampling sites) and along the medium Hungarian section of River Tisza (two sampling sites). In geographical order, the first one is on the Isle of Tát (site”C”), which is situated near to Esztergom (fig. 1.) at the Hungarian-Slovakian frontier. The second one is on the Háros Island (site ”A”), which is situated at the Danube section at Budapest. The third one is on the Csepel Island, near to Szigetújfalu (site ”B”), approximately 35 km south of Budapest. The fourth sampling site (site “D”) is situated near Tiszabábolna, in upstream position with “Lake Tisza” (reservoir of Tiszalök HydroPower Plant. The fifth sampling point (site “E”) is situated near Tiszasüly, downstream position with “lake Tisza”.

The both investigated rivers have highly shrunken active floodplains. The distance between the main dyke and the riverbank somewhere is less than 200 m. The bank profile of four study sites is convex, so a natural levee is situated. In case of site E, the height is continuously increasing from the bank to the dyke. The texture of the sediments is loamy on the surface in case of site B and C, and sandy-loamy in case of sites A, De and E. Sandy sediments are prevail from the 1-1,5 m depth in every sites. The mineral composition of the investigated sediments shows characteristic distribution: the Danubian sediments are calcareous sediments, where the calcite, dolomite are the main components. Their proportion may exceed the 30 %. The sediments of River Tisza have completely different, because the main component of fine sediments is the quartz, which the proportion is always higher than 50 % (fig. 2.). The “A” sample areas have relatively diverse alluvial landforms: various generations of abandoned meanders on low and high floodplains. The average groundwater table is at 3-4 m depth under high floodplains and at 1-2 m depth under low floodplains. In case of the other four study areas the width of active floodplains is very low, so their catena include only three sampling points: riverbank, natural levee, backswamp. The vegetation and the vegetation pattern of the sites have

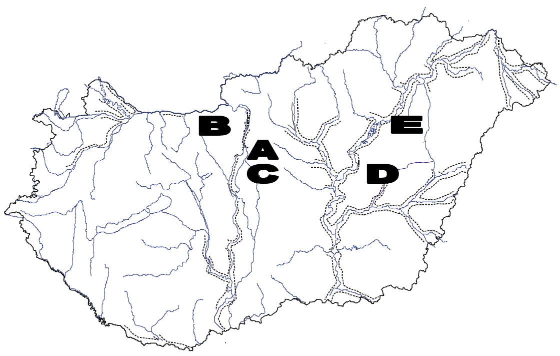


Figure 1. Map of study sites

[1] Department for Physical Geography, Geographical Research Institute, Hungarian Academy of Sciences Budaörsi út 45, H-1112 Budapest, Hungary. Tel: +36-20-3361049; Fax: +36 53 379869; E-mail: szalaiz@iif.hu, szalaiz@mtafki.hu

similarities. The lowest strip of riverbank is covered by mud vegetation. The second step of the succession series is the willow bush vegetation.

This belt is partly appears as a neighbouring belt of mud vegetation and it can appear in the deepest parts of backswamps. The tissue of this vegetation is highly accelerates the sedimentation on the natural levees. The highest surfaces are covered by willow-poplar and white poplar groves.

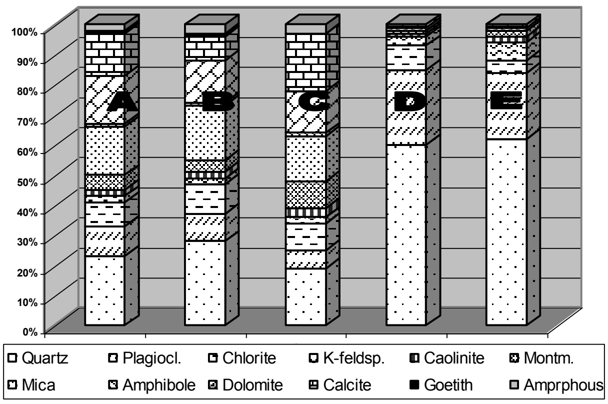


Figure 2. Mineral composition of investigated alluvial sediments

Sampling and chemical measurement

Each sampling sites includes at least three sampling points. The sampling points are situated along a catena. The site A includes two transects with 26 sampling sites. The sites B-E include 3 sampling points. The sediment samples were taken from each 10 cm. Depth of sampling is 210 cm in sites A-C and 50 cm in sites D and E. The majority of sampling points have low floodplain position. High floodplain (inundated only the high flood) points are situated only in site A and site C.

The soil solution was extracted from the soil by modified Davies-Davies procedure. After the sampling the samples were isolated by hot-proof bags. These samples were centrifugized for120 min on 3000 1/min. they were conserved by 1 cm^3 HNO_3 (/100 cm^3). The remained soil and sediment samples were extracted by H_2S-HNO_3 method for measuring "total element content" and Lakanen–Erviö method for investigating the bio-available amount. The prepared samples were measured by Zeiss AAS 30 electrothermical atom-absorption spectrometer (ETA-AAS) and by PlasmaLab inductively coupled plasma atomic emission spectrometer (ICP AES).

Results

Micro-topography, vegetation pattern and heavy metal distribution in floodplains

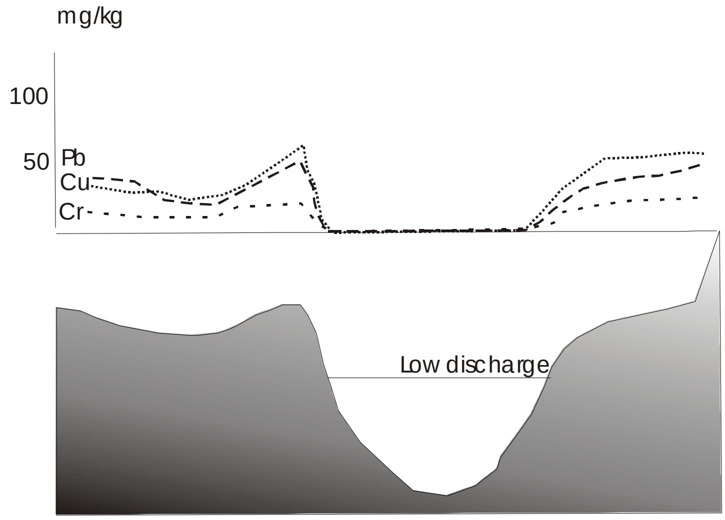


Figure 3. Cu, Cr and Pb distribution along riverbanks. Left bank: Site D, with natural levee, right bank: Site E without natural levee

The spatial distribution of total amount of heavy metals is depends on the topography of active floodplain and on the vegetation stucture (which also highly influenced by the topography). There are two possibilities for spatial heavy distribution on shrunken floodplains. If there is natural levee, the highest concentrations can be experimented there, while the sediments have lower concentrations in the backswamps. This phenomenon is enforced by the vegetation, because the levees are covered dense bush or woody vegetation. This vegetation serves as an effective filters against the suspended load (during the floods). If the elevation is increasing continuously towards the dykes, the highest heavy metal concentrations can be measured in the first dense vegetation patch, or in the sediments of the highest part of floodplain (fig. 3). Where the active floodplain is relatively wide (higher than 200 m) the vegetation structure influence the horizontal heavy metal distribution. This phenomenon is based on the influence on dry and wet deposition of airborn particles. The spatial distribution of most of heavy metals follows the structure of riparian groves.

Differences heavy metal availability between study areas

The heavy metal caused environmental hazard practically can be defined as an amount of available and amount of potentially available heavy metals. The availability is changing spatially and temporally. While the local differences in heavy metal availability is depends on the quality of land mosaics, the regional differences also are influenced by the mineral composition of alluvial sediments.

There are relevant differences between Danubian sites (A-C) and the floodplains of River Tisza (D, E). The investigated elements have lower proportion in the soil solution and in the Lakanen-Erviö extraction compare to the total amount in the calcareous sediments than the quartz dominated sediments.

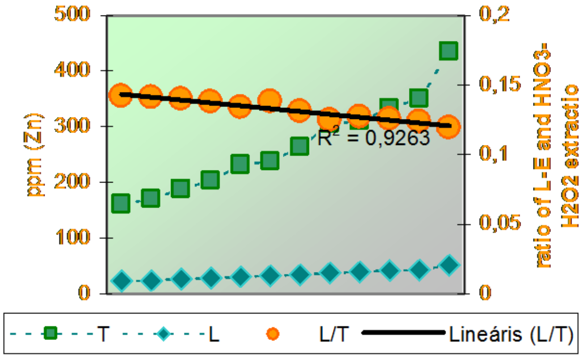


Figure 4. Relationship between total and LE extractable Zn

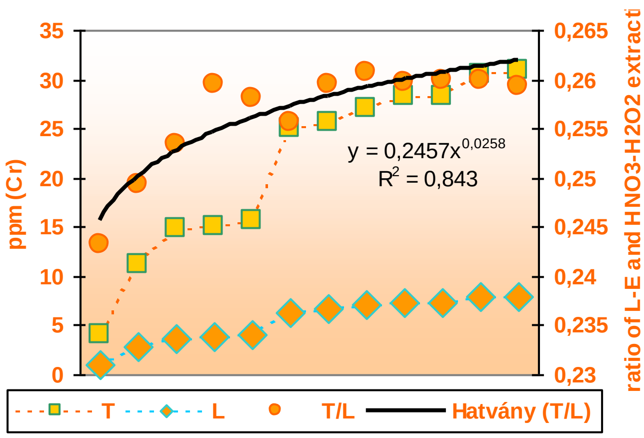


Figure 5. Relationship between total and LE extractable Cr

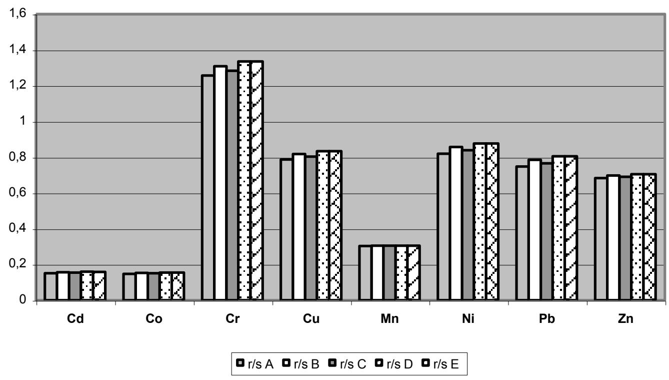


Figure 6. Root/soil ratio (R/S) of Urtica dioica in the investigated study sites

The differences in availability can be based on the source as well. If the elevated concentration is resulted from a deposition of polluted sediments (e.g. Cu) the ratio of availability (LE/total) decreases with increasing total element concentration (fig. 4). If the concentration differences are based on natural geochemical processes (as e.g. in case of Co), the above mentioned ratio will increases with increasing total element concentations (Fig 5.).

Differences in Cu uptake of Urtical dioica

The real availability appears in the amount of uptaken elements. In this research the common nettle (Urtica dioica) was studied for estimation the bioavailability by higher plants. The nettles were collected from different geomorphic position and from open and shaded position. The ratio of root concentrations and total element content of sediments were not depended on the mineral composition of sediments. The differences of this ratio were experimented between the open and shaded patches. The uptake is more intensive in the open patches, because the higher evapotranspiration on the foliar surface drives element transport from the roots towards theleaves in the xilem and this accelerates the uptake as well. The average root/soil concentration ratios (R/S) usually are lower than 1 (fig. 6.). The Al and Fe R/S values re bellow 0.001, which is caused by the high amount of these elements in the sediments. The Cd, Co and Mn have 0.2-0.3 R/S values. However the Cd is a non-essential trace element, so its uptake is strongly related with the Ca uptake. The Cu, Ni, Pb and Zn are between 0.7-0.8. The R/S value of Cr is higher than 1, it is around 1.2. This value indicates the Cr accumulation of common nettle. The difference of R/S values between study sites is extremely low, but the standard deviation (STD) of individual sites can be much more higher.

Conclusion

The riparian structure directly and indirectly affect on availability. The indirect influence appears as the spatial distribution of the investigated elements. The morphology and vegetation pattern determine the accumulation zones in the floodplains and this determine directly the inhomogenity in sediment quality.

The direct influence appears as the state of water logging and the vegetation quality and the structure (in an individual patch).

The availability can be characterising as ratio of available and total amounts of investigated elements. The indicator of availability can be an extraction method or the concentration of root tissue. Lakanen –Erviö method were used for modelling availability, which is a widespread (and standard) method in Hungary. The common nettle where used for testing it under “natural like” conditions.

The L-E extraction method resulted lower element concentrations than heavy metal concentrations in root tissues of Urtica dioica. The trace element uptake is a genetically determined characteristic of (higher) plants. This is the reason of the lower heavy metal concentrations of L-E method. (Lakanen-Ervö method were developed for estimating heavy metal uptake by crops.). The L-E extraction method can be used as a rough availability indicator for natural vegetation.

Very low differences were experimented in the average R/S ratios of studied heavy metals (Cd, Co, Cr, Cu, Ni, Pb, Zn) of Urtica dioica between study sites. This phenomenon was unexpected, because the mineralogical properties of sediments show relevant differences between Danubian floodplains and the floodplains of River Tisza. However the R/S values are quiet higher in were have shown

The indicated availability of heavy metals depends on the “origin” of alluvial sediments. If the deposited sediment is polluted (e.g. it is polluted by with material of a tailing pond) the L-E/total concentrations ratios are decreasing. This phenomenon cannot be experimented in the Urtica dioica root tissues. The R/S values were stationary in the experimented range. The differences in R/S values were not caused by the concentrations, and the mineral sediment properties.

Acknowledgements

This research was financed by Hungarian Scientific Research Fund (OTKA, project no. T38122) and Environmental Fund the Department of Environment Protection and Water Management (KAC). The authors would like to thank to Mária Baloghné di Gléria for sedimentological measurements.

References

LUNE, P., ZWART, K. B. 1997.Cadmium Uptake by crops from the subsoil. Plant and Soil, 189. pp. 231-237.

RIVETTA, A., NEGRINI, N., COCUCCI, M. 1997. Involvement of Ca^{2+}-calmodulin in Cd^{2+} toxicity during the early phases of radish (Raphanus sativus) seed germination. Plant Cell Environment, 20. pp. 600-608.

SZALAI Z.: 1998. Trace metal pollution and microtopography in a floodplain. Geografia Fisica e Dinamica Quaternaria, 110. pp. 75-78.

Trace metal concentrations in the soil solution at increasing phosphate rock doses and acid loads in a bulk soil experiment

Csillag, J.[1] – Lukács, A. – Osztoics, E. – Csathó, P. – Baczó, Gy.

Introduction

Slowly dissolving (reactive) basic phosphate rocks (PRs) are suitable for direct application to acidic soils as P fertilizers. However, their use may cause environmental problems since, similarly to other, commercial P-sources, they contain potentially toxic elements as pollutants: among others trace metals (e.g. Cd, the metal of the greatest toxicological concern, as well as Co, Cr, Cu, Mn, Ni, Pb, Zn, etc.) and nontrace metals (e.g. Ba, Sr) (Sauerbeck, 1992; Kpomblekou and Tabatabai 1994). Their appearance in the soil solution may constitute environmental threats, since the water soluble forms might be leached towards the groundwater and are easily available for plants. Since, on one hand, the dissolution of trace metal pollutants generally depends on the measure of acidity of the soil (Sauerbeck 1992; Kabata-Pendias and Pendias 2001) and on the other hand, metal uptake by plants is strongly influenced by pH of the soil, it is important to know how the increasing amounts of basic PR and acid loads influence the actual pH of the soil.

The main focus of this study was to determine trace metal concentrations in the liquid phase of an acidic soil at increasing PR and acid doses and to assess their mobilities in the studied system. The acid load, necessary to decrease the basic PR-elevated pH of the soil solution to its original value, was also determined.

Materials and methods

The main chemical and physical properties of the 0-20 cm layer in the acidic sandy soil (originated from Nyírlugos, Hungary) are the following: pH_{H2O}: 5.0; pH_{KCl}: 3.8; y_1 (hydrolytic acidity, measured after the first extraction by applying 0.5 mol L^{-1} Ca-acetate solution at pH 8.2): 11; y_2 (exchangeable acidity, measured after the first extraction by applying 1 mol L^{-1} KCl solution): 3.7; organic matter content: 0.6 %; cation exchange capacity: 3.0 $cmol_c \cdot kg^{-1}$ soil; clay + silt content (< 0.02 mm, weight %): 5.0 %; clay content (<0.002 mm, weight %): 2.2 %; bulk density: 1.5 g cm^{-3}.

The "total" amounts of trace metals and other elements in the soil and in a Senegal sedimentary PR (which was previously ground to pass a 500 μm sieve) were determined after cc HNO_3 + cc H_2O_2 microwave wet digestion in a teflon bomb, from the 1:50 extract, by ICP-AES method (Table 1). Total P_2O_5 content of the PR sample was 31 %. Its total carbonate (mainly Ca and Mg carbonate) content (determined by 10 % HCl treatment in Scheibler calcimeter, and expressed as $CaCO_3$) was, as compared to the majority of PRs, relatively low, 4.3 %.

Different doses of the PR (containing 0 mg, 1500 mg and 3000 mg P_2O_5 kg^{-1} soil: D0, D1 and D2, resp.) were added and mixed into 1300 g air-dried soil samples. The soil was then moistened to field capacity (-10 kPa water potential, corresponding to 26.5 % gravimetric water content) with HNO_3 solutions of various concentrations (0, 0.05, 0.075, 0.1 and 1.5 mol L^{-1}: Ac0, Ac1, Ac2, Ac3 and Ac4, resp.). To control reproducibility, treatments were made in duplicates. After one week incubation, during which the wet soil samples were homogenized three times, the soil solution was extracted by centrifugation, a method developed in our institute (RISSAC) (Csillag et al. 1999). A rotor speed corresponding to -1500 kPa (which is equal to the conventional wilting point of plants, i.e. to the maximum suction that can be exerted by the root) was applied, so the separated solution could be regarded as energetically utilizable for plants. As, Ba, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sr, Zn concentrations in the centrifugated solutions were determined by ICP spectrometry. Data in the tables are averages of the duplicate measurements, pH values are calculated from averages of proton activities measured in two parallel solutions.

Results and discussion

Element contents in the untreated original soil determined by cc HNO_3 + cc H_2O_2 digestion were below the Hungarian threshold levels. In the PR sample, however, Cr and especially Cd concentrations considerably exceeded the corresponding strict Hungarian limit values for P fertilizers (Table 1).

Effect of acid treatments on pH and element concentrations in the soil solution:

Concentrations of potentially toxic elements in the liquid phase of the untreated soil were, with the exception of Co, lower than or near to the allowed concentrations in subsurface waters (Table 2). Solubility of cation forming elements, in good agreement with literature data (Sauerbeck 1992; Csillag et al. 1999; Kabata-Pendias and Pendias 2001), increased in a great extent due to acidic treatments, their concentrations in the soil

[1] Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, 1022 Budapest, Herman Ottó u. 15.; Tel.: 36-1-2243-651; E-mail: csillag@rissac.hu

solution at high acid loads were several orders of magnitude higher than those in the control samples. Cd concentration, for example, which was 1.8 μg L^{-1} in the liquid phase of the control soil (just above the detection limit: 1 μg L^{-1}, and less than the maximum permissible concentration in subsurface waters: 5 μg L^{-1}), increased considerably with elevating acid loads: when the pH of the soil solution decreased from 4.5 by two units, Cd concentration increased about 30 times as compared to the unacidified sample. This acid load, 26 mmol H^+ kg^{-1} soil, was very high, nearly 20 times more than the annual average acid load estimated on agricultural lands in Hungary: 4.5 kmol $H^+ \cdot ha^{-1}$ $year^{-1}$, i.e. 1.5 mmol $H^+ \cdot kg^{-1}$ soil $\cdot$ $year^{-1}$. It was also above the critical acidity (within the pH range between 4.0 and 4.5), at which a 0.2 unit drop in pH results in a 3 to 5 times increase of Cd concentration in the soil solution (Kabata-Pendias and Pendias 2001). Concentration of anion forming elements (As, Mo) in the acidic soil solution was below the detection limit.

Effect of PR doses and acid loads on pH and element concentrations in the soil solution:

Application of high dose of PR elevated pH in the soil solution of the acidic soil with about two units: from 4.5 at the D0 dose to 5.2 and 6.4 at the D1 and D2 doses, resp., shifting its reaction to nearly neutral (D2-Ac0 treatment on Figure 1). To compensate this pH elevating effect of the high dose PR treatment 13 mmol $H^+ \cdot kg^{-1}$ soil acid load was necessary (this was enabled by 0.05 mol L^{-1} HNO_3 treatment; see D2-Ac1 treatment on Figure 1).

It was shown that trace metal concentrations in the soil solution, following one week incubation of the wet soil, were less influenced by the amount of pollutants carried into the soil with different PR doses than by the pH increasing effect of this material. This means that metal concentrations were lower in the liquid phase of the PR-containing soil sample (at D1 dose) than in the control sample (D0 dose), and elevation of PR dose (to D2) further decreased the concentration of many elements (Ba, Cd, Co, Mn, Pb, Sr, Zn) in the soil solution (Table 3). It should be taken into consideration, that with the addition of PR to the soil, solubility of cations is lowered also by the probable precipitation reactions.

The concentration of the anion forming Mo exceeded the detection limit at the higher (D2) PR dose. Its appearance in the soil solution may be the consequence of the increase of solution pH and its small dissolution from PR added to the soil. It is known that in acidic soils availability of Mo as micronutrient is increased by liming, elevating the pH of the soil (Kabata-Pendias and Pendias 2001).

By applying acid loads, release of metals from the [soil + PR] mixture to the soil solution increased as compared to the deionized water treatment (Ac0). However, when the dose of the PR was increased, metal concentrations in the soil solution decreased - due to the pH increasing and/or solubility altering effect of the PR - except in the liquid phase of the samples subjected to the strongest acid treatment (Ac4). To characterize the release of the metals to the soil solution due to the various PR and acid treatments, their concentration in the soil solution (c_S) was expressed as percentage of their total amount in the soil and in the PR sample ($100\ c_S / (c_{soil} + c_{PR})$). c_S was given as μg kg^{-1} = (μg L^{-1} · gravimetric water content of the soil) 100^{-1}.

These mobilized (relative) amounts of the metals, especially of Cd, increased significantly with the increase of acidity (Figure 2). However, addition of PR in many cases decreased the release of the metals into the soil solution. In case of the extreme high acid load (1.5 mol L^{-1} HNO_3 treatment) the solubility decreasing effect of PR was observed only at Pb, probably due to formation of Pb phosphates. In the case of Cd, Sr and Zn with the increase of metal contamination (at D0<D1<D2 doses) higher amounts of metals entered the soil solution than at the smaller dose. The changes of the relative mobilized amounts of Ba, Co, Cr, Cu, Mn and Ni due to increasing PR doses were negligible; presumably the opposing effects (i.e. higher input of pollutants ↔ pH increasing + solubility altering effects of PR) were compensated.

The pH of the soil solution (Figure 1), thus the mobility of the metals depended more on acidity than on the applied PR treatments (Figure 2). Their mobility order generally corresponded to literature data (Sauerbeck 1992, Kabata-Pendias and Pendias 2001): Cd, Mn and Sr proved to be the most mobile elements in this experiment. Evaluating the mobility order of the elements and considering the changes due to the various PR and acid treatments (Figure 2), it was concluded that

- Cd was the most mobile element at every acid treatment (Ac0, Ac3, Ac4) in the soils not containing PR and at the highest acid load (Ac4) in the PR-enriched samples. In the other PR containing samples the mobility of many elements (Sr, Mn, Co, Zn, Ba at Ac0 and Sr, Mn at Ac3, D2) exceeded that of Cd.

- Mn, which was present in the studied [soil + PR] mixture in the highest amount, was among the first three most mobile elements, independent from the applied treatments.

- With increasing acidity the mobility of Cd, Mn and of the relatively stable Pb increased in higher degree, that of Cu in a lower degree compared to the other elements. Depending on PR dose, Cu was 2nd (at D2 dose) to 7th in the mobility order of the elements in the nonacidified soil, 8th at the 0.1 mol L^{-1} HNO_3 treatment and 9th or 10th at the strongest, 1.5 mol L^{-1} HNO_3 treatment. Pb, on the other hand, got from the 9th rank (at Ac0, D0,D1,D2) to 3rd (at Ac4, D0).

- Chromium was the least mobile element, in accordance with literature data (Sauerbeck 1992, Csillag et al. 1999, Kabata-Pendias and Pendias 2001).

Conclusion

Application of PR as P-source on the soil may cause the risk of potentially toxic metal contamination. Soil acidification promotes mobilization of cation forming metals originally present in the soil or added with fertilizers. However, the pH increasing (and probably the solubility altering) effects of the basic PR (at a one-time, high dose application), unless extreme strong acid load had prevailed it, lowered the release of metals into the soil solution.

References

Csillag J., Pártay G., Lukács A., Bujtás K., Németh T. 1999. Extraction of soil solution for environmental analysis. Intern. J. Environ. Anal. Chem. 74: 305-324.

Kabata-Pendias A., Pendias H. 2001. Trace Elements in Soils and Plants. 3rd edition. CRC Press, Boca Raton.

Kpomblekou K., Tabatabai M.A. 1994. Metal contents of phosphate rocks. Commun. Soil Sci. Plant. Anal. 25: 2871-2882.

Sauerbeck D. 1992. Conditions controlling the bioavailability of trace elements and heavy metals derived from phosphate fertilizers in soils. Proc. 4th Int. IMPHOS Conf. (Phosphorus, Life and Environment), 419-448.

10/2000. (VI. 2.) Joint KöM-EüM-FVM-KHVM order on threshold values for the protection of the quality of subsurface water and soil.

50/2003. (V. 9.) FVM order on authorization, storage, distribution and utilization of fertilizers and other soil amendments.

Supported by the Hung. Nat. Sci. Res. Fund (OTKA) under grant No. T 038046.

Table 1. Concentrations of potentially hazardous elements in the studied soil and PR sample determined by cc HNO_3 + cc H_2O_2 digestion (mg kg^{-1}), and the corresponding threshold levels

	As	Ba	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sr	Zn
Soil	1.2	32	0.04	3.4	13	2.8	<dl	212	<dl	7.9	6.2	11	16
10/2000	*15*	*250*	*1*	*30*	*75*	*75*	*0.5*		*7*	*40*	*100*		*200*
PR	<dl	77	86	2.5	122	46	<dl	125	2.5	33	4.5	745	532
50/2003	*10*		*6**		*100*		*1*			*50*	*100*		

dl: detection limit (Hg: 0.5, Mo: 0.08 mg kg^{-1})
10/2000 KöM-EüM-FVM-KHVM: threshold levels for soils
50/2003 FVM: max. permitted contents of toxic elements in P-fertilizers
*: allowed Cd content in case of the applied PR sample, which contained 31 % P_2O_5

Table 2. Effect of increasing acid loads on pH and element concentrations (μg L^{-1}) in the liquid phase of the soil moistened to field capacity

HNO_3 mol L^{-1}	pH	As	Ba	Cd	Co	Cr	Cu	Hg	Mn	Mo	Ni	Pb	Sr	Zn
0	4.5	<dl	320	1.8	57	4.4	11	<dl	9240	<dl	19	13	430	160
0.1	2.6	<dl	15850	56	1480	87	120	<dl	133500	<dl	590	150	10750	2070
1.5	0.2	<dl	36900	110	4750	5070	1670	<dl	453000	<dl	5590	11500	13350	14500
10/2000		*10*	*700*	*5*	*20*	*50*	*200*	*1*		*20*	*20*	*10*		*200*

dl: detection limit (As: 8, Hg: 5, Mo: 1.5 μg L^{-1})
10/2000 KöM-EüM-FVM-KHVM: threshold levels for subsurface waters

Table 3. Element concentrations (μg L^{-1}) in the liquid phase of the PR treated soil

PR dose	Ba	Cd	Co	Cr	Cu	Mn	Mo	Ni	Pb	Sr	Zn
D0	320	1.8	57	4.4	11	9240	<dl	19	13	430	160
D1	120	1.3	16	3.6	8	2410	<dl	11	12	180	78
D2	86	<dl	9	11	18	1180	1.9	18	11	97	40

dl: detection limit; D0, D1 and D2: see Figure 1.

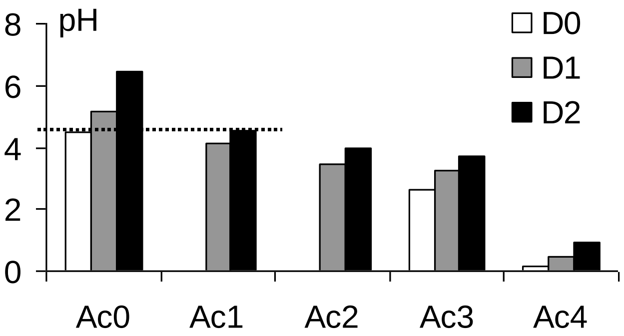


Figure 1. Change of soil solution pH at different PR doses and acid loads
D0, D1 and D2: PR doses equal to 0 mg, 1500 mg and 3000 mg P_2O_5 kg^{-1} soil, when 0, 4.85 and 9.70 g PR, resp., were added to one kg soil; Ac0, Ac1, Ac2, Ac3 and Ac4: acid loads, i.e. concentrations of HNO_3 solutions (0, 0.05, 0.075, 0.1 and 1.5 mol L^{-1}, resp.) applied to moisten the soil to field capacity. Remark: in case of 0.05 and 0.075 mol L^{-1} HNO_3 acid loads (Ac1 and Ac2, resp.) only PR-treated soils (at D1 and D2) were analysed; dotted line: shows the acid load, which compensates pH elevating effect of the basic PR sample at D2 dose

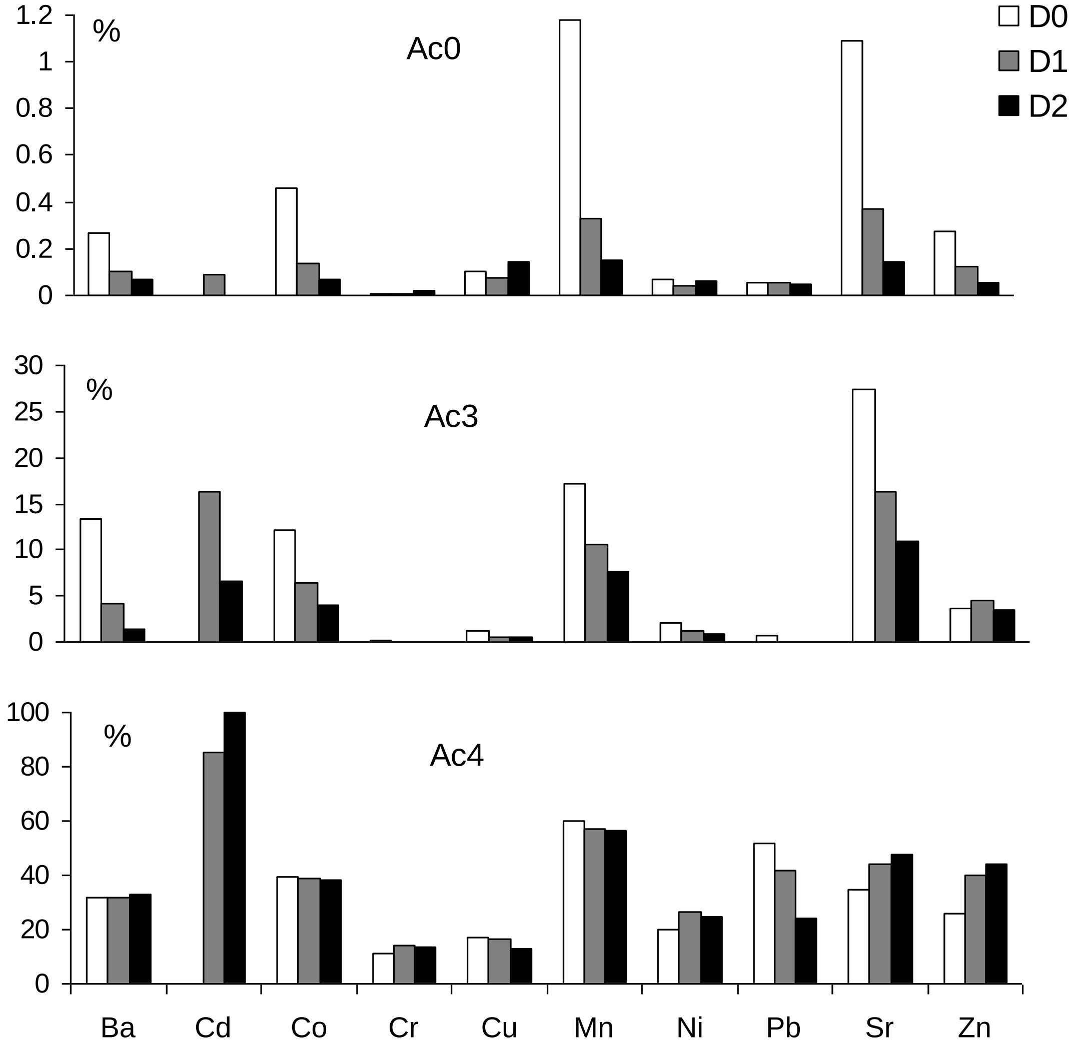


Figure 2. Relative amounts of metals (%) entering the soil solution at increasing PR doses and acid loads
% = 100 c_S / (c_{soil} + c_{PR}), where c_S and c_{soil}: metal concentrations in the soil solution and in the soil, resp., (μg kg^{-1}), c_{PR}: metal amount carried into the soil with PR (in case of D1 dose, for example, it was 416, 592, 160 and 2580 μg kg^{-1} soil for Cd, Cr, Ni and Zn, resp.); D0, D1, D2 and Ac0, Ac3, Ac4: see Figure 1.

The effects of green manure on the migration of nitrogen compounds in fine - textured soils in Lithuania

Tripolskaja, L.[1] – Romanovskaja, D.

Introduction

Lithuania is of the countries of Baltic States. Lithuania has a transitional climate between the maritime climate of west Europe and the continental climate of Russia. Annual precipitation in Lithuania amounts to 661 mm. According to the precipitation, the territory of Lithuania is the zone of excessive humidity. The mid-annual temperature makes 6.1 ^{0}C. Such hydrothermal conditions forming a periodically percolative soil moisture regime. The soil cover in Lithuania is various – 56 % of soils were generated on moraine, 18 % - on glacial lacustrine deposits, 14 % - on fluvioglacial deposits. Prevailing soil types are Cambisols, Luvisols, Albeluvisols, Planosols, and Arenosols /Lietuvos dirvožemiai, 2001/. Up to 52.4 % are sandy and sandy loam soils which at their agricultural use demand application of various agrotechnical means for stabilizing and improving their fertility. One of the major problems of these soils is a lack of organic carbon. That requires constantly restoring its losses of a mineralization. Manure was widely applied to this purpose in Lithuania at the end of 20th century. For 1 hectare of an arable land it was brought about 10 t manure. Last decade, as a result of reduction of a livestock, application of manure was considerably reduced. To restore the pool of organic substance various plants – red clover, lupine, oil radish, oilseed rape and others for the green manure were widely used. In conditions of Lithuania green manure is used for winter crops in August, or for a spring crops of the next year – at the end of October. The processes of decomposition of green mass of plants depend on time of entering in soil. And correspondingly influencing the pollution of drainage and subsoil waters with nitrogen compounds.

Materials and methods

The work was performed in 1997–2001 at the Voke Branch of the Lithuanian Institute of Agriculture, situated in South-eastern Lithuania in sandy plain and, according to climatic-hydrothermal belongs, ascribed to the region of medium soil eluviations and decomposition of organic matter. The experimental plots were established in sandy loam on carbonaceous fluvial-glacial gravel ordinary eluviated soil (Idp), according to FAO-UNESCO classification Haplic Luvisols (LVh). The depth of carbonate effervescence – 60–80 cm.

The sources of organic matter of plant origin i. e., green manure of all kinds and straw were aimed to enrich the soil with organic carbon and nitrogen, released through the decomposition of the inserted organic matter, while the leguminous plants – by the accumulated rhizobially fixed nitrogen. The following matter of organic origin were tested: leguminous plants (red clover and peas), green manure (yellow lupine, undersowing red clover, oil radish as an aftercrop, vegetation of a fallow), and straw.

All tested elements were introduced into crop rotation after harvesting of the first crop of the rotation (manure, undersowing clover, and radish as an aftercrop for green manure) or during the second year of the investigation (1st year of use clover, peas, lupines for green manure, fallow). The straw was ploughed under after the harvesting of first (barley) and third (winter rye) members of the rotation. Therefore, depending upon the experimental treatment, the impact of organic fertilisers on the yield and chemical composition of plants was investigated for 2–3 years.

Aiming to clarify the migration of mineral nitrogen, soil samples were taken after the insertion of organic fertilisers in 1997–1998, 1998–1999 and 1999–2000 during the season of autumn–winter–spring. Soil samples were taken employing the method of individual profiles from the depth of 0–20, 20–40, 40–60, 60–100 cm, in pursuance of the genetic soil horizons.

Results and discussion

Green manure plants whose primary purpose is to enrich the soil with organic matter and nitrogen are incorporated into the soil before winter crops' sowing, or late in the autumn for the following year's spring crops. Thus, in the first case, decomposition of the freshly incorporated organic matter occurs at relatively high air and soil temperatures. In the second case, the decomposition of green manure takes place in the conditions of relatively low soil temperatures and high soil moisture. These differences in temperature and moisture regimes determine differences in green manure decomposition rate and the peculiarities of the effects of the decomposition products on the environment / Gerzabek et al., 1997, MacLeod, 1996, Ritter et al., 1998, Teit, 1990/.

Chemical composition of the incorporated green manure has some impact on the decomposition processes, and consequently on the migration of nitrogen in the soil. Leguminous green manure is subject to rather rapid mineralisation. For winter cereals fertilisation, green manure crops are generally grown throughout

[1] Lithuanian Institute of Agriculture, Voke Branch, Zalioji aikste 2, Vilnius 02232; Tel.: 370 5 2645439; Fax: 370 5 2645430; E-mail: liudmila.tripolskaja@voke.lzi.lt

the whole growing season, and as a rule produce heavier vegetative mass, compared with aftercrops grown after harvesting of primary crops (Table1).

Our experimental findings suggest that leguminous plants as green manure not only produce a higher organic matter yield, but also considerably enrich the soil with symbiotic nitrogen. In terms of nitrogen accumulation in the biomass, clover aftermath and lupines were very similar- 94.9 and 90.5 kg ha^{-1} N, respectively, including 61.7 and 58.8 kg ha^{-1} symbiotic nitrogen. The generalised data on mineral nitrogen reserves in the soil profile up to 100 cm depth have shown that incorporation of green manure (lupine, clover aftermath, vegetation of uncultivated fallow) for winter crops increased the content of mineral nitrogen in the

Table 1. The biomass yield of the sources of organic matter and accumulation of nitrogen of plants for green manure.

Plants	Dry organic matter t ha^{-1}	Accumulated nitrogen in yield kg ha^{-1}	
		total	symbiotic
Undersown clover	2.58	76.50	49.72
Oil radish	1.33	44.12	-
Spring barley straw	3.73	29.83	-
1 st yr. clover aftermath	4.00	94.99	61.74
Lupine	3.69	90.49	58.82
Vegetation of uncultivated fallow	3.52	60.90	-

plough layer by 5.5-16.5 kg ha^{-1} N two months after incorporation, three months after incorporation - by 12.9-18.4 kg ha^{-1} N, compared with the soil where roots and stubble of cereals were ploughed in (fig.1). In subsoil layers (25-100 cm) these differences were even more significant. As a result of leaching, mineral nitrogen content in the 25-100 cm soil layer after lupine, clover aftermath and fallow crops incorporation increased by 25.9-43.7 kg ha^{-1} N in October, in November by – 39.1-63 kg ha^{-1} N.

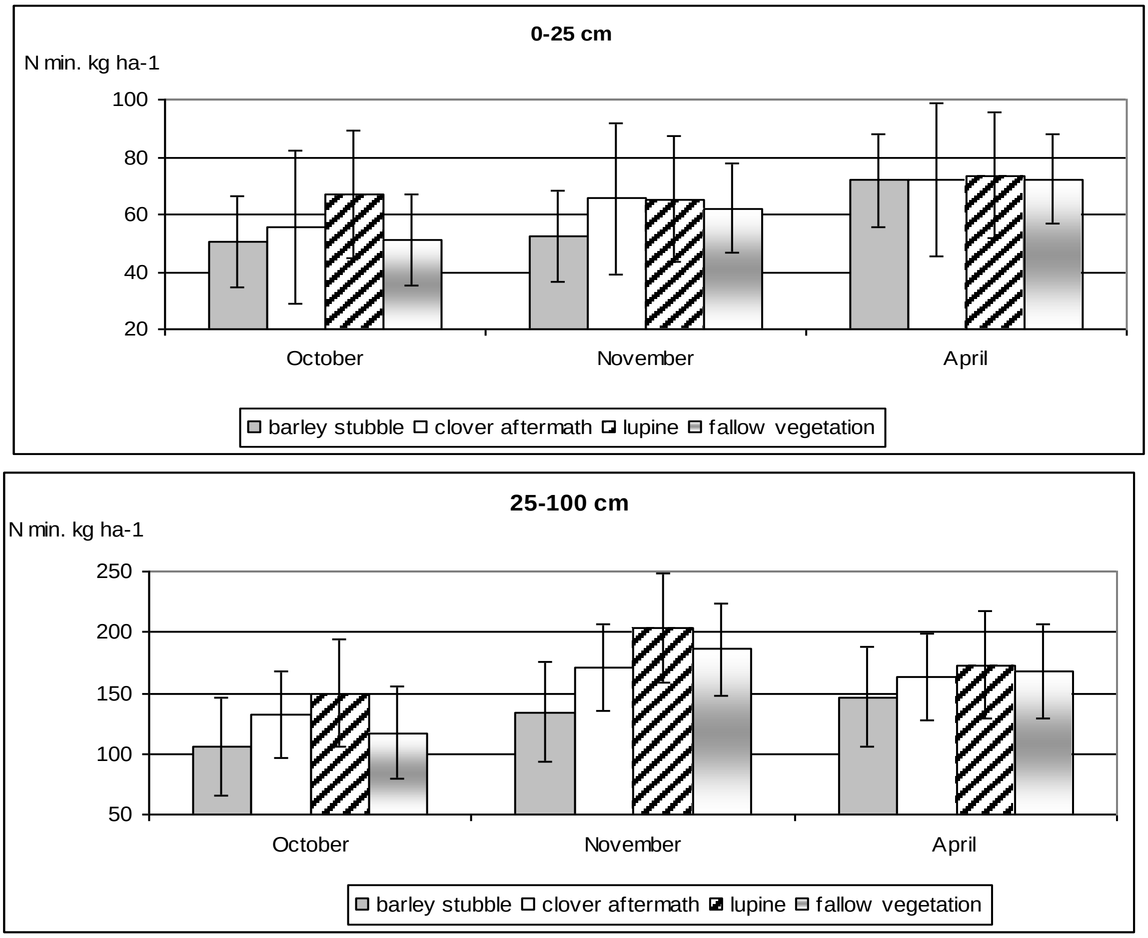
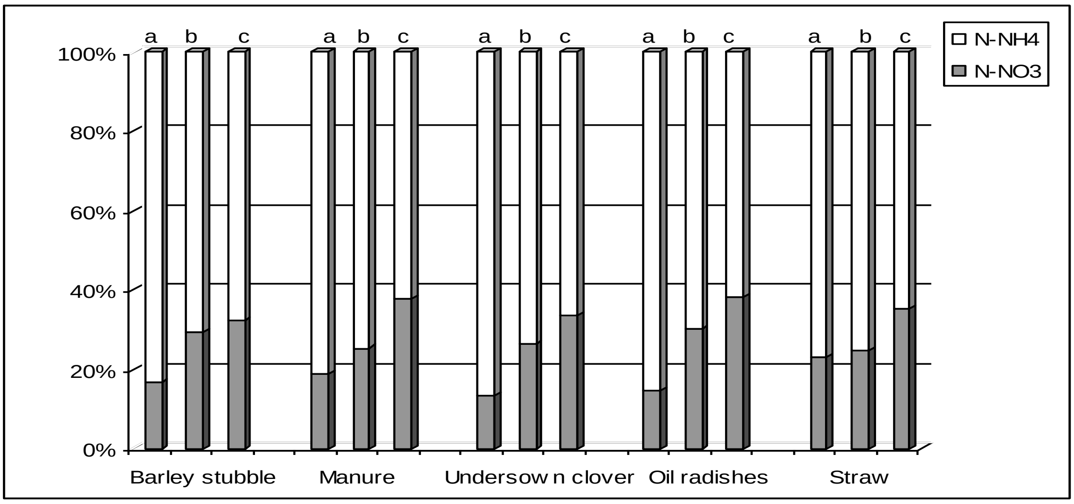


Figure 1. Effect of various organic fertilizers incorporated before the soil got frozen, on the migration of mineral nitrogen, Voke, 1997-1999

Decomposition of the incorporated organic fertilizers (oil radish, undersown clover) late in the autumn and also cereal straw and manure occurs differently than that of green manure, ploughed in for winter crops. During this period the air temperature ranges between 0 to +10º C , therefore, decomposition of organic matter occurs more slowly. However, even in such conditions, 2-3 weeks after incorporation of green manure, the content of mineral nitrogen in subsoil horizons increases. Having ploughed in cereal stubble, mineral nitrogen reserves in the 25-100 cm layer were 147.5 kg ha $^{-1}$ at the end of October, while having entered green manure and straw -by 14.3-19.3 % higher. Straw, manure and intermediate plants for green manure are incorporated before the soil has frozen, which considerably shortens the decomposition period during the autumn and nitrogen leaching into subsoil horizons. In this case, nitrogen leaching increases only by 14%, while when green manure is incorporated at the end of a summer by 24-63%. According to research evidence (Zvegincev, 1987), the activity of ammonifying bacteria is renewed at low positive temperatures in December-January, while nitrifying bacteria are more active in October-November.

Our research into soil microorganisms' activity during the winter period carried out at the Institute of Ecology have shown that the positive temperatures during the autumn-winter period had some effect on the activity of microorganisms, especially in the soil treated with manure. The findings suggest that in January the content of ammonifying bacteria increases, and the content of mineral nitrogen assimilating bacteria decreases. At low air temperatures mineral nitrogen assimilating bacteria cannot meet their energy needs because of the lack of readily available organic carbon, therefore they are outrivaled by nitrifying bacteria that meet their energy needs by CO_2 fixing. This may result in an increase in nitrate content in winter, which may readily leach from the wet soil. The experimental evidence of Norwegian researchers (Henriksen, Breland, 1999 confirm that the heavy losses of nitrogen during the autumn-winter period can be caused by low temperatures limiting microbic immobilization of nitrogen. Our experimental findings have shown, that dynamics of mineral nitrogen in the soil is connected with the ratio of ammonium nitrogen to nitrate nitrogen, that is the reduction in mineral nitrogen is connected with the increase in the share of nitrate nitrogen (Fig.2).



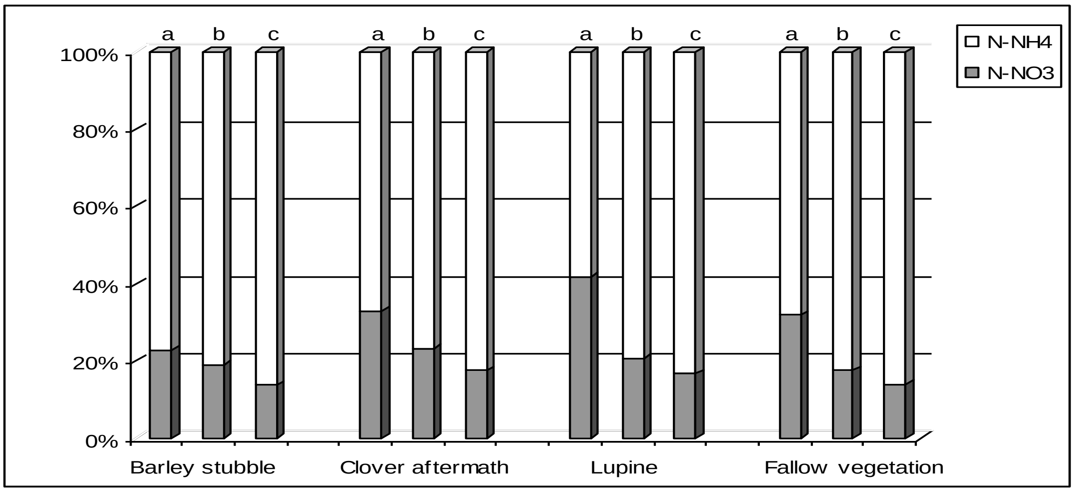


Figure 2. Dynamics of ratio nitrate and ammonia nitrogen in soil during the autumn-winter season Voke, 1998-2000

It was found that the reserves of mineral nitrogen when green manure (clover aftermath, lupine, vegetation of uncultivated fallow) was incorporated for winter crops were less during the autumn period when nitrates accounted for 14-17 % of the total mineral nitrogen. Similar regularities were established in the treatments applied with organic fertilizers (manure, straw, oil radishes, and undersown clover). In this case, an essential reduction in the reserves of mineral nitrogen in the 0-100 cm layer was identified when nitrates made up 33-38 %.

Conclusions

1. Decomposition of various kinds of organic fertilizers depended on their chemical composition and meteorological conditions succeeding their incorporation. When green manure (lupine, clover aftermath) was incorporated for winter crops, nitrogen leaching in the 25-100 cm soil layers during the autumn period increased by on average 24-63%, compared with incorporation of cereal roots and stubble. Larger amounts of mineral nitrogen (+17-36%) were leached in the case of lupine biomass incorporation. During mineralization of uncultivated fallow vegetation, the content of mineral nitrogen in the autumn in the 25-100 cm soil layer increased by on average 11-38, while in the case of aftercrops as green manure (oil radishes, undersown clover) by 14%.

2. Investigations on the dynamics of the concentrations of mineral nitrogen in soil revealed that the decomposition of organic fertilisers proceeds up to the freezing of soil, and during winter thaws the process of mineralisation rapidly resumes. Changes in the ratio of nitrate and ammonia nitrogen allow the supposition that in winter, under favorable conditions for the renewal of mineralisation, the processes of nitrification of nitrogen compounds prevail.

3. Hydrothermal conditions influenced the migration character of mineral nitrogen. It was determined that after cold (without thaws) winter, as in spring snow intensively melts, together with melt-water higher amount of mineral nitrogen is being washed out if compared with a spring of mild winter. During mild winters the migration of mineral nitrogen is gradual, and, because of constant formation of mineral nitrogen, at the beginning of the vegetation period its supplies remain more abundant.

References

Bagdanavičienė Z. Metodičeskij podchod k ocenke funkcionalnych otnošenij i dominantnoj struktury fiziologičeskich grupp mikroorganizmov v počvach različnych ekosistem // Ekologija. 1998. Nr. 3. P. 3-17.

Gerzabek M.H., Pichlmayer F., Kirchmann H. et.al. The response of soil organic matter to manure amendments in a long –term experiment at Ultuna, Sweden // European Journal of Soil Science, 1997, Vol. 18, Iss2, p. 273-282.

Henriksen T.M., Breland T.A. Decomposition of crop residues in the field: evaluation of a simulation model developed from microcosm studies // Soil Biology and Biochemistry. 1999. Vol. 31(10). P. 1423-1434.

MacLeod J.A., Sanderson J.B. Catch crops for reducing nitrate leaching following potato harvest on Charlottetown fine sandy loam: Abstr. Can. Soc. Soil Sci. Annu. Conf. Quebec, 1995 // Canadien Journal of Soil Science,1996, 76, N.2, p.241.

Lietuvos dirvožemiai. Editors : Eidukevičiene M., Vasiliauskiene V. –Vilnius: Lietuvos mokslas, 2001, s. 114-237.

Ritter W.F., Scarborough R.W., Chrinside A.E.M. Winter cover crops as a best management practice for reducing nitrogen leaching // Journal of contaminant Hydrology, 1998, Vol. 34, Iss1-2, p.1-15.

Tripolskaja L., Bagdanavičienė Z., Romanovskaja D. Mineralinio azoto ir dirvožemio mikrobinis aktyvumas irstant organinėms trąšoms rudens-žiemos laikotarpiu // Žemės ūkio mokslai. 2002. Nr. 2. P. 3-12.

Soil and Water Conservation as Affected by Changing Mediterranean Climate and Land Management in Vineyards of Catalonia (NE Spain)

Pla Sentís, I.[1] – Ramos, M.C. – Nacci, S. – Fonseca, F. – Abreu, X.

Introduction

Vineyards, for dry land grape wine production, are a traditional crop in the highly sloping agricultural lands of Catalonia (NE Spain). In Catalonia, as well as in other regions of Mediterranenan Europe, the dryland vineyards have sufferd great changes in the last 15-20 years. Some cropped lands have been abandoned, but in others, with vineyards dedicated to production of high quality wine and cava, the cropped area has increased, with more intensive and highly mechanized agricultural systems (Pla & Nacci, 2003). In some cases, the removal of great soil volumes, to change the topography of slopes to facilitate water retention and mechanization, like terracing and levelling with bulldozer, affect the hydrological properties and natural drainage, favouring erosion and mass movements, mainly during extreme events (Pla & Nacci, 2001; Nacci et al, 2002).

Tillage is considered necessary for weed control, for loosening compacted and crusted surface soils to increase rain water infiltration, to reduce losses of water by evaporation and for increasing rooting depth of vines. Although the benefits of no tillage together with green cover crops, in protecting the soil surface against direct raindrop impact, and increasing soil organic matter content, reducing runoff and surface erosion are recognized, it is considered that in dryland vineyards it may cause more water deficiencies and insufficient N supply, specially in dry years (Rupp & Fox, 1999). Besides, it has been proved that in some cases the green cover crop or cover residues increase the survival rate of pathogens, and favors the development of mildiu. The use of herbicides, associated to no tillage practices may cause fito-toxicity problems in the vines.
Additionally, there has been detected a trend of increasing frequency of dry years and at the same time of more aggressive extreme rainfall events, apparently as a consequence of general climate changes in the Mediterranean region (Ramos, 2001).

The actual and potential effects of those changes in land management and climate on the soil and water conservation has been studied in two representative areas (Alt Penedés and Priorat), covering the range of more common soils, topography, climate and land management changes in dry land vineyards of Catalonia (Spain) and of many other Mediterranean regions. The studies included evaluations of soil and land hydrological properties and processes, throughout field and laboratory measurements, and field monitoring. They were integrated, using flexible models based on hydrological processes, to deduce the potential effects on soil surface and mass erosion, and on the soil moisture regime affecting the sustainability, quantity and quality of grape and wine production, under changing scenarios of climate and land conditions (Pla, 1997; 2002).

Materials and Methods

The research has been carried on in two of the regions (Alt Penedés and Priorat) of Catalonia (NE Spain), where vineyards for high quality wine production has increased the last 20 years, drastically changing the traditional practices and introducing new varieties. In both regions the climate is Mediterranean semiarid, with an average annual rainfall close to 550-600 mm, very irregularly distributed, with the highest rains in autumn-winter, a very dry summer, and with high differences from one year to another (400-750 mm in Alt Penedés, and 300-900 mm in Priorat). Many storms in autumn, and occasionally in spring, are of high concentration and intensity (Alquézar et al. 1990; Ramos and Porta, 1994). Climate changes may increase the irregularity of rainfall, the frequency of dry years and the probability of extreme events, phenomenon that has been observed in both regions in the last 25 years. The extrapolation to the future of past or historical information may not be very reliable due to those previewed greenhouse effects on climate changes. In any case, the past information about extraordinary events is not very good, both due to not enough length of the periods of measurement, and to the low quality of the measurements (Gallart, 1990).

The water use of vines throughout the growing season is characterized by a lowered use in the periods before bloom and after harvest until fall, and a maximum consumption in the mid part of the growing season. If the reserve water capacity of the soil in the rooting zone is not enough, reduced amounts of rainfall during the main growing season of vines (June-august) may lead to a long term soil water deficit, which can affect growth, production and maturation, in spite of the natural capacity of survival of vines under drought conditions (Maigre et al , 1995).

[1] Departament de Medi Ambient i Ciències del Sòl. Universitat de Lleida. Lleida, Spain. Tel.: +(34)-973-702617; Fax +(34)-973-702613; E-mail: ipla@macs.udl.es

In order to decrease costs of the scarce available hand work, to increase production and to speed all operations, the tendency is towards the full mechanization of all practices, including harvesting. This requires vine guided lines with lateral pruning, with rows 2,4 – 3,2 m apart, and 1,2 – 1,4 m among plants. This gives a much lower soil surface protection than the traditional planting systems, although in both cases the protection is low in autumn-winter, when the strong storms usually occur. Mechanization also requires long and straight lines, sometimes in favour of the slope. To reach these conditions there are required heavy land levelling or terracing operations, with drastic changes in the surface drainage network and on the effective soil rooting depth and surface soil properties (Nacci et al, 2002; Pla & Nacci, 2003)

In the Alt Penedés region, the topography of the area is highly undulated, and even hilly, with cropped fields in 4-20% slopes, and altitudes of 250-400 m a.s.l. The soils generally have low or not profile development, mainly as a result of levelling operations for smoothing the land surface for mechanization. These soils, formed from calcareous lutites, are low in organic matter (< 1,5%), high in silt fraction (40-60%) and very rich in Ca carbonates. They have a high susceptibility to surface sealing (Ramos, Nacci & Pla, 2000), resulting in high runoff and high surface erosion rates. Periodical tillage, do not allow root growth in the surface 15-20 cm soil, which is maintained loose most of the time to increase rainfall water infiltration, to decrease evaporation of deeper soil water, and to control weeds.

As a water conservation practice, in some cases there are built narrow (2-3 m wide and 15-20 cm depth) bench terraces across the slope, every 10-15 vine rows (depending on the slope), with the purpose of absorbing and deviating runoff water and sediments coming from the upland rows. These terraces, made of loose surface soil frequently suffer mass movements, specially after extraordinary rainfall events, originating active growing gullies when they receive concentrated surface runoff and subsurface flow of water coming from higher parts of the field.

In the Priorat region, the climate is also semiarid, and the topography is mountainous, with cropped areas in 10-80 % slopes, at 200-650 m a.s.l. Soils are developed on slates and schists , and are not calcareous, slightly acid, very poor in organic matter, and very stony (20-60% by weight), sometimes with a gravelly pavement in the soil surface. Fine soil fractions, mainly smectite clays, increase with soil depth, which is generally less than 50-60 cm, on top of a highly weathered and fragmented rock.

The traditional vineyards in the Priorat are planted with varieties producing wines of high graduation and high quality, but low yields. The planting pattern mainly follows the contour lines, in very small individual fields, with vines and lines 2-3 m apart. There is usually maintained the original relief and slopes, and the only conservation structures are non continuous stone walls, located across the drainage ways and in places where based on local experience are more danger of soil movement by surface or mass erosion. In the past, the land between vine rows was removed, generally after harvest, by ploughing the surface 10-15 cm using man or animal power. Nowadays this practice has almost disappeared, except where a gentler slope allows the use of a small tractor, and the control of weeds is mainly done with herbicides. As a result of continuous no-tillage, frequently the vine roots concentrate on the surface soil, where the effects of droght, derived of scarcity or of non well distributed rainfall, are more marked.

The new plantations of vines in the Priorat region are made in a way to allow mechanical operations in the vineyards, looking for more soil water retention and higher and more stable grape and wine production. There are built bench terraces, 2-5 m wide, depending on the slope, with very steep and unstable embankments, which requires the clearing of the forest (in case of new plantations), followed by removal of very high volumes of soil and underground rock using heavy bulldozers. In the terraces there are planted one to three rows (2-3 m apart) of vines of generally new introduced more productive varieties, 1,2 m between plants. In most of the cases, the very steep embankments of the terraces are not protected, except by the slow re-growth of natural vegetation. The effects of these drastic changes on the relief and soils for new plantations, and of the changes in land management in the traditional plantations, on the surface and subsurface hydrology, and on the derived consequences, have been and still are being studied under different field and laboratory conditions.

Both in the Alt Penedés and Priorat regions, most of the problems of soil and water conservation appear associated to the effects on the soil water regime caused by changes in climate and on soil and cropping management practices. Measurements and continuous monitoring of appropriate soil hydrological parameters and rainfall characteristics, at different sites in the field, complemented with laboratory measurements, were used as a basis for the application and validation of a model (SOMORE), which allows the simulation and prediction of the soil moisture regimes, and of the associated potential problems of soil erosion and of water supply to the vines at different growth stages (Pla, 1997; Pla & Nacci, 2001). In many cases there were required adaptations and changes in the methodologies to make adequate measurements, particularly under field conditions, derived of the very particular characteristics of the soils (natural and transformed through land management), climate and topography.

In this paper there are presented the results, based on field measurements in selected sites located in commercial fields, and on simulation modelling of the range of more commonly found conditions of soils, slopes, and management. There is also included, besides the present clean tillage management (NC), the potential use of green cover grass (C) during the resting period (R), followed by cover with the killed grass residues during the rest of the growing periods (Tables 1 and 2).

Table 1. Rainfall distribution in selected extreme (return period: 5 years) dry and humid growing seasons of grapevines during the last ten years in the Alt Penedés and Priorat regions (Catalonia, NE Spain)

	mm rainfall												
Month:	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Ap.	May	Jun.	Jul.	Aug.	Sept.	YEAR
Alt Penedés													
Dry (D)	29	0	106	53	20	8	32	40	9	22	4	85	408
Humid (H)	130	150	135	118	0	17	44	19	57	9	44	0	723
Priorat													
Dry (D)	81	19	0	12	28	15	53	67	10	8	17	63	333
Humid(H)	370	63	62	20	15	24	46	51	7	48	12	15	733

Table 2. Soil Characteristics and hydrological properties in selected sites of the Alt Penedés and Priorat region

	% Slope	cm Effective rooting Depth (95 % roots)	mm AWC	mm Saturation	mm/hour Rain Inf. Rate (NC)	(C)	mm/hour Ksat (subsoil)
Alt Penedés							
AP – 1	6	20 – 80	200	240	20	50	3
AP – 2	10	15 - 60	120	150	5	20	3
AP – T	0	0 – 20	70	80	0	50	0,4
Priorat							
P -1	50	0 – 70	82	140	66	66	1200
P – 2	30	0 – 40	61	96	62	62	800
P - T	0	0 – 70	110	210	100	100	700

The selected growing seasons in each region, are the driest (D) and the most humid (H) during the last ten years, with return periods of about 5 years. In the selected humid (H) seasons, the rainfall was highly concentrated (> 70 % of the total annual rainfall) in autumn (Priorat) and in autumn – early winter (Alt Penedés).

In the Alt Penedés region there are included two soil conditions, one of the essentially non disturbed area (AP-1) and the other from a highly disturbed (by land levelling) area (AP-2), with slopes 6-10%, and another soil condition in one of the small bench terraces (AP-T) built every 10-15 rows.

In the Priorat region there were selected two soils in sloping (30-60% slope) lands, with effective rooting depth of 70 cm (P-1) and of 40 cm (P-2), in a field with traditional management system, and one soil in a neighbour bench terraced land (P-T).

The obtained experimental data were fitted using a water balance model (Pla, 1997) to the water requirements of the grapevines and cover crop, during the approximate different growing periods of vines (with slight differences according to to the year, to the region and to the variety) for wine production in those areas:

- Resting period (R). October- February
- Budburst – Bloom period (Bu – Bl). March – April
- Bloom – Veraison period (Bl – Ve). May – July
- Veraison – Harvest – Fall period (Ve – H – F). August – September

The given values of water requirements (ET) for vines, correspond to the more common range of requirements under semiarid Mediterranean climate. The water requirements for the green cover crop, correspond to the ones of a well developed rye crop.

Results and conclusions

Table 3 shows the values of the different calculated components of the soil water balance during the different growing periods of vines for wine production, in the different selected seasons, under variable soil and management conditions. It is shown that in all cases, the only possibility to have a green cover (C) between the vine rows, is during the resting (R) period, and that if we liked to keep a cover the rest of the year we would have to kill it with a selective herbicide, not causing toxicity to the vines. In any case, the use of a green cover crop in the resting period would increase the possibilities of drought in the critical (Bl - Ve) period in drier years (D), in soils with lower available water retention capacity (AWC) (associated to soil characteristics and effective rooting depth), and in climates with higher water requirements (ET) of the vine. A positive effect of the green cover crop, in many cases, would be a reduction in the water runoff losses (RUNOFF) and in the accompanying soil water erosion.

The small absorption terraces in the Alt Penedés (AP-T), may reach conditions triggering mass movements (days with soil moisture higher than the liquid limit, high runoff under saturation, and high potential internal drainage), mainly in the resting period (R) of the more humid seasons (H).

Table 3. Soil water balance components in relation to the crop water requirements in the different growing periods of grapevine, in the selected years and sites of the Alt Penedés and Priorat regions (*with cover crop)

	mm				
Growing period:	**Resting**	**Budbreak – Bloom**	**Bloom-Veraison**	**Veraison-Harvest-Fall**	TOTAL
ET (Cover)	130	140	419	250	639
ET (Vine)	10 - 20	40 – 45	200 – 265	95 – 100	340 - 430
Alt Penedés					
RAIN (D)	208	40	71	89	408
AP – 1 (NC)					
RUNOFF	75	0	0	0	75
DRAINAGE	56	0	0	0	56
DEFICIT (ET)	0	0	0	0 – 5	0 – 5
AP -1 (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	0	0	0	0	0
DEFICIT (ET)	0*	0*	0(70-135*)	0	0
AP – 2 (NC)					
RUNOFF	160	10	8	65	243
DRAINAGE	0	0	0	0	0
DEFICIT (ET)	0	0	27 – 97	61 – 66	88 – 163
AP – 2 (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	98	0	0	0	98
DEFICIT (ET)	0*	0(60-65*)	9 – 79	6 – 11	15 – 90
RAIN (H)	533	61	85	44	723
AP – 1(NC)					
RUNOFF	110	0	3	0	113
DRAINAGE	189	15	0	0	204
DEFICIT (ET)	0	0	0	0 – 39	0 – 39
AP – 1 (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	320	15 (0*)	0	0	335
DEFICIT (ET)	0*	0*	0(4 -9*)	0 – 26	0 – 26
AP – 2 (NC)					
RUNOFF	292	12	14	9	327
DRAINAGE	47	9	0	0	56
DEFICIT (ET)	0	0	9 – 74	51 – 56	60 - 130
AP – 2 (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	310	21(0*)	0	0	331
DEFICIT (ET)	0*	0 (0*)	0 – 60	46 – 51	46 - 111
AP – T (C)					
RUNOFF (SAT.)	250	0	0	0	250
DRAINAGE	190	0	0	0	190
Days (SAT):	20 days	0	0	0	20 days

Table 3. (Continued)

Priorat					
RAIN (D)	140	65	88	80	333
P – 1 (NC)					

RUNOFF	0	0	0	0	0
DRAINAGE	76	20	0	0	96
DEFICIT (ET)	0	0	30 – 95	15 – 20	74 – 149
P- 1 (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	0	0	0	0	0
DEFICIT (ET)	0*	0 (87-92*)	59 – 129	15 – 20	74 – 149
P – 2 (NC)					
RUNOFF	0	0	0	0	0
DRAINAGE	97	25	0	0	122
DEFICIT (ET)	0	0	51 – 116	15 – 20	66 – 136
P – 2 (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	0	0	0	0	0
DEFICIT (ET)	0*	0 (100-105*)	67 – 137	15 – 20	82 – 157
P – T (NC)					
RUNOFF	0	0	0	0	0
DRAINAGE	70	20	0	0	90
DEFICIT (ET)	0	0	2 – 67	15 – 20	17 - 87
P – T (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	0*	0	0	0	0
DEFICIT (ET)	0*	0 (75-80*)	47 – 117	15 – 20	62 - 137
RAIN (H)	530	70	108	25	733
P – 1 (NC)					
RUNOFF	142	0	0	0	142
DRAINAGE	303	30	0	0	333
DEFICIT (ET)	0	0	10 – 75	70 – 75	80 – 150
P -1 (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	315	30(0*)	0	0	345
DEFICIT (ET)	0*	0(28-33*)	10 – 75	70 – 75	80 – 150
P – 2 (NC)					
RUNOFF	132	0	0	0	132
DRAINAGE	298	30	0	0	328
DEFICIT (ET)	0	0	31 – 96	70 – 75	101 – 171
P – 2 (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	300	30 (0*)	0	0	330
DEFICIT	0*	0 (49-54*)	10 – 75	70 – 75	80 – 150
P – T (NC)					
RUNOFF	0	0	0	0	0
DRAINAGE	450	30	0	0	480
DEFICIT (ET)	0	0	0 – 47	52 – 57	52 – 104
P – T (C)					
RUNOFF	0	0	0	0	0
DRAINAGE	320	30 (0*)	0	0	350
DEFICIT (ET)	0*	0 (0-5*)	0 – 47	52 – 57	52 – 104

In the bench terracing of the Priorat region (P-T), with more effective rooting depth of vines and higher available water retention capacity, there would be less probabilities of drought in the drier (D) years, but in extreme humid years, specially with continuous and concentrated rainfall in the resting period (R), there would be potential conditions (high internal drainage following soil moisture conditions close to saturation on the soil profile for prolonged periods) for triggering landslides in the non protected embankments of the terraces. A green cover crop in that period, using part of the excess water, would decrease the possibilities of landslides.

In general, it may be concluded that the new fully mechanized, land management and cropping practices in dry land vineyards of the Alt Penedés and Priorat regions of Catalonia (Spain) result in drastic changes in the soil moisture regime, with effects on surface runoff, on surface erosion and mass movements, and in the retention of rainfall water in the soil to be used by the grapevines. Analysis, based on appropriate in situ evaluations of climate characteristics and of soil hydrological properties and processes, complemented with the use of simple simulation water balance models based on those processes, may be very useful, and even indispensable, for an adequate planning of more sustainable land use and management for grape wine production, or other alternative uses, under different previewed scenarios of changing climate and agricultural policies leading to changes in land use and management in the Mediterranean region.

References

Gallart, G. F. 1990. El papel de los sucesos lluviosos de baja frecuencia en la evolución geomorfológico de las áreas montañosas. In: “ Geoecología de las áreas de montaña” (I.M. García Ruiz, ed): 95-113. Geoforma Ed. Logroño (Spain)

Maigre, D., J. Aerny and F. Murusier. 1995. Entretien des sols vitícoles et qualité des vins de Chasselas : influence de l´enherbement permanent et de la fumure azotée. Revue Suisse Vitic. Arboric. Hortic. 27: 237-251

Nacci, S., C. Ramos e I, Pla. 2002 .Dynamics of the soil physical properties in vineyards highly mechanized of the Anoia- Alt Penedes. Region. (Catalunya, Spain). In: “Man and Soil at the Third Millenium”. (J.L.Rubio et al, ed). II:1615-1624. Geoforma Ed. Logroño.(Spain).

Pla, I. 1997. A soil water balance model for monitoring soil erosion processes and effects on steep lands in the tropics. In:" Soil Erosion Processes on Steep Lands" . Special Issue of Soil Technology. (I. Pla, ed).11(1):17-30.Elsevier. Amsterdam (Holanda)

Pla, I. 2002. Hydrological approach to soil and water conservation. In: "Man and Soil at the Third Millenium". (J.L. Rubio et al,ed). I: 65-87. Geoforma Ed. Logroño (España).

Pla, I. y S. Nacci. 2001.Impacts of mechanization on surface erosion and mass movements in vineyards of the Anoia- Alt Penedés.Area (Catalonia, Spain) In: "Sustaining the Global Farm". (D.E.Scott et al , ed).812-816.Purdue Univ.-USDA, ARS. West Lafayette, In.(USA)

Pla, I. y S. Nacci. 2003. Tradicional compared to new systems for land management in vineyards of Catalonia (Spain). In: Techniques Traditionnelles de GCES en milieu mèditerranien. (E. Roose et al, ed). Bulletin Reseau Erosion 21:213-223. Montpellier (Francia)

Ramos, M.C. 2001. Rainfall distribution patterns and their changes over time in a Mediterranean area. Theoretical and Applied Climatology. 69: 163-170

Ramos, M.C., S.Nacci e I.Pla. 2000.Soil sealing and its influence on erosion rates for some soils in the Mediterranean area. Soil Science.165(5) 398-403.

Rupp, D. and R. Fox. 1999. Optimized water and nitrogen supply by adapted soil management in the Württemberg Vineyard region. Acta Horticultura Nº 493: 83-85

Particulate and dissolved phosphorus loss by rill erosion from the watershed of Tetves-stream

Sisák, I.[1] – Máté, F. – Strauss, P. – Azazoglu, E.

Introduction

Rill erosion is a severe form of erosion, it can deliver much more sediment and phosphorus to the receiving surface waters and it causes more siltation problems than sheet erosion does. The water quality of Lake Balaton has been sufficiently good for years but the P loading from diffuse sources should be further reduced in order to stabilize the good results. Erosion prone watersheds like that of the Tetves-stream may contribute strongly to P load of the lake. Since there is no daily measurement of water quality on the stream the annual soil and P yield has to be estimated from experimental data.

Material and methods

A set of rainfall simulation experiments was carried out in Hungary in the south watershed of Lake Balaton at Somogybabod on a Calcaric Regosol (sandy clay loam, slope 13.5 %) in 2001. The description of the simulator and the methodology is given by Strauss et al. (2000). The site is in the watershed of the Tetves-stream (Figure 1) 240 m above the Adriatic see level.

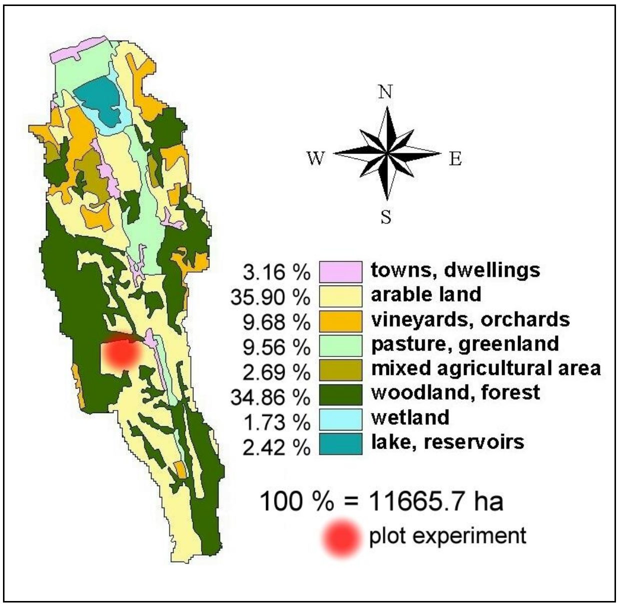


Figure 1 Land use and experimental site on the watershed of Tetves-stream

The soil was prepared to seedbed conditions after the removal of maize plants two days before the experiment started. Pre-wetting (30 mm) was applied to each plot one day prior to the rainfall simulation to reach uniform soil moisture conditions for the beginning of the simulations. The soil surface was protected with a light and dense plastic net during the pre-wetting. Simulated rainfall was applied (uniform intensity of 60 $mm.h^{-1}$) on four plots (2x5 m). Rainfall application was repeated after week one and two. Runoff and total soil erosion were measured and total P content of the eroded material determined after digestion with sulphuric acid and hydrogen-peroxide. Few samples were let settle in the laboratory and suspended solid content of the upper 5 cm layer was determined by filtration (0.45 μm) after 1000 and 10,000 seconds. Rill development during consecutive simulations was photographed digitised and the length of the rills measured with a software routine. The erosion potential of rainfall (R) and slope LS factors were determined by the method of Renard et al. (1997):

$$R = \Sigma\, EI_{storm} \qquad EI_{storm} = \{\Sigma\, 0.29\, [1 - 0.72 \exp(-0.05\, X_i)]\, D_i\}\, I_{30}$$

where

EI_{storm} = storm erosivity
i = rainfall hyetograph time interval

[1] University of Veszprém, Georgikon Faculty for Agriculture, Department of Soil Science and Agrochemistry, Deák F. St. 16, H-8360 Keszthely, Hungary; E-mail: talajtan@georgikon.hu

D_i = rainfall during time interval i (mm)
I_{30} = maximum 30-min rainfall intensity of the storm (mm/hr)
X_i = rainfall intensity (mm/hr)

$L = (\lambda / 72.6)$
$S = 10.8 \sin\theta + 0.03$ $\quad s < 9\ \%$
$S = 16.8 \sin\theta - 0.5$ $\quad s \geq 9\ \%$

where
λ = slope length in ft
θ = slope angle

The monthly and yearly C factors were adopted from the work of Horváth and Kamarás (1980)

Results

The soils in the watershed of Tetves-stream were formed on sandy loess and they are highly eroded under the conditions of arable farming. Usually the whole solum, or large part of the solum is eroded from the original Haplic Luvisols and Eutric Cambisols and the calcaric parent material is the top layer with less developed soils on it. There are some Gleysols near the stream, too (Figure 1). The eroded soils are prone to further erosion, thus rills have formed very quickly on the experimental plots. One example of rill formation is shown on Figure 2.

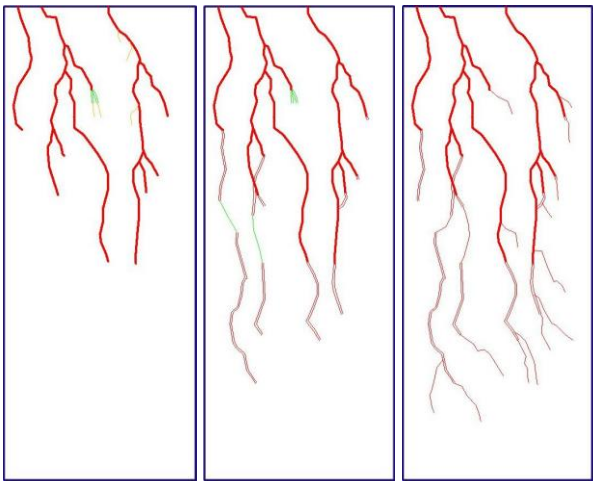

rain1 rain2 rain3

Figure 2. Development of rills in the consecutive simulations

By relating soil loss to the total length of rills, one should recognize that the mean and the variance of the data are higher in the first simulation than in the following ones, and these statistical measures are practically the same and they are small in the second and third simulations (Figure 3), where the average soil loss rate per rill length unit is 0.984 $kg.m^{-1}$ (see also Table 1). It was observed that mixed sheet and rill erosion are present at the beginning, but rill erosion dominates later. According to the field observation, the ratio of rill erosion approximates 100 percent after the first simulation.

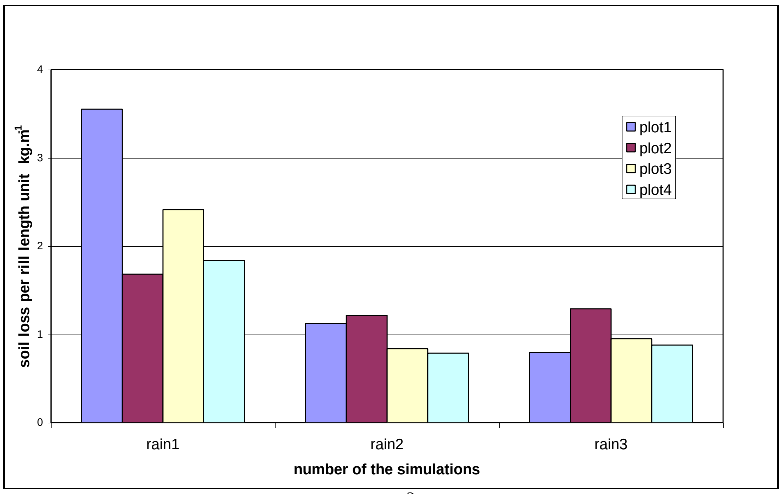


Figure 3 Soil loss rates from the 10 m^2 plot

The rill development in the experiment has been linear and the variance of data among the plots in the consecutive simulations has been rather uniform (Figure 4). Storm erosivity (R) was chosen as independent variable at fitting the line. The equation indicates that rill formation is a permanent process on this soil presumably in the whole year at this slope and rainfall intensity. Based on the experiment, 20 $t.ha^{-1}.yr^{-1}$ rainfall erosivity was considered as the lower limit for rill formation and all the cumulative rainfall erosivity above this level was considered as rill forming (Table 1).

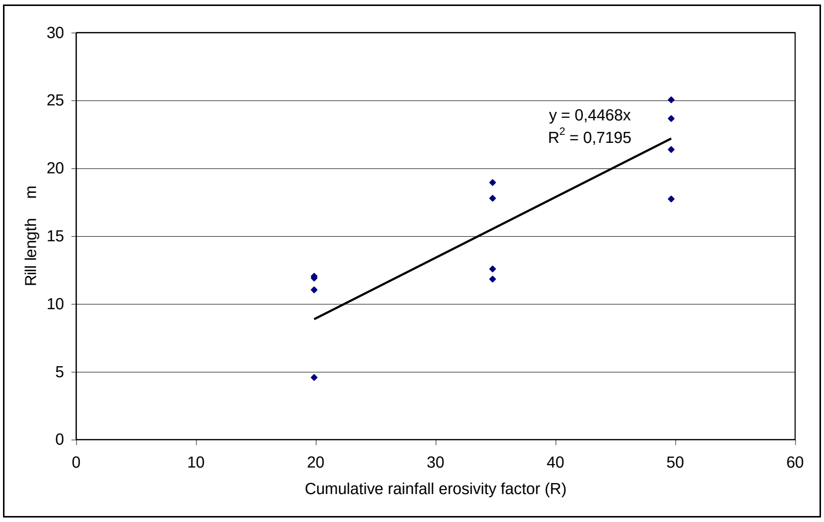


Figure 4 Rill formations in the consecutive simulations

The sediment P concentrations have varied only slightly and have shown no significant differences among simulations and plots. The average value was 0.743 g $P.kg^{-1}$ (or kg $P.t^{-1}$) and that is approximately equal to the P content of soil (Table 1). Dissolved P concentration has been equal to zero in almost all samples. The concentrations of eroded soil in runoff have varied between 20 and 140 $g.l^{-1}$, the suspended sediment content varied between 5 and 25 $g.l^{-1}$ after 1000 s deposition time and there was a linear relationship with the original concentration but, interestingly, the concentrations have been almost constant (3.64 $g.l^{-1}$) after 10,000 s deposition time (Figure 5). Another calculation has shown that residual suspended sediment content after 10,000 seconds is 5,5 % of the original one with ± 3,5 % standard deviation. The later relationship was used to calculate sediment and particulate P delivery ratio between field and lake because of its simplicity (Table 1). The settling experiment with the longer deposition time may be good physical representation of the long-distance delivery of sediment and P once soil is eroded.

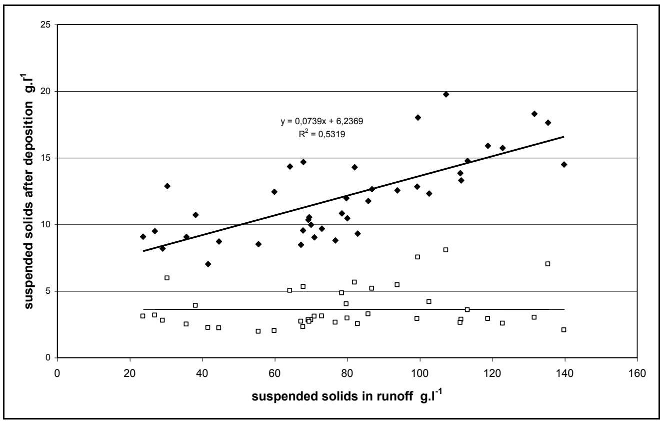


Figure 5 Suspended sediment content of samples after 1000 and 10,000 seconds deposition time in the upper 5 cm layer.

The RCLS products have been above 20 $t.ha^{-1}.yr^{-1}$ even in the first month of calculation (October) at slopes higher than 12 %. That means, rill erosion can be assumed throughout the whole year from that slopes.

The RKLSCP product became larger than the limit in November at slopes 5-12 % and in April at slopes 0-5 % so even slight slopes may produce considerable amount of rill erosion (Figure 6).

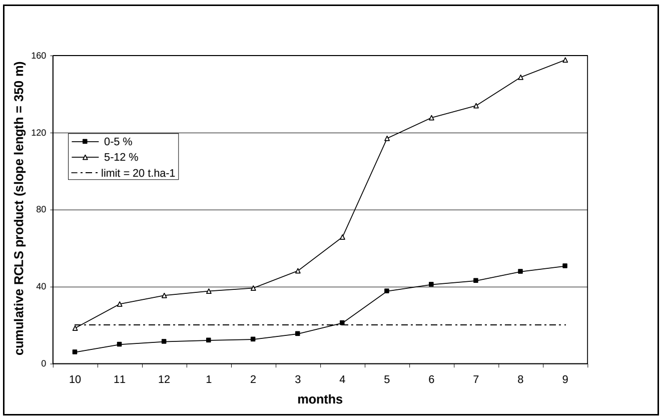


Figure 6 Rill erosion risk at lower slopes

Dominating part of soil and phosphorus may come from arable land, other areas` contribution is relatively small. Different slope categories were calculated for the arable land of the study area (Table 1) and with help of the mathematical relationships described above in this paper, particulate P loading to the lake was calculated.

Table 1. Soil and phosphorus loss from arable land on the watershed of Tetves-stream

		slope categories on arable land					
		0-5 %	5-12 %	12-17 %	17-25 %	above 25 %	**sum**
A	area ha	2473	1329	90	202	93	4187
B	rill forming[1] RCLS product (USLE) $t.ha^{-1}.yr^{-1}$	31	138	303	479	711	1660
C	sediment yield from rills[2] $t.ha^{-1}.yr^{-1}$	13	61	133	210	312	730
D	sediment yield from the whole watershed[3] $t.yr^{-1}$	33319	80472	11980	42553	28912	197236
E	primary total P loss from field[4] $kg.yr^{-1}$	24756	59791	8901	31617	21482	146547
F	particulate P load to Lake Balaton by rill erosion[5] $kg.yr^{-1}$	1362	3289	490	1739	1181	8060

[1] – see text and Figure 6; [2] – C = 0.984 x 0.4468 x B (see text and Figure 3 and 4); [3] – D = C x A; [4] – E = 0.743 x D (see text); [5] – F = 0.055 x E (see text)

Discussion and conclusions

The total calculated particulate P load per total surface area is 0.691 kg P.ha^{-1}yr^{-1} which is higher than the average calculated total P load from the whole watershed (Istvánovits, 2000). The P load should be even higher if mixed agricultural land, orchards and vineyards (12.4 % of the watershed) would be calculated with similar loss rates as arable land. Istvánovits (2000) has tried to correct the P load calculations of the Tetves-stream based upon biweekly water quality measurements at the mouth of the stream (influenced by the pond at the lower section of the stream – see Figure 1) and upon daily water flow measurements at Visz that represents 76 km^2 (65 %) of the watershed (not influenced by the pond). The calculated average total P load was only 0.11 kg.ha^{-1}.yr^{-1}, even smaller than the average load from the whole (5200 km^2) watershed. This may be an effect of the additional settling in the pond. However, a lot of other processes may happen between the erosion site and the final sink in the lake and there is no common agreement on the quantification of these effects yet. Sediment traps might be effective way of keeping P away from the lake temporarily until the traps silt up, but it does not solve the problem of the diffuse agricultural load in long-term and even not the problem of soil and P loss from arable land at any moment.

It also should be recognized that the physical representation of the delivery ratio in our settling experiment may overestimate the load, since it does not consider the infiltration of runoff and the removal of sediment by that process.

It can be declared based upon the calculations that the initial soil and P loss is several magnitude higher than actual P load from the watershed at the mouth of the stream but even soil and P load of the valley may be one magnitude higher. The fish-pond is an effective trap of sediment and particulate P but it masks the huge mass movement by erosion processes on the watershed that can be recognized by mere eye-observation, still our study has assigned figures to that process.

Summary

Sediment and total P losses (practically equal to particulate P) from the watershed of Tetves-stream were calculated based upon plot experiments and GIS analysis of the watershed. The investigation pointed out that total P load can be as high as 0.691 kgP.ha^{-1}yr^{-1}, much higher than reported data but several magnitudes lower than primary P loss from the field. The fish-pond near to Lake Balaton is an effective trap of sediment and particulate P but it masks the huge mass movement by erosion processes on the watershed and it does not solve the problem of diffuse agricultural load in long-term and the problem of soil and P loss from arable land.

Acknowledgement

This work was carried out with support of the DESPRAL (EVK1-CT-1999-00007) and 3/024/2001 NKFP projects.

Reference

Renard, K.G., G.R. Foster, G.A. Weesies, D.A. McCool, and D.C. Yoder (1997): Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). Agric. Handb. 703. US Gov. Print Office, Washington, D.C.

Horváth, V –Kamarás I. (1980): Possibilities for reduction of agricultural nutrient load by soil protection methods on the watershed of Lake Balaton. VIZITERV. Budapest. Manuscript (in Hungarian)

Strauss, P., J. Pitty, M. Pfeffer and A. Mentler (2000). Rainfall simulation for outdoor experiments. in: P. Jamet, J. Cornejo (Eds.): Current research methods to assess the environmental fate of pesticides. p. 329-333, INRA Editions

Istvánovics, V (2000): Long-term nutrient load of Lake Balaton. Hungarian Academy of Sciences. Budapest. Research report. (in Hungarian)

Evaluating the Soil Conservation Potential of Palm (*Borassus*) Leaf Geotextiles at the Hilton Experimental Site, Shropshire, UK

Davies, K. [1] – Fullen, M.A.

Introduction

Synthetic geotextiles have been the mainstay of the erosion control industry since the 1950s (Mitchell *et al*., 2002). However, geotextiles constructed from organic materials are highly effective in erosion control and vegetation establishment (Sutherland and Ziegler, 1996; Langford and Coleman, 1996; Ogobe *et al*., 1998). The market leader in organic geotextiles is jute, however natural fibres such as coir, sisal and ramie also have geotechnical applications (Ranganathan, 1992).

A B.Sc. study was completed in 1999, in which runoff plots at the Hilton Experimental Site, Shropshire, UK, were replicated with 3 m buffer zones of palm mat geotextiles. Results showed that sediment yield from the buffer zones was 71.76% lower than the yield from bare soil (Davies, 2000).

The aim of this investigation is to evaluate the soil conservation potential of geotextiles constructed from palm leaves (*Borassus aethiopum*) at the Hilton Experimental Site. A three year study is in progress evaluating palm mat effectiveness in controlling runoff and sediment yield from established runoff plots, together with a field study of the potential of the palm mats in reducing splash erosion. A rainfall simulator study will be conducted, to investigate the effectiveness of the palm mats in reducing runoff and sediment loss during simulated storm events. Further laboratory studies include an assessment of the effect of palm mats on soil physico-chemical properties.

Materials and Methods

The Hilton Experimental Site has been used extensively since 1976 (Fullen and Mitchell, 2000). The site covers 0.52 hectares with an upper elevation of 67.46 m and slopes to the south and west. The region experiences a temperate climate with a mean annual precipitation of 648.3 mm (Mitchell *et al*., 2002). The soil is a Bridgnorth series loamy sand with a typical Ap horizon texture of 79.8% sand, 14.8% silt and 5.4% clay and 1.9% organic matter content (Fullen and Brandsma, 1995).

The runoff plots are situated on the south-facing slope, numbered D1-D8, measuring 10 x 1 m. Prior to observations, the control and treated plots were rotavated to ~20 cm depth and treated with Roundup herbicide to remove vegetation. Observations began on 14 January 2002, with a calibration period until 25 March 2002, when the plots were treated. Using random selection, plots D2 and D8 were completely covered with palm mats, D4 and D5 had 1 m buffer zones of palm mats at the plot lower end, D1 and D6 are the control (bare soil) plots and D3 and D7 are grassed plots (Plate 1). Observations have regularly continued with runoff and sediment yield being collected. Splash erosion studies are also being conducted on the same site on the lower west-facing slope. An area measuring 3 x 3 m was prepared using Roundup herbicide and dug to ~20 cm depth and then raked. Twelve 50 cm^2 areas were marked out and plastic piping 14.5 cm in diameter and 20 cm in length were placed in the soil. Within the piping, 1 litre plastic bottles and funnels were placed to catch splashed sediments (Plate 2). The control and palm mat plots were periodically sprayed with 'Roundup' herbicide to prevent vegetation growth. Measurements of runoff, sediment yield and splash were regularly collected, usually every two weeks.

[1] Research Institute in Advanced Technology (RIATec), The University of Wolverhampton, Wolverhampton V1 1SB, UK

Plate 1. Runoff Plots, Hilton Experimental Site, UK

Plate 2. Splash Plots, Hilton Experimental Site, UK

Results

Runoff Plots: Year 1 Observations

Observations from 8 April 2002–10 March 2003 (precipitation total 610.7 mm) showed similar runoff values from the grass plots. However, there were noticeable differences between the replicated bare soil plots, covered plots and the buffer zone plots (Figure 1). Runoff from the covered plots was higher than the control plots by a mean of 125.2%, while runoff from the buffer zones was lower than the control plots by a mean of 68.8%. However, sediment yield from the treated plots was significantly lower than the yield from the control plots during the same period (Table 1). The mean sediment yield (Table 2) from the control plots was 0.09 kg, from the covered plots 0.03 kg, from the grass plots 0.02 kg and 0.03 kg from the buffer zone. The total erosion rate (t/ha) was 0.9 from bare soil, 0.2 from grassed soil and 0.3 from soil covered with palm mats and with buffer zones. As erosion from buffer strips plots equals plots completely covered with mats, this indicates that buffer strips are very effective in reducing erosion.

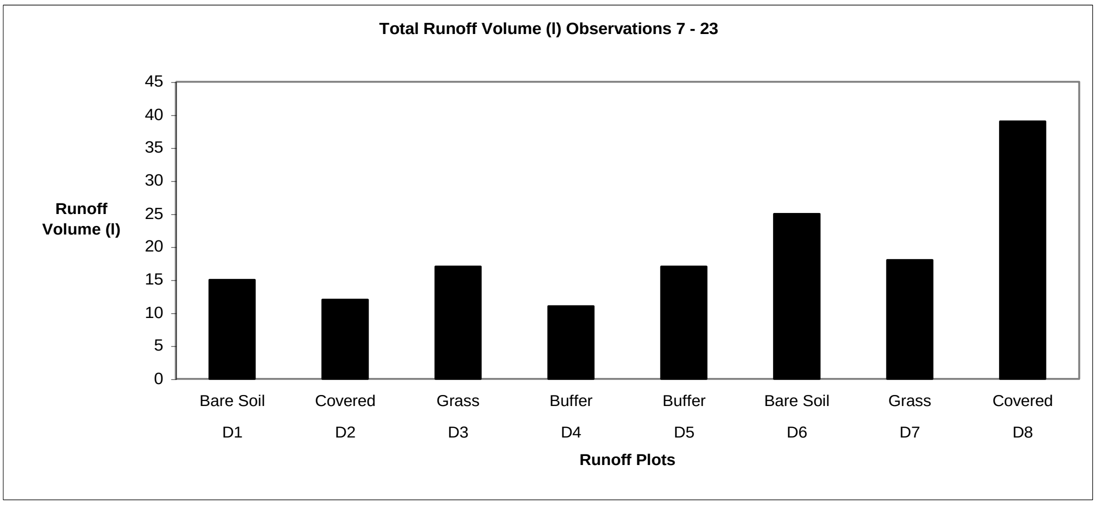


Figure 1. Runoff Volume (l) Observation 8 April 2002 - 10 March 2003

Table 1. Sediment Yield Observations (g) 8 April 2002-10 March 2003

	Bare Soil	**Covered**	**Grass**	**Buffer**	**Buffer**	**Bare Soil**	**Grass**	**Covered**
Date	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**
08/04/2002	2.9	1.1	0.7	0.3	0.3	0.8	0.2	0.5
13/05/2002	1.3	0.8	0.5	0.6	1	1.9	0.2	0.9
20/05/2002	3.3	0.5	0.1	0.7	0.1	3.3	0.1	0.3
30/05/2002	1.9	1.4	1	0.2	0.2	1.3	0.2	0.7
17/06/2002	1.1	3	1.1	0.5	0.4	1.2	0.6	0.9
08/07/2002	0.4	0.6	0.1	0.4	0.2	0.7	0	0.7
22/07/2002	4.2	2.5	1.7	1.2	0.7	1.5	0.2	0.2
05/08/2002	0.8	0	0.2	1.2	0.7	0.6	0.3	0.5
19/08/2002	1.3	0.6	0.2	0.4	1.6	0.4	0.6	0.4
09/09/2022	0.6	0.4	0.6	0	0	0.5	1.6	0.5
23/09/2002	1	0.8	0.2	0.5	0.7	27.8	0.3	0.1
14/10/2001	9.1	2.1	0.9	3.8	4.5	2	0.4	0.5
21/10/2002	0.2	0.4	0.4	0.4	0.4	1.6	0.1	0.4
18/11/2002	1.6	1.4	1.2	2.4	0.6	0.6	0.2	1
09/12/2002	1.4	1	0.7	0	0.3	0	1.2	0.7
06/01/2003	3.8	3.1	0.5	0	1.8	2.3	0.5	0.6
10/03/2003	4.2	3	0.9	2.9	3	3.6	0.2	1.2
Total	**39.1**	**22.7**	**11.0**	**15.5**	**16.5**	**50.1**	**6.9**	**10.1**

Table 2. Mean Sediment Yield (g) Observation 8 April 2002-10 March 2003

	Bare Soil (Control)		**Covered**		**Grass**		**Buffer Zone**	
Plot	**D1**	**D6**	**D2**	**D8**	**D3**	**D7**	**D4**	**D5**
Mean Sediment Yield (g)	44.6		16.4		9.0		16.0	
% of Control			36.8		20.2		35.9	

Splash Plots: Year 1 Observations

The observations from the splash plots (9 September 2002-10 October 2003) show statistically significant differences in sediment yield between the treated and untreated plots (Table 3). The mean sediment yield from the treated plots was 25.8% of the untreated mean.

Table 3. Splash erosion (g) Observations 9 September 2002-10 October 2003

Untreated Plots		Treated Plots	
K2	58.4	B7	13.9
G10	61.7	J3	20.3
C12	53.4	L5	10.3
F11	39.0	H9	7.2
E6	39.7	D4	11.5
A1	50.6	I8	14.9
Total	302.8		78.1
Mean	50.5		13.0
% of control			25.8

Conclusions

Over one year of investigations, geotextiles constructed from (*Borassus aethiopum*) palm leaves reduced water erosion by ~63% and splash erosion by ~74% compared to bare soil. These geotextiles have considerable potential for soil conservation, as the mats stabilize the soil and encourage vegetation growth. When compared to organic geotextiles already on the market, the cost of palm mat shows that at $0.30–0.55 per square metre, the mats are economically viable compared to current market value for jute ($0.30-1.00 per square metre) and coir ($0.90-2.20 per square metre) (Smith, 2000). If constructed using indigenous materials, the mats can be effective, affordable and compatible with sustainable land management strategies.

Acknowledgements

We gratefully acknowledge the help of A.W. Black, D. Townrow and K. Thompson, School of Applied Sciences, University of Wolverhampton, in field and laboratory studies and Mr. PM Sanneh for co-ordinating and managing the workshop in The Gambia.

References

Davies, K. (2000). An evaluation of the effectiveness of palm mat geotextiles on the conservation of loamy soils of the Bridgnorth series. Unpublished B.Sc. dissertation, The University of Wolverhampton, U.K. 78 pp.

Fullen, M.A. and Brandsma, R.T. (1995). Property changes by erosion of loamy sand soils in east Shropshire, U.K. **Soil Technology** 8, 1-15.

Fullen, M.A. and Mitchell, D.J. (2000). **Summary of Teaching and Research Activities on the Hilton Experimental Site, East Shropshire 1976-2000**. University of Wolverhampton, School of Applied Sciences (copy available on request).

Langford, R.L. and Coleman, M.J. (1996). Biodegradable erosion control blankets prove effective on Iowa wildlife refuge. **In**: International Erosion Control Association **Proceedings of Conference XXVII, Seattle**, (USA), 13-20.

Mitchell, D.J., Barton, A.P., Fullen, M.A., Hocking, T.J., Lu Liguang, Wu Bo Zhi and Zheng Yi (2002). Effects of jute geotextiles on runoff and sediment yield: field experiments in the UK. **Soil Use and Management**, 19, 182-184.

Ogbobe, O., Essien, K.S. and Adebayo, A. (1998). A study of biodegradable geotextiles used for erosion control, **Geosynthetics International**, 5(5), 545-553.

Ranganathan, S.R. (1992). Jute geotextiles in soil erosion control. **In**: International Erosion Control Association Proceedings **of Conference XX111**, Indianapolis, (USA), 343-351.

Smith, R. (2001) The potential market for sisal and henequen geotextiles. **In**: Food and Agricultural Organisation and Common Fund for Commodities **Proceedings of Seminar**, Rome, Technical Paper 14

Sutherland, R.A. and Ziegler, A.D. (1996). Geotextile effectiveness in reducing interill runoff and sediment flux. **In**: International Erosion Control Association **Proceedings of Conference XXVI**, Atlanta, (USA), 359-370.

Chemical and physical properties of soil under organic management in Central Italy

Marinari, S.[1] – Mancinelli, R. – Campiglia, E. – Grego, S.

Introduction

It is known that different soil management influence the crop resistance to summer drought (Altieri, 1995). The objective of this study was to verify the effects of organic management on some physical properties typically related to crop water stress resistance and on some chemical properties in Mediterranean environment. In this study, two fields in Central Italy, one managed according to organic and the other according to conventional farming methods, were compared to determine the effects of these two agricultural systems on soil available water content, cation exchange capacity, nutrients and soil organic matter content.

Materials and methods

Two adjacent fields have been differently managed from 1993 until 2001, in Viterbo, Central Italy (latitude 42° 29' N and longitude 12° 16' E). Available water (AW) was estimated as the volume percentage of water retained between –33 kPa [Field Capacity Water Content (FCWC)] and –1500 kPa [Wilting Point Water Content (WPWC)], water content (WC) was also measured at –200 kPa and –500 kPa. The volume was measured using Richards apparatus. Total organic carbon (TOC) was determined by dichromate oxidation. Total organic nitrogen (TON) was determined by sulphuric acid digestion and regular Kjeldahl distillation method. Ammonium nitrogen (NH_4-N) and nitrate nitrogen (NO_3-N) were determined after extraction from the soil with 0.5 M K_2SO_4 and analysed using colorimentric methods. Available phosphorus (P) was determined following the method reported by Bray and Kurtz (1945). All the results are the mean of six replicates.

Results and discussion

Soil texture, pH and cation exchange capacity (CEC) (Tab. 1) were not different between the two fields, whereas electrical conductivity (EC) in organic soil was higher than in conventional soil. This difference was probably due to the widest level of available nutrient in organic soil. In addition, the organic orchard showed significantly better physical and nutritional conditions, with improved available water holding capacity (+25%), increased level of total nitrogen, nitrate and available phosphorus. The average of nutrient content of organic soil was two- or three- fold than the conventional soil (+177% TON and +67% available P). In addition, a small increase in soil organic matter was observed, whereas C/N ratio was significantly lower in organically than in conventionally managed soil (Tab. 1).

[1] [1]Dipartimento di Agrobiologia e Agrochimica, Università degli studi della Tuscia, Via S. Camillo De Lellis, Viterbo 01100, Italy. Tel.: +39 0761 357246; Fax +39 0761 357242; E-mail: marinari@unitus.it

Table 1. Soil physical and chemical properties of organic and conventional fields. Values between brackets are standard deviations (n = 6).

		Organic	Conventional
Sand	(%)	45.9 (±6.8)	39.9 (±3.6)
Loam	(%)	36.2 (±5.2)	36.9 (±2.8)
Clay	(%)	17.8 (±1.6)	23.2 (±0.9)
Texture		Sandy Clay Loam	Sandy Clay Loam
FCWC –33 kPa	(%)	20.9 (±0.3)	20.4 (±0.6)
WC -200 kPa	(%)	17.5 (±0.8)	16.4 (±0.8)
WC -500 kPa	(%)	13.7 (±1.0)	15.0 (±0.4)
WPWC -1500 kPa	(%)	12.5 (±1.0)	13.6 (±0.3)
AW	(%)	8.5 (±1.19)	6.8 (±0.37)
Organic matter	(%)	2.17 (±0.14)	1.89 (±0.14)
TOC	(%)	1.26 (±0.08)	1.10 (±0.08)
TON	(%)	0.197 (±0.014)	0.071 (±0.015)
C/N ratio		6.5 (0.8)	18.1 (±3.9)
NO_3-N	(μg N-NO_3 g^{-1})	15.3 (±1.85)	6.0 (±1.16)
NH_4-N	(μg N-NH_4 g^{-1})	3.0 (±0.5)	2.8 (±0.6)
Available P	(μg P g^{-1})	13.0 (±1.6)	7.8 (±0.5)
pH (H_2O)		7.61 (±0.016)	7.61 (±0.018)
pH (KCl)		7.05 (±0.023)	7.13 (±0.020)
EC	(μS cm^{-1})	192 (±1.35)	185 (±2.08)
CEC	(meq 100 g^{-1})	43.4 (±1.33)	41.8 (±1.63)

The results of this study suggested that, in agricultural system, organic management over the long-term (8 years) could be an efficacy strategy to preserve water in the soil, maintaining and improving soil physical and chemical properties. The improving of whole soil properties were probably influenced by the differences between organic and conventional farming systems on organic matter quality and quantity.

References

Altieri MA (1995). Agroecology. The Science of Sustainable Agriculture. Westview Press

Bray RH, Kurtz LT (1945). Determination of total, organic and available forms of phosphorus in soils. Soil Science; 59, 39-45.

Introduction of conservation agriculture in a highly mechanised agricultural system in Flanders, Belgium

Gillijns, K.[1] – Govers, G.

Over recent years scientists have advocated the introduction of less intensive tillage systems (conservation tillage) in order to remedy the problems of soil compaction and soil erosion caused by modern, intensive agriculture. However, the overall adoption rates of conservation tillage in Europe remain relatively low. This paper reports on a project that was set up in order to demonstrate the feasibility and stimulate the adoption of conservation tillage to the farming community of Flanders. In order to achieve this, the project combined the collection of scientific data on farmer's fields with intensive communication and discussion with the farmers.

The fields that were selected for investigation were split up in two parts. One part was cultivated using conventional ploughing implements while on the other part a form of conservation tillage was applied. The effect of tillage techniques on runoff and sediment production was investigated using field surveys and rainfall simulations. The results indicate that runoff production as well as soil loss is significantly reduced by conservation tillage.

Also, a cost-benefit analysis with special attention to the crop yields was made, as this information is essential for farmers. The results indicate that there was no difference between the yield of maize and sugar beets on the different tilled parts. The costs of conservation tillage techniques were equal or a little less than those of conventional tillage resulting in a small economic benefit for the farmer.

Every year, the results were presented to the farmers on a field day. The farmers show a lot of interest in the technique and react positively, but the adoption of the techniques remains rather low. We think that, besides a certain reluctance to start using a new technique, the investment costs necessary to adapt or replace current machinery is a major factor hindering the acceptance of conservation tillage.

[1] Section of Physical and Regional Geography, Katholieke Universiteit Leuven, Belgium. E-mail: Katleen.Gillijns@geo.kuleuven.ac.be

High resolution determination of bulk density–distribution in sealed soils

Hecker, J.-M.[1]

Soil surface sealing is a common phenomenon of cultivated soils. Seals are known as thin layers at the soil surface and are characterized by higher bulk density, high shear strength, lower porosity, and lower hydraulic conductivity compared to the underlying undisturbed soil. They are identified as a key factor in soil erosion processes.

The bulk density distribution is suitable to qualify surface seals. The bulk density–depth function, $\rho_c(z)$-function, i.e. bulk density ρ_c against depth *z*, is widely accepted for the characterization of seals and/or modelling the linked processes (Mualem et al. 1991; Roth 1997). The small thickness of seals is the main technical problem for bulk density measurements: In most cases less than 5 [cm] for structural crusts

To face this pitfall a non-destructive method is presented to measure the bulk density distribution in surface seals by X-ray computed tomography (CT): The scanning of soil cores provides a stack of slices. These slices build a 3D-matrix of X-ray mass attenuation coefficients, expressed as [HU]. Each value of this matrix represents a distinct volume – a so called *voxel*. Due to the linear relation between attenuation and bulk density (Petrovic et al. 1982; Anderson et al. 1988) – if water content and mass attenuation coefficient of the sampled soil is known – we obtain a 3D-bulk density matrix for further analysis.

Soil samples sealed under natural rainfall conditions will demonstrate the capability of the proposed method. Two sites were prepared in spring 1996 and 1997. One sites near *Adenstedt* in south Lower Saxony/ Germany (three plots with soils derived from loess), the second site *Bäckerweg* is located near Müncheberg/ Brandenburg with two plots with sandy soils (Pleistocene sediments). For details see Hecker (2002).

The sealed soil cores were scanned in a medical CT with voxel size of 1.0 x 0.125 x 0.125 mm^3 and 64 slices (average). Virtually we cut a cube with 64^3 [mm^3] off from the sample. Two images (slices) of a well developed seal are shown in figure 1. This sample consists of a silt influenced by a few rainfall events with a total amount of 69 mm cumulative precipitation and 854 [J m^{-2}] cumulative kinetic energy of precipitation respectively.

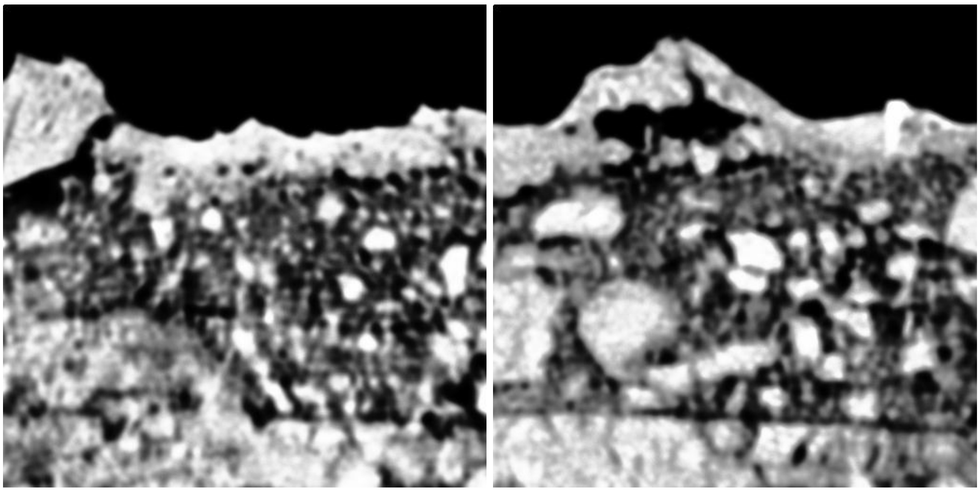


Figure 1. Well developed structural crust; slice 26 and 53 of the sample 97eg21(Ut2, silt)

After the CT-scanning process subsequent data processing steps are necessary to generate the digital elevation model (DEM) of the soil surface, the 3D-reconstruction of the cube for visualization purposes, and – last but not least – the $\rho_c(z)$-function including derived parameters.

[1] Center for Agricultural Landscape and Land Use Research (ZALF), Institute for Landscape Systems Analysis, Eberswalder Straße 84, D-15374 Müncheberg, Germany; Tel.: +49 33432 82-393; Fax: +49 33432 -82-334; E-mail: hecker@zalf.de

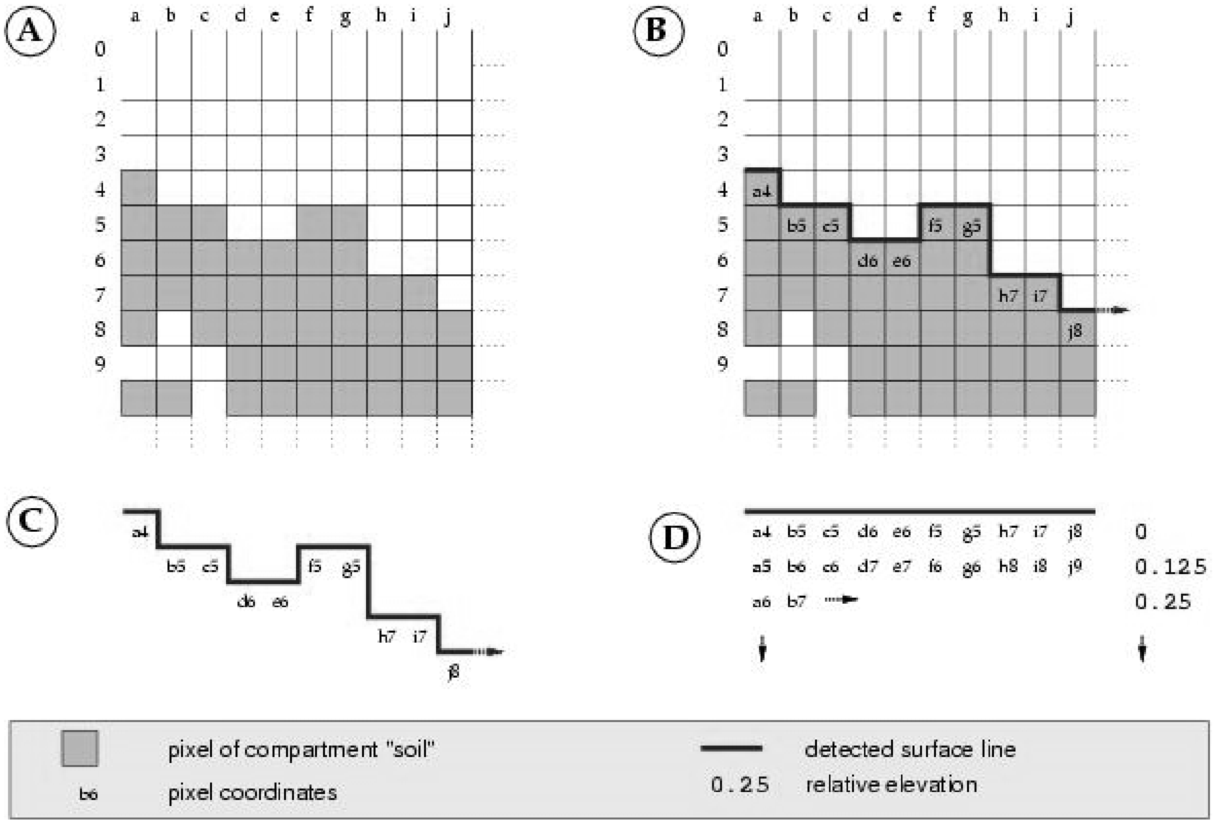


Figure 2. Sketch of surface detection

For quantification issues (quantitative characterization of the sealed soil) following steps are proposed:

1. computation of bulk density representation of the sample-cube following Petrovic et al. 1982,
2. detection of the soil surface (⇒ DEM),
3. generating of the bulk density–depth function and
4. computation of derived parameters.

For the surface detection, in a first step, every voxel is labeled as soil bulk or pore (figure 2/A). This is done by usage of a threshold which is set to a porosity of 66%. The uppermost voxel in each column which belongs to the soil compartment is taken as a surface voxel with depth = 0.

Stepping downward within the column we pick up the bulk density for each voxel as shown in fig.1/C. Putting all columns together we got the resulting bulk density–depth function representing the mean bulk density of each level (distance to surface) against depth (figure 3). For the characterization in a quantitative manner parameters were used which are derived from the bulk density–depth function. These are parameters such as mean bulk density of the seal [g cm^{-3}], the maximum density of the upper 10 mm, ρ_{max10} [g cm^{-3}] and thickness of disturbed layer d_c [mm].

Additionally the *surface*-voxels were interpreted as a digital elevation model of the microtopography (-relief) so that typical micro–relief parameters can be calculated: such as the random roughness coefficient (Luk 1983), the specific surface area (Helming et al. 1993), and depression storage capacity.

Images and other visualizations are important diagnostic tools, especially for opaque materials like soils. Therefore CT-slices transformed to images of bulk density matrixes are of interest to get additional information leading to adequate interpretation of many processes linked to soil sealing.

Volume rendering with alpha blending is also useful to visualize the whole cube and the inner arrangements of seal, pore structure, soil matrix and skeleton. For figure 4 a ray tracing with alpha blending is used to visualize the soil bulk as 3D–bulk density matrix.

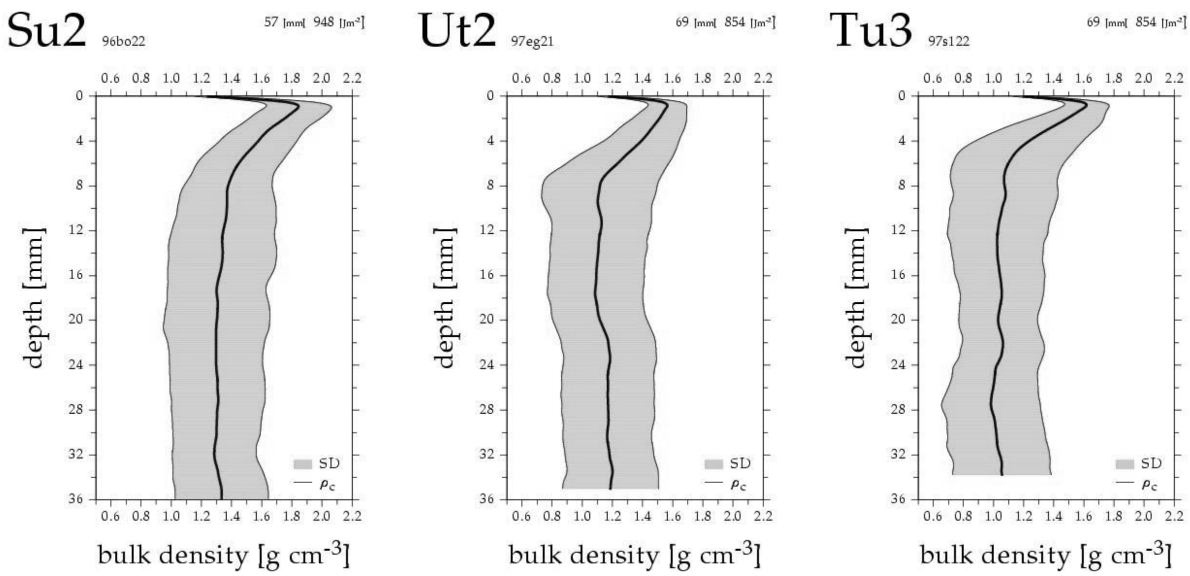


Figure 3. Bulk density–depth functions of selected samples with comparable rainfall pattern. *Legend: upper left corner: texture (AG Boden 1994); right corner: cumulative precipitaion [mm] and corresponding kinetic energy [J m^{-2}]; SD: 68 % area of mean ± standard deviation; ρ_c : mean bulk density of depth-level (N≈32.700 voxel per level). Su2 ≈ loamy sand, Ut2 ≈ silt, Tu3 ≈ silty clay loam.*

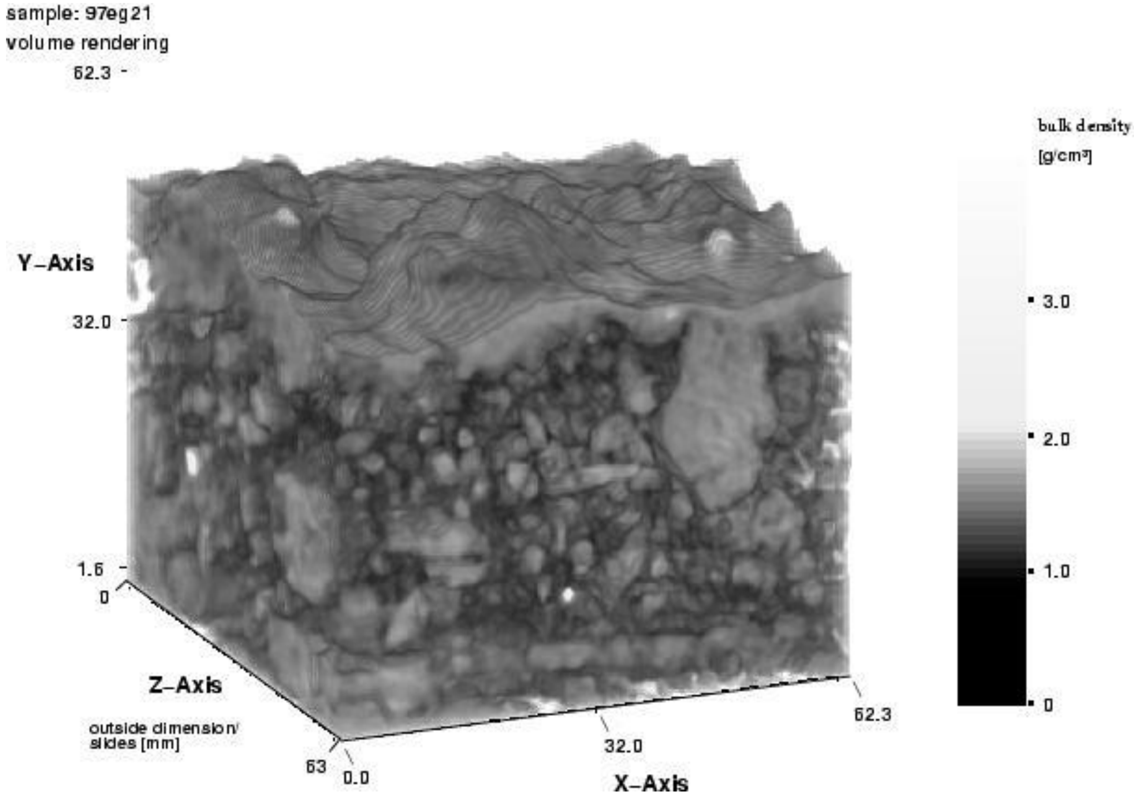


Figure 4. 3D-reconstruction of the sample 97eg21 (Ut2, silt)
Volume rendering with alpha blending is used to visualize the bulk density: below 0.90 [g cm^{-3}] fully transparent, above this threshold a linear increasing alpha value; bulk density itself is spread between black (0.90 [g cm^{-3}]) and white(2.65 [g cm^{-3}]). Sample was exposed to natural rainfall (69 mm cumulative precipitation/ 854 [J m^{-2}] cumulative kinetic energy)

Conclusions

The advantages of the proposed method are: (i) non-destructive, (ii) high resolution (< 1 mm in depth), in conjunction with adequate data processing programs (iii) it is useful for multi purposes (bulk density distribution, digital elevation model (DEM) of soil surface, the characterization of macro-pore system etc.), as well as (iv) other subsequent soil physical or chemical measurements. The latter is possible because of the non-destructive character of the CT-scanning method.

Results showed that the method is capable to characterize seals in detail and to contrast structural differences of surface seals in a qualitative, quantitative, and nondestructive manner. The resulting quantitative descriptions – in conjunction with the diagnostic capabilities of the visualization possibilities – are well suited to investigate several processes at the soil surface. For example the development of the seal and related morphological formations, interactions between surface roughness and soil sealing, and modelling the bulk density–depth function.

References

AG Boden (1994) Bodenkundliche Kartieranleitung, 4. Aufl., Hannover 1994

Anderson , S.H.; Ganzer, C.J.; Boone, J.M. & Tully, R.J. (1988): Rapid nondestructive bulk density and soil-water content determination by computed tomography. Soil Sci. Soc.Am. J. 52: 35-40.

Hecker, J.-M. (2002): Morphometrie und Dynamik verschlämmter Bodenoberflächen. Computertomographische Untersuchungen und Überprüfung von Modellen des Lagerungsdichte-Tiefenprofils. Diss. TU-Berlin, Wiss. Verlag Berlin.

Helming, K., Roth, C.H., Wolf, R. & Diestel. H., (1993): Characterization of rainfall - microrelief interactions with runoff using parameters derived from Digital Elevation Models (DEMs). Soil Technol. 6: 273-286.

Luk, S.H. (1983): Effect of aggregate size and microtopography on rainwash and rainsplash erosion. Z. Geomorphologie NF 27(3): 283-295.

Mualem, Y.; Assouline, S. & Rhodenburg, H. (1990): Rainfall induced soil seal. (A) A critical review of observations and models, Catena 17: 185-203.

Petrovic, A; Siebert, J. & Rieke, P. (1982): Soil bulk density analysis in three dimensions by computed tomographic scanning. Soil Sci. Soc. Am. J. 46: 445-450.

Roth, C.H. (1997): Bulk density of surface crusts: depth functions and relationships to texture. Catena 29: 223-237.

The soil quality concept as a tool for exposing values in science and promoting sustainability considerations

Schjønning, P.[1]

Introduction

In the developed and industrialized countries, modern agriculture has fulfilled its primary goal of providing adequate and reliable sources of food of good quality, and even more so as witnessed by surplus production and subsidized export of agricultural products. This has contributed to a switch in societal concerns from sheer productivity to sustainability of agriculture, including the effects of production methods on the environment, the diversity of the natural flora and fauna, the welfare of domestic animals, and on the soil resource itself. The quality of air, water and - as yet to a minor extent - soil has come more into focus. Almost every aspect of modern agriculture is now under scrutiny from concerned producers, environmentalists and consumers, from researchers and government as well as non-governmental organizations, and agricultural sustainability is on the agenda of most political movements and parties.

This development has increased the demand for scientifically based solutions that incorporate a wider range of aspects. Scientists have been involved in problem solving and development in the society for centuries but the pressure from society for a pro-active role of science is much more pronounced than a few years ago. Bouma (2001b) denotes the present-day community a network society and urges soil scientists to take active part in ‘negotiations’ with stakeholders in society. More specifically, he suggests ‘research chains’ of scientists and stakeholders in order to optimize the implementation of scientific results in land use planning. However, many (soil) scientists are reluctant to take part in such work and claim that science (and hence scientists) should not be involved in value-laden discussions on sustainable development. The present paper deals with some basic issues on values in science. It is crucial that any (soil) scientist realizes how his/her personal opinions and priorities influence his/her research. The soil quality concept offers itself as a tool in this exercise. Many of the considerations presented here are derived from a recent editorial work on a book on soil quality (Schjønning *et al.*, 2004).

Descriptive and prescriptive science

Typically, scientists in ecology, geography and other classical scientific disciplines perceive soil as an ecosystem component, and their approach is descriptive and observational in nature. Agricultural researchers, on the other hand, are concerned primarily with the production of food and fibre, and perceive soils mainly as media to support plant growth. Fertility trials, crop rotation studies, tillage experiments, etc., have provided the basis for an increasing productivity. Thus, researchers involved in agricultural sciences are accustomed to produce prescriptions with the clear aim of increasing yields. Ellert *et al.* (1997) advocated a combination of the conceptual/descriptive approaches of ecologists and the quantitative/prescriptive approaches of agronomists. I concur in this opinion, and call attention to the importance of this for organizations as the European Society for Soil Conservation (ESSC). Our knowledge of soil degradation processes is of no need for soil conservation issues if we do not address the management options to combat the degradation.

Soil quality as a technical concept

Numerous publications addressing ‘soil quality’ have appeared over the last decade. Most papers assign specific soil attributes to the term (e.g. organic matter content, structural stability, and microbial activity). I.e., the soil quality term is often used unreflectively for a vast number of soil characteristics. Also Carter (2002) noted that most studies are purely descriptive. This approach is typical for classical ecologists and geographers. In order to make this approach operational, much focus has been on soil quality *indicators*, hoping that a collection of such indicators may fully classify the quality of some specific soil. Larson and Pierce (1991) suggested a *minimum data set* to describe the quality of a soil. This data set should consist of a number of indicators describing the quality/health of the soil. Using an analogue to human medicine, reference values for each indicator would set the limit for a healthy soil (Larson and Pierce, 1991). The use of indicators has been widely discussed in the literature on soil quality (e.g. Doran and Jones, 1996). Seybold *et al.* (1998) and Sojka and Upchurch (1999) stressed the difficulty in dealing with the 18-20.000 soil series occurring in the USA. Considering the diverse agricultural uses of soils (e.g. growing different crops with dissimilar soil requirements) and the different optima associated with each specific use, Sojka and Upchurch (1999) emphasized *understanding* rather than *rating* of the soil resource. The use of soil quality indicators is even more problematic, when they are indexed (e.g. to range between 0 and 1). One reason is that indexing effectively hides all

[1] [1]Department of Agroecology, Danish Institute of Agricultural Sciences, Research Center Foulum, P.O. Box 50, DK-8830 Tjele, Denmark; Tel.: +45 8999 1766; Fax: +45 8999 1719; E-mail: Per.Schjonning@agrsci.dk

mechanistic details and reduces a complex soil property/function to a naked value. Another is the fact that judgements on good/poor made by the scientist are embedded in the term.

Confining the soil quality term to a technical denominator of soil properties, indicators and indices is in my opinion both unambitious and – more importantly – even harmful because unreflected societal priorities and personal values are embedded in the term. In consequence, I suggest that the term should be used only in combination with considerations of sustainability issues. Before elaborating on this approach, it is necessary to reflect on values in science and their crucial role in communication on soil issues.

The cognitive context and the reflexive objectivity

Agricultural research is an applied science with the main objective to improve production methods and develop production systems. In consequence, agricultural science influences its own subject area, agriculture, in important ways (Lockeretz and Anderson, 1993). In general, science that influences its own subject area is defined as *systemic science* (Alrøe and Kristensen, 2002). The fact that science plays a pro-active role in the world that it studies makes the criterion of objectivity as a general scientific ideal less straightforward. It is important that the scientist is able to view her- or himself as part of the system (self-reflection). This ability to take an 'objective' stance but at the same time being aware of the intentional and value-laden aspects of science is denoted *reflexive objectivity*, and the framework in which these reflections take place is labelled the *cognitive context* (Alrøe and Kristensen, 2002). The cognitive context may be divided into three: the observational, the societal, and the intentional. The observational context includes the actual methodological aspects of the research, the societal context is the group or segment for which the research is relevant, and the intentional context is the goals and values employed.

In this paper, only a few remarks will be added to the above definition (please consult Alrøe and Kristensen (2002) for a more thorough introduction to the cognitive context and the reflexive objectivity). The relevance of the scientific work depends on the *societal context* pervading at the time of the study. There is no 'universal' science that is independent of social context. When pesticides became available to farmers in the mid 20th century, the most relevant task for agricultural researchers was to optimise their use for maximum production and minimum costs. Today's scientists are engaged in studies of the detrimental rather than the beneficial effects of pesticides (e.g. ground water pollution, bioaccumulation, side-effects on non-target organisms). The example serves to illustrate that the societal context has changed dramatically during the period discussed here. The *intentional context* in science has to do with values and goals for the specific research group or scientist. Sojka and Upchurch (1999) gave a critical review on the concept of soil quality. Some of their concerns were abstracted as 'we are .... reluctant to endorse redefining the soil science paradigm away from the value-neutral tradition of edaphology and specific problem solving to a paradigm based on variable, and often subjective societal perceptions of environmental holism'. That is, the authors support the classical understanding of objectivity in science. In their paper, however, they draw the attention to articles dealing with different aspects of soil quality and raise the query whether a high biodiversity in soil is more valuable than animals at the other end of the food chain. I interpret their statement as giving a high production of foods (higher animals) a higher priority than a high biodiversity in the soil. This is of course a legitimate standpoint, but my point is that this opinion also reflects an 'intention' or a 'value/goal'. Awareness of these values is what the reflexive objectivity is all about.

Soil quality as a cognitive concept

The soil quality term emerged in North America (Alexander, 1971; Warkentin and Fletcher, 1977). Despite an early, intense discussion in the USA (e.g. Allan *et al.*, 1995; Karlen *et al.*, 1997) and the governmental support for an institute addressing the soil quality concept (Anonymous, 1996), the relevance and impact of the concept are currently being disputed (Sojka and Upchurch, 1999; Karlen *et al.*, 2001; Letey *et al.*, 2003; Sojka *et al.*, 2003; Karlen *et al.*, 2003). It appears that this dispute is fuelled largely by the lack of a clear objective for the use of the soil quality concept.

Soil quality is how well soil does what we want it to do'. This statement, extracted from the web-site of the USDA Soil Quality Institute, represents the very essence of the soil quality concept. The statement includes two aspects: 'how well' relates to grading soils (the descriptive approach discussed above), while 'what we want' relates to priority of soil functions. And priorities are based on sustainability considerations, which further are founded in values pervading in the society at the specific time (the societal context) and the opinions of the researcher (the intentional context). What is important in this context is the fact that any evaluation of some property or function in soil necessarily involves values and priorities. The literature cited above clearly illustrates that it is a prerequisite for fruitful communication among scientists as well as between scientists and stakeholders that these values are explicitly stated together with the basic scientific results.

Mans interaction with soil

Blum and Santelises (1994) and Blum (1998) considered the functions and services of soil as related to human activity and grouped them into six categories. Three ecological uses are 1) the production of biomass, 2) the use of soils for filtering, buffering and transforming actions, and 3) the provision of a gene reserve for plant and animal organisms. Three other functions relate to non-agricultural human activities: 4) a physical medium for technical and industrial structures, 5) a source of raw materials (gravel, minerals etc), and 6) a cultural heritage. This classification of man's interest in and interaction with soil may facilitate an operational definition of soil quality: *Soil quality is the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation* (Allan *et al*., 1995; Karlen *et al*., 1997). Keeping the above reflections on the cognitive context in mind, the exercise of soil quality evaluation thus involves explicit judgement of which soil conditions will fit the sustainability expressions in this definition. This link between soil quality and sustainability is so very important because soil quality should not remain an abstract concept but rather something to be strived for by management (Bouma *et al*., 1998).

Indicator threshold and management threshold

Threshold was defined by Smyth and Dumanski (1993) as 'levels beyond which a system undergoes significant change; points at which stimuli provoke response'. Thus threshold links to resilience. As an example, Smyth and Dumanski mentioned the threshold for erosion as the level (extent of erosion) beyond which erosion is no longer tolerable (in order to maintain sustainability). Thus, thresholds are values of a variable beyond which rapid, often exponential, negative changes occur (Pieri *et al.*, 1995). Because of their intimate association with resilience, focus should be on *thresholds* rather than on *references*, *baselines* or *benchmarks*, often employed in the literature on soil quality indicators.

This paper advocates a shift from *assessing* soil quality to *managing* soil quality. Of course management cannot be addressed without evaluating soil attributes (i.e. indicators) but putting the focus on the effects of management may establish a more relevant foundation for the soil quality concept. When the common knowledge on soil functions and properties (including indicator thresholds) is combined with that derived from studies on the effects of specific management tools, the potential outcome can be *management thresholds*, i.e. the most severe disturbance any management may accomplish without inducing significant changes towards unsustainable conditions (Schjønning *et al*., 2004). Let me give an example: regarding soil acidity, soil pH is a soil quality indicator for which a threshold can be established, while the rate of liming (e.g. kg $CaCO_3$ ha^{-1} $year^{-1}$) required to maintain the pH at some prescribed level represents the management threshold.

Science, scientists and society

Bouma *et al.* (1998) advocated a 'research chain' for implementation of scientific results in decisions on management and land use. This would imply methodical steps in a process of identifying, selecting, resolving and presenting the soil quality problem and the knowledge gained. This 'chain'-approach should be performed by an interdisciplinary group of researchers and stakeholders. A step-by-step increase in complexity of succeeding research chains may further improve the quality of decisions on land use (Bouma, 2001b). At the same time, this will optimise the focus and the contribution from all branches of science, both fundamental, strategic and applied research. Bouma (2001b) also mentions the benefits of such procedures in highlighting the key role of soil science in producing optimized solutions to management and planning problems in society. He even claims that a continued passive role of soil scientists is a threat to the mere survival of the profession of soil science!

The reader is encouraged to consult the papers of Bouma for inspiring ideas on this important role of the modern scientist (e.g. Bouma *et al*., 1998; Bouma 2000, 2001ab, 2004). However, the examples of communication problems among scientists mentioned above clearly stresses that first we need a shift in the research paradigm (Fig. 1). Barrett and Raffensperger (1999) speak of 'precautionary science' as an alternative to classical, positivistic science. The precautionary principle is related to and interacts with the sustainability concept. One basic issue of the precautionary principle is 'thoughtful action in advance of scientific proof' (O'Riordan *et al*., 2001), which – from a first sight – is rather difficult to combine with natural sciences. However, this exercise of combining societal concerns and research results is in accordance with the notion 'reflexive objectivity'. The difference between the 'reflexive objectivity' approach suggested by Alrøe and Kristensen (2002) and the 'precautionary science' approach of Barrett and Raffensperger (1999) is the way that values associated to science are treated (Fig. 1). The reflexive objectivity yields an important and explicit differentiation of the specific experimentation on one side and the values and goals associated to the experimentation on the other. In contrast, Barrett and Raffensperger (1999) arrive at a situation very much alike that predominating for the positivistic view of science: values and priorities are closely – and at the end in reality unreflectively – associated with the observations and experiments. This is a big mistake and in my opinion really 'dangerous' for a fruitful implementation of the concerns addressed in the precautionary principle. A new, alternative research paradigm should put explicit considerations on values in science to the activities of scientists by increasing their awareness of the cognitive context. The shift should not retain the mix (read: mess) of specific scientific observations and evaluations of sustainability (Fig. 1). It is important for me to state that the above statements do not include an attitude to the precautionary principle.

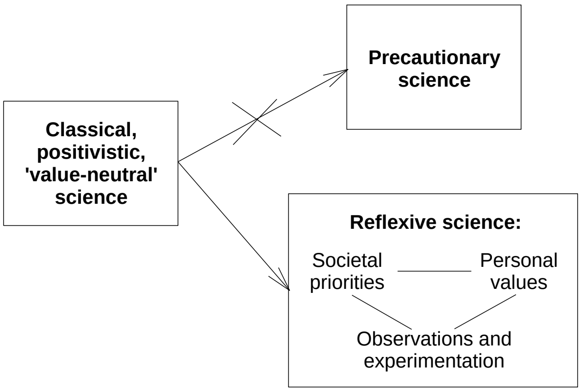


Figure 1. Science is influenced by the societal priorities and personal values of the scientist. The shift from the classical, positivistic research paradigm should take use of the explicit considerations on societal priorities and personal values offered by the reflexive objectivity approach ('reflexive science', lower box). The notion of 'precautionary science' is dissuaded because this paradigm keeps the (unreflected) mix of observations and values also found in the positivistic approach. Consult text for details.

Summary and conclusions

The term soil quality has mainly been used as a technical concept for grading soils. It is important that the values and goals in soil use planning and soil management are explicitly stated and related to the soil quality indicators. Such a cognitive soil quality concept may facilitate the urgent need of soil scientists to interact with stakeholders in the society. Useful approaches for such exercises have been proposed in the literature. A shift in research paradigm away from the classical, positivistic, 'value-neutral' approach is, however, a prerequisite for a fruitful outcome of this endeavour. The reflexive objectivity is a valuable tool in differentiating the basic scientific observations from societal priorities and personal values of the scientist. Other suggestions of associating 'post-positivistic-science' societal priorities to observations and experiments (e.g., 'precautionary' science) are strongly dissuaded. The suggested increase in focus on sustainability-based decisions on soil management induces a recommended search for 'management thresholds' rather than the more descriptive 'soil quality indicator benchmarks/thresholds'. I strongly recommend the ESSC to increase its activities on prescriptive and management-oriented research and in this endeavour make use of the proposals given above.

References

Alexander, M. (1971) Agriculture's responsibility in establishing soil quality criteria. In: *Environmental Improvement – Agriculture's Challenge in the Seventies*. National Academy of Sciences, Washington, D.C., pp. 66-71.

Allan, D.L., Adriano, D.C., Bezdicek, D.F., Cline, R.G., Coleman, D.C., Doran, J.W., Haberen, J., Harris, R.G., Juo, A.S.R., Mausbach, M.J., Peterson, G.A., Schuman, G.E., Singer, M.J. and Karlen, D.L. (1995) SSSA Statement on soil quality. In: Agronomy News, June 1995, ASA, Madison, WI, p.7.

Anonymous (ed.) (1996) *The Soil Quality Concept*. The Soil Quality Institute, Natural Resources Conservation Service, United States Department of Agriculture, 89 pp.

Alrøe, H.F. and Kristensen, E.S. (2002) Towards a systemic research methodology in agriculture. Rethinking the role of values in science. *Agriculture and Human Values* 19, 3-23.

Barrett, K. and Raffensperger, C. (1999) Precautionary science. In: Raffensperger, C. and Tickner, J.A. (Eds.) *Protecting public health & the environment. Implementing the precautionary principle*. Island Press, Washington, D.C., pp. 106-122.

Blum, W.E.H. (1998) Basic concepts: Degradation, resilience, and rehabilitation. In: Lal, R., Blum, W.E.H., Valentine, C. and Stewart, B.A. (eds.) *Methods for Assessment of Soil Degradation*. CRC Press, Boca Raton, New York, pp. 1-16.

Blum, W.E.H. and Santelises, A.A. (1994) A concept of sustainability and resilience based on soil functions: the role of ISSS in promoting sustainable land use. In: Greenland, D.J. and Szabolcs, I. (eds.) *Soil Resilience and Sustainable Land Use*. CAB International, Wallingford, UK, pp. 535-542.

Bouma, J. (2000) The land quality concept as a means to improve communication about soils. In: Elmholt, S., Stenberg, B., Grønlund, A. and Nuutinen, V. (eds.) *Soil Stresses, Quality and Care*. Proceedings from

NJF Seminar 310, 10-12 April 2000, Ås. DIAS Report, Plant Production No. 38, Danish Institute of Agricultural Sciences, Foulum, pp 1-14.

Bouma, J. (2001a) The role of soil science in the land use negotiation process. *Soil Use and Management* 17, 1-6.

Bouma, J. (2001b) The new role of soil science in a network society. *Soil Science* 166, 874-879.

Bouma, J. (2004). Implementing soil quality knowledge in land-use planning. In: Schjønning, P., Elmholt, S. and Christensen, B.T. (Eds.) *Managing Soil Quality: Challenges in Modern Agriculture*. CABI Publishing, Wallingford, UK, pp. 283-296.

Bouma, J., Finke, P.A., Hoosbeek, M.R. and Breeuwsma, A. (1998) Soil and water quality at different scales: concepts, challenges, conclusions and recommendations. *Nutrient Cycling in Agroecosystems* 50, 5-11.

Carter, M.R. (2002) Soil quality for sustainable land management: Organic matter and aggregation interactions that maintain soil functions. *Agronomy Journal* 94, 38-47.

Doran, J.W. and Jones, A.J. (eds.) (1996) *Methods for assessing soil quality*. Soil Science Society of America Special Publication Number 49.

Ellert, B.H., Clapperton, M.J. and Anderson, D.W. (1997) An ecosystem perspective of soil quality. In: Gregorich, E.G. and Carter, M.R. (eds.) *Soil Quality for Crop Production and Ecosystem Health*. Developments in Soil Science 25, Elsevier, Amsterdam, pp. 115-141.

Karlen, D.L., Andrews, S.S. and Doran, J.W. (2001) Soil quality: Current concepts and applications. *Advances in Agronomy* 74, 1-40.

Karlen, D.L., Andrews, S.S., Weinhold, B.J. and Doran, J.W. (2003) Soil quality: Humankind’s foundation for survival. *Journal of Soil and Water Conservation* 58, 171-179.

Karlen, D.L., Mausbach, M.J., Doran, J.W., Cline, R.G., Harris, R.F. and Schuman, G.E. (1997) Soil quality: A concept, definition, and framework for evaluation. *Soil Science Society of America Journal* 61, 4-10.

Larson, W.E. and Pierce, F.J. (1991) Conservation and enhancement of soil quality. In: *Evaluation for Sustainable Land Management in the Developing World.* Int. Board for Soil Res. and Management, Bangkok, Thailand, pp. 175-203.

Letey, J., Sojka, R.E., Upchurch, D.R., Cassel, D.K., Olson, K., Payne, B., Petrie, S., Price, G., Reginato, R.J., Scott, H.D., Smethurst, P. and Triplett, G. (2003) Deficiencies in the soil quality concept and its application. *Journal of Soil and Water Conservation* 58, 180-187.

Lockeretz, W. and Anderson, M.D. (1993) *Agricultural Research Alternatives*. University of Nebraska Press, Lincoln, NE, USA, 239 pp.

O’Riordan, T., Cameron, J. and Jordan, A. (eds.) (2001) *Reinterpreting the Precautionary Principle*. Cameron May Ltd., London, UK.

Pieri, C., Dumanski, J., Hamblin, A. and Young, A. (1995) *Land Quality Indicators*. World Bank Discussion Papers 315, The World Bank, Washington, D.C., USA, 63 pp.

Schjønning, P., Elmholt, S. and Christensen, B.T. (Eds.) (2004) *Managing Soil Quality: Challenges in Modern Agriculture*. CABI Publishing, Wallingford, UK, 368 pp.

Seybold, C.A., Mausbach, M.J., Karlen, D.J. and Rogers, H.H. (1998) Quantification of soil quality. In: Lal, R., Kimble, J.M., Follett, R.F. and Stewart, B.A. (eds.) *Advances in Soil Science*. CRC Press, Boca Raton, Florida, USA, pp. 387-404.

Smyth, A.J. and Dumanski, J. (1993) *FESLM: An International Framework for Evaluating Sustainable Land Management*. World Resources Reports 73. Land and Water Development Division, FAO, Rome, 77 pp.

Sojka, R.E. and Upchurch, D.R. (1999) Reservations regarding the soil quality concept. *Soil Science Society of America Journal* 63, 1039-1054.

Sojka, R.E., Upchurch, D.R. and Borlaug, N.E. (2003) Quality soil management or soil quality management: Performance versus semantics. *Advances in Agronomy* 79, 1-68.

Warkentin, B.P. and Fletcher, H.F. (1977) Soil quality for intensive agriculture. In: *Proc. Int. Sem. on Soil Environ. and Fert. Manage. in Intensive Agric*. Soc. Sci. Soil and Manure, Natl. Inst. of Agric. Sci., Tokyo, pp. 594-598.

Environmental impact of energetical cropping systems in central Italy

Ginanni, M.[1] – Bonari, E. – Risaliti, R. – Silvestri, N. – Pampana, S.

Introduction

Bioenergy production has become one of the main topics of the Italian Biofuel Programme. Alternative farming systems aimed at energy production are considered effective in satisfying both energetic and ecological needs (Mi.P.A., 1997). The short rotation forestry system represents an interesting opportunity for the agro-forestry sector, promoting an alternative and renewable energy source characterized by low environmental impact, with regards to CO_2 emissions.

Besides, SRF can give a sensible contribution to soil conservation, both reducing the removal of valuable topsoil and containing the loss of natural nutrients, applied fertilizers and soil organic matter light-weight fractions. The positive effect on soil conservation and water quality is supported by different Authors (Hoenstein & Wright, 1994 Pimentel & Krummel, 1997, Ranney & Mann, 1994), even if studies concerning the environmental impact of SRF cultivation are still lacking. In order to evaluate the ecological feasibility of bioenergetic system, SRF have been studied and compared with an ordinary crop rotation.

Materials and methods

The experimental field trial started in 1996 at Centro Interdipartimentale di Ricerche Agroambientali "E. Avanzi", University of Pisa, at a plain site representative of the central Italy environment (43° 40, N latitude, 10° 10' E longitude, 6 m a.s.l.). Soil characteristics are resumed in Table 1. Three different farming systems were compared: two SRF poplar cultivation (planted in 1996) characterized by high (SRFH) and low (SRFL) mechanical and chemical input and a two years rotation (sunflower-winter wheat) managed following the agro-techniques commonly applied by the farmers of the area (CS). Total rainfall amount and its distribution were recorded throughout the experimental period. Runoff collection was performed according to the sprinkling infiltration system, following the method proposed by Van Der Linden (1983) and Agassi (1990). The erosion plots have been enclosed by metal sheets rectangle shaped (2 m²), pushed 10 cm into the soil to ensure hydraulic isolation. Water and sediments were channelled by means of both a metal frame and a plastic tube to collecting tanks. Samples were collected after every significant rainfall event. After the total volume determination the collecting tanks were stirred, sub-samples were collected and placed into 1 l jars. The sampling campaign corresponded to the whole three years experimental period (1996-1998). In order to evaluate rainfall contribution to runoff, special collecting systems to be used as blank were arranged (Syversen N., 2002). Runoff analysis was performed soon after sampling. Total solid determination was performed by means of gravimetric method, pH determination followed the potentiometric method. N-NO3 was measured on filtered runoff samples by means of potentiometric method (Eaton et al 1995).

Table 1. Soil characteristcs in the 0-60 soil layer

Soil depth		0 – 30	30 – 60
Sand	%	30.2	28.8
Silt	%	51.9	53.1
Clay	%	17.9	18.1
Organic matter	%	1.79	1.59
pH	-	7.93	8.03

The erosion plots were periodically removed from CS plots in order to allow cultivation practices. Thus, even if forty erosive rainfall events were monitorized as a whole, proper comparisons were possible within six sub sampling period (Table2). The last sampling sub-period (P6) can be considered as the most significant one, as the SRF cultivation reached a relative steady state. Rainfall amounts recorded in each erosive events are showed in Figure 1.

Table 2. Experimental monitoring as divided in subsampling periods

Subsampling periods					
P1	P2	P3	P4	P5	P6
From Aug. 1996 To Sept. 1996	From Oct. 1996 To Jan. 1997	From Feb. 1997 To Jul. 1997	From Aug. 1997 To Sept. 1997	From Oct. 1997 To Feb. 1998	From Mar. 1996 To Sept. 1996

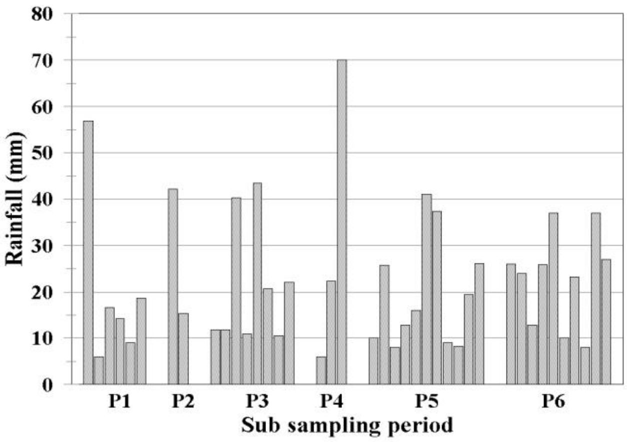
[1] Centro Interdipartimentale di Ricerche Agro ambientali "Enrico Avanzi", University of Pisa, Via Vecchai di Marina n. 6 San Piero a Grado, 56010 Pisa, Italy. Tel.: 0039-50-960063; Fax: 0039-50-960330; E-mail: ginanni@tiscali.it

Table 3. SRF main cultivation practices		
Operation	SRFH	SRFL
Main tillage	Deep ploughing	Chieseling
Poplar clone	Lux	
N Fertilization (kg ha^{-1})	48 + 100*	48 + 50*
Plant spacing	10.000 trees ha^{-1}	8.000 trees ha^{-1}
*top dressing N fertilization has been performed every two years		

SRF and CS main cultivation practices are resumed in Table 3 and Table 4. Three years from the experiment beginning soil samples were taken from each plot to a depth of 60 cm, in 30 cm steps. Organic Carbon analysis was performed by dichromate oxidation (Nelson & Sommers, 1982). Aggregate stability was determined on topsoil samples (0-5 cm depth), collected immediately before second SRF harvesting (December 1998), the analysis was performed according to wet sieving method (Pagliai et al., 1997). SRF leaf litter biomass was recorded by means of collecting plots net made, 1 m^2 wide, left at soil surface during the leaves fallen period (from August to November). Leaf biomass was determined by means of gravimetric method.

Table 4. CS main cultivation practices		
	Sunflower	Durum Wheat
Main tillage	Deep ploughing (40 cm)	Shallow ploughing (25 cm)
Fertilization N-P-K (kg ha^{-1})	24.72.72	36.92.0
Top dressing N fertilization (kg ha^{-1})	92	50 + 50
Herbicide	Pre emergence	Post emergence

Figure 1. Erosive Rainfall amount as recorded in the six sub-sampling periods



The experimental scheme was a randomized complete block design with three replicates of 700 m^2.

Statistical analysis of runoff experimental data was performed considering the six subsampling periods separately. The last sampling period (P6) was studied in details, the rainfall events being considered one by one.

Data collected were analysed by ANOVA. Treatment means were separated according to Duncan's Multiple Range Test at $P \leq 0.05$ (Gomez and Gomez, 1984).

Results and discussion

Throughout the experimental period the monitorized erosive rainfall amount was by 893 mm; the selected runoff events accounted for 30% of the total rainfall fallen during the same period (Fig. 1) The erosion cumulative results, concerning the period from July 1996 to December 1998, are showed in Table 5. The flowdown coefficient was lower under the two SRF systems with respect to CS (respectively by 3.6 and 5.4 %). Considering the two SRF crop systems average results, sognificant lower soil and nitrogen losses were recorded, by 56% and 37% of the ones recorded under CS.

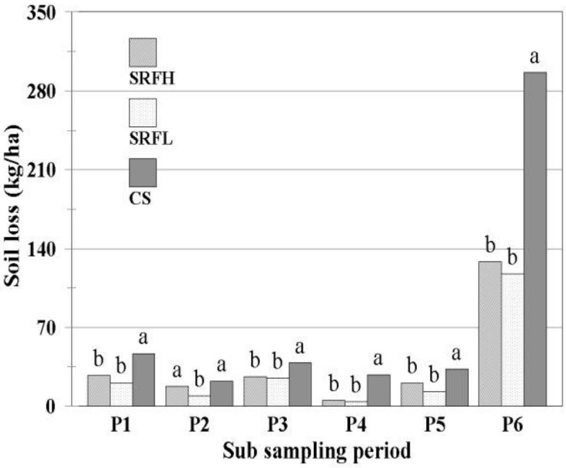


Figure 2. Soil losses via runoff as recorded throughout the six sub sampling periods (kg ha^{-1}). In the same period bars labelled with different letters are significantly different P≤0.05 (Duncan's Multiple Range Test)

Table 5. Runoff, Soil and nitrogen losses as affected by different farming systems. In the same column values followed by Different letters indicate significant differences at P≤0.05 (Duncan's Multiple Range Test)

Cropping system	Runoff (mm)	Soil loss (kg ha^{-1})	N NO_3 (kg ha^{-1})
SRFH	33 b	224 b	1.0 b
SRFL	32 b	189 b	0.9 b
CS	49 a	465 a	1.5 a

Table 6. SRF wood biomass production (t ha $^{-1}$)in the experimental period. In the same column different letters indicate significant differences at P≤0.05 (Duncan's Multiple Range Test)

SRF system	1996	1998	Total
SRFH	6.8 a	68.4 a	75.2 a
SRFL	5.6 b	53.2 b	58.5 b

The SRF performance in terms of runoff and soil loss reduction (Pimentel & Krummel 1987, Hoenstein & Wright, 1994, Ranney & Mann, 1994) was evident just after SRF planting. This may be a consequence of rapid SRF growth rate observed under the experimental conditions.

Soil loss amounts (Fig. 2) were always significantly higher under CS with respect to both the SRF crop systems. The most relevant differences were recorded in P4, P5 and P6 when CS results were by 6.3, 2 and 2,5 folds the ones recorded under the energetic crop cultivation systems. In the meantime no relevant differences were observed between SRFH and SRFL.

Similar trend was observed taking into account nitrogen losses; low fertilization rates (Tab. 3) together with a good runoff control (tab. 5) contributed to SRF effectiveness in soil protection.

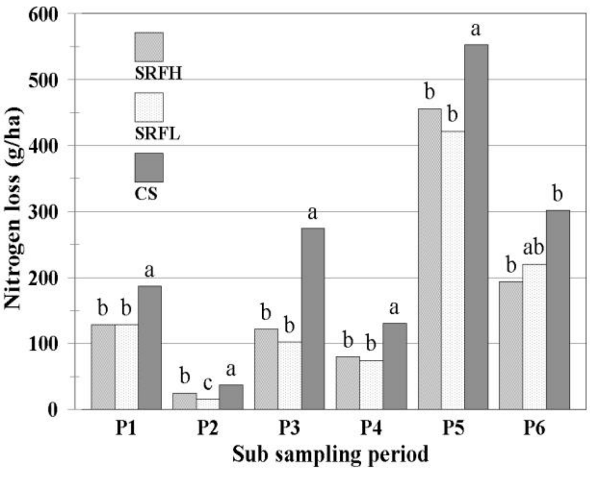


Figure 3. Nitrogen losses via runoff as recorded throughout the six sub sampling periods (g ha^{-1}). In the same period bars labelled with different letters are significantly different P≤0.05 (Duncan's Multiple Range Test)

Remarkable results were obtained in P6 sampling period, when ten erosive events were observed for a total rainfall amount of 230 mm. As a whole the most relevant soil losses were recorded under CS whereas both the SRF crop systems showed their effectiveness in containing soil erosion. Considering the CS cultivation cycle, with regards to tillage techniques and fertilizers distribution (Mazzoncini & Bonari, 1997) related risk factors in terms of soil erosion and nitrogen losses can be easily identified in Figure 3 and 4. On the contrary, the SRF environmental vulnerability is distributed along the course of the year in a quite homogeneous way.

Considering the two herbaceous crops separately, within the P6 sub sampling period, sunflower soil losses overcame the SRF average performances by 277.5 kg ha^{-1}, and wheat by 208 kg ha^{-1}.

With regards to nitrogen losses winter wheat showed the higher water contamination potential.

Soil erosion results of P6 sampling period are showed in figure 4. Under CS winter wheat and sunflower showed a different susceptibility to erosion as a consequence of their growth rate and soil cover capability. Differences in eroded soil amount were always significative from March to October. With regard to sunflower, the highest erodibility corresponded with the leaves senescence (end of summer). On the contrary, winter wheat guaranteed an effective soil cover also after harvesting, thanks to the straw presence above the soil surface.

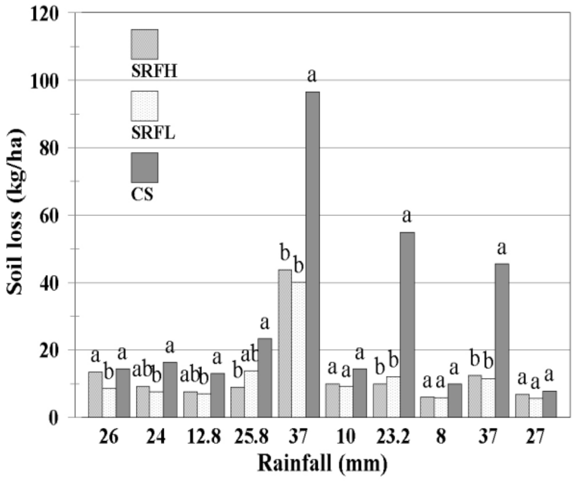


Figure 4. Soil losses via runoff as recorded throughout the P6 sampling periods (kg ha^{-1}). For the same rainfall event bars labelled with different letters are significantly different P≤0.05 (Duncan's Multiple Range Test)

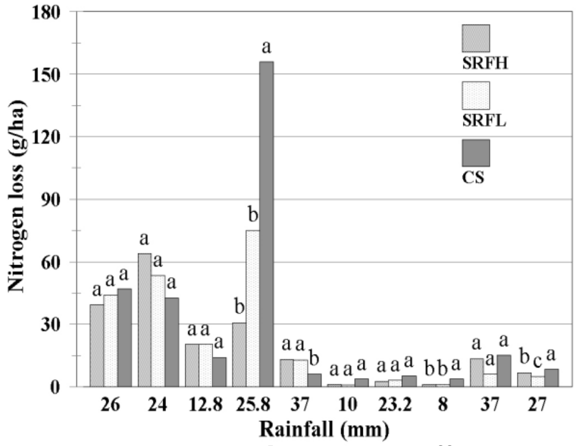


Figure 5. Nitrogen losses via runoff as throughout the P6 sampling periods (g^{-1}). For the rainfall event bars labelled with different letters are significantly different P≤0.05 (Duncan's Multiple Range Test)

Nitrogen losses data related to P6 sub sampling period are shown in figure 5. The peak time result corresponds to winter wheat top dressing fertilization, when nitrogen displacement reached the 2/3 of the total annual amount. Sunflower crop showed a lower vulnerability, thanks to hoeing associated to the top dressing nitrogen distribution.

The SRF effectiveness in containing soil erosion may be due to the elevate aggregate stability, as influenced by the organic matter content (Figure 6). This characteristic can be related to the leaves mulch decomposition (Makeschin, 1994). Furthermore SRF canopy and dead leaves mulch (Figure 7) assure an effective soil protection for a major portion of the year, thus reducing rainfall erosivity.

Conclusions

Data collected in the three years period indicate substantial environmental sustainability of SRF crop system. The SRF positive effect on soil erosion control is expected to be more significant as well as the agroforestry management will be more consolidated, and also appreciable at soil organisms scale in terms of diversity and abundance (Pinzari et al., 1998 ; Fyles and Cote, 1994 ; Ugolini & Spaltenstein, 1992). In order to confirm the economical and ecological feasibility of the bioenergetic crop, further experimentation are needed. Proper comparison including conventional crops managed following low input systems (Bonari et al, 1996) will allow to obtain more objective results, without emphasizing the SRF environmental performances.

Figure 6. Aggregate stability (AS) and soil organic matter (OM) in the 0-5 cm soil layer. Different letters in bars with the same colour indicate significant differences at P≤0.05 (Duncan's Multiple Range Test)

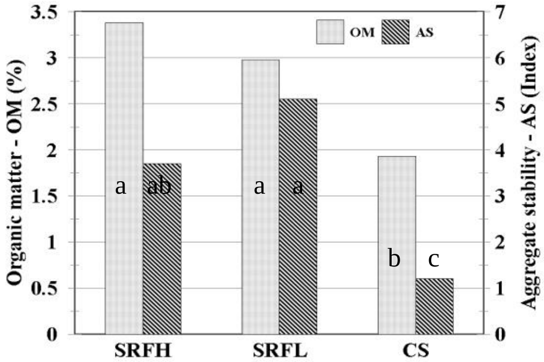


Table 7. SRF leaf biomass production (q ha^{-1}) in the experimental period. In the same row different letters indicate significant differences at P≤0.05 (Duncan's Multiple Range Test)

	SRFH	SRFL
1996	35	26
1997	117 a	91b

References

Agassi, J.E., Shainberg, I. e Morin, J. (1990). Slope aspects and phosphgypsum effects on runoff and erosion. Soil Science Society American Journal, 54, 1102 - 1106.

Bonari E., Mazzoncini M., Ginanni M,. Menini S. (1996) Influenza delle tecniche di lavorazione del terreno sull'erosione idrica dei terreni argillosi della collina Toscana. Rivista di Agronomia, 1996, 30, 3 suppl. 470 – 477.

Cogo N.P., Moldenahuer W.C., Foster G.R. , (1984). Soil loss reduction from conservation tillage practices. Soil Science Society American Journal, 48: 368-373.

Eaton A.D., Clesceri L.S.,. Greenberg A.E, (1995). Standard Methods for the examination of water and wastewater, 19th Edition. American Public Health Association, Washington, pp. 2.53-54; 4.65-69; 4.86-87.

Fyles J.W., Cote B., (1994). Forest floor and soil nutrient status under Norway spruce and red pine in a plantation in Southern Quebec. Can. J. Soil Sci. N. 74

Gomez K.A., Gomez A.A., (1984). Statistical procedures for agricultural research, ed.by Wiley and Sons, NY, pp. 680

Hohenstein, W.G. e Wright, L. (1994). Biomass energy production in the United States: an overview. Biomass and Bioenergy, 6, 161 - 173.

Knudsen D., Peterson G.A., Pratt P.F., (1982). Total carbon, organic carbon, and organic matter.

Makeschin, F. (1994). Effects of energy forestry on soils. Biomass and Bioenergy , 1994, 6, 1/2, 63 - 79.

Mazzoncini M., Bonari E. (1997). The relationship between soil tillage and herbicide dissipation. State of the art. In Effects of tillage systems on herbicide dissipation, an experimental approach at field scale. Ed. by Borin M., Sartori L., Giupponi C., Mazzoncini M., During R.A,, Basch G., Unipress Padova 1997, pp 3-24.

Mi.P.A. (Ministero Politiche Agricole) (1997). Programma Nazionale energia rinnovabile da biomasse - Bozza del 17 Dicembre 1997

Nelson D.W., Sommers L.E., (1982). Total carbon, organic carbon, and organic matter. Methods of soil analysis Part 1 Physical and Minerological Methods Second Edition Part 2 - Chemical and Microbiological Properties Second Edition ASA SSSA , Madison, Wisconsin USA. 1982.

Pagliai M., Torri D., Patruno A., (1997). Stabilità e distribuzione dimensionale degli aggregati. In Metodi di analisi fisica del suolo. Franco Angeli parte V, pp. 1-13. Pimentel, D. e Krummel, J. (1987). Biomass energy and soil erosion: assessment of resouce costa. Biomass 14, 15-38.

Pinzari F., Dell'Abate M.T., Benedetti A., Dazzi C., 1998. Effetto della lettiera sulla fertilità del suolo in aree riforestate. Atti del Convegno La qualità del suolo per un ambiente sostenibile, Delta grafica Città di Castello, pp. 257-269.

Ranney,J.W. e Mann, L.K. (1994). Environmental Considerations in Energy Crop Production. Biomass and Bioenergy, Vol. 6, N° 3: 211 - 228

Syversen N. (2002). Effect of a cold-climnate buffer zone on minimising diffuse pollution from agriculture. Water science and technology, vol.45, n.9 pp69-76.

Ugolini & Spaltenstein, 1992. Pedosphere in Global biogeochimical Cycles, Academic Press.

Van Der Linden, P. (1983). Soil erosion in Central Java (Indonesia). A comparative study of erosion rates obtained by erosion plots and catchements discharges. In Rainfall simulations, run-off and soil erosion. Ed Jan de Ploey, Catena supplement, 4, Braunschweig, 1983.

A simplified semi-distributed approach for mapping the risk of phosphorus sources connecting with surface water bodies

Freer, J.E.[1] – Quinton, J.N.

Abstract

The risk of phosphorus reaching streams and surface water bodies associated with overland flow and sediment, where it can cause pollution, is a combination of a source connecting with a sink. While this has been recognised in the literature, few models explicitly take account of the delivery of material to water bodies and how this relates to the source material. In this paper we present a new approach whereby the sources of material reaching the stream are calculated using semi-distributed functions, enabling delivery maps to be produced of high and low risk areas. We do this by characterising the individual flow pathways using a multiflow algorithm and using soil and land use information to characterise the source. Soluble phosphorus (P) is generated using a simple empirical relationship between soil P test values and soluble P; sediment associated P is mobilised by using a simple erosion model. The proportion of phosphorus is then routed through the landscape and the cumulative contributions of delivered-phosphorus from individual pixels is tracked. We demonstrate this using data from 109ha Ganspoel research catchment, Belgium.

Introduction

Erosion and sediment transport appears to be a relatively straightforward topic for modelling. Rain falls and impacts on the soil surface, soil particles are dislodged and may be transported by rain splash or overland flow. Overland flow can also detach material and transport it. This conceptualisation of erosion processes on an interrill area was used by Meyer and Wischmeier (1969) in their mathematical model of the process of soil erosion and is still found at the heart of many process-based soil erosion models. Two key processes are identified: detachment and transport. Meyer and Wischmeier modelled splash detachment as a function of rainfall intensity, an approach also adopted in ANSWERS, KINEROS2, and GUEST (Morgan and Quinton 2001). The transport capacity of the rainfall was described as a function of soil, slope and rainfall intensity. Flow detachment was modelled as a function of discharge slope and soil erodibility and the transport capacity of the flow as a function of slope, discharge and a soil factor. For splash and flow detachment the sediment detached is compared with a value for transport capacity, if the value is below the transport capacity figure the material is transported, above it is deposited. Meyer and Wischmeier (1969) recognised that their model was not comprehensive and highlighted the need for further components to be added to it.

Similar concepts are at the heart of several 'current generation' erosion models, such as EUROSEM (Morgan et al. 1998a) and WEPP (Flanagan and Nearing 1995, Laflen et al. 1997). However, unlike Meyer and Wischmeier’s model these models have attempted to define and characterize the controls on erosion processes in more detail. For example, EUROSEM contains an expression linking soil cohesion to the resistance of the soil to erosion by flowing water. Importantly such relationships are based on only a few measurements from laboratory scale experiments. As a consequence, attempts to more explicitly model erosion processes have led to large requirements for parameters (and more complex spatial model structures) which are intrinsically uncertain and difficult to measure, especially at the 'effective field scale' of the processes concerned. Thus many of the current generation of erosion models are based upon models which we cannot easily parameterise and based on processes which we find it hard to characterise.

In this brief paper we describe a modelling strategy which is a pragmatic response to the known complexities and uncertainties inherent in understanding soil erosion processes and P movement - well associated with landscape areas where surface runoff generation occurs (Heathwaite et al. 2003), this strategy can be outlined as follows:

- To develop a parameter efficient method for identifying the risk of a contaminant generated at a given point in the catchment reaching the stream or reaching a depositional (sink) area.
- To develop a parameter efficient method for identifying the risk of erosion and sedimentation and the associated transport of P.
- The simplification of processes by primarily using surface erosion by water as the source of sediment and associated P movement.

Importantly, we are trying to identify areas of erosion risk, the processes that define the mobility, transport and delivery of sediments and associated pollutants (i.e. P) to the stream channel through the use of simple topographically derived characteristics in a parsimonious and conceptually simple way. This modelling strategy, commensurate with the limits/extent of our spatial observations, is now discussed in more detail.

[1] Department of Environmental Science, Lancaster University, Lancaster, LANCS, LA1 4YQ, UK; Tel.: +44 (0)1524 593563; Fax: +44 (0)1524 593985; E-mail: j.freer@lancaster.ac.uk

A simple spatial model of runoff, erosion and P loss

Figure 1 details the spatial datasets and topographically derived characteristics that form the basis of the definition of the Erosion Response Unit (ERU). Using the multiflow algorithms of Quinn et al. (1991), an index of hydrological similarity *ln(a/tanβ)*, the topographic index (Beven and Kirkby 1979), can be calculated from the

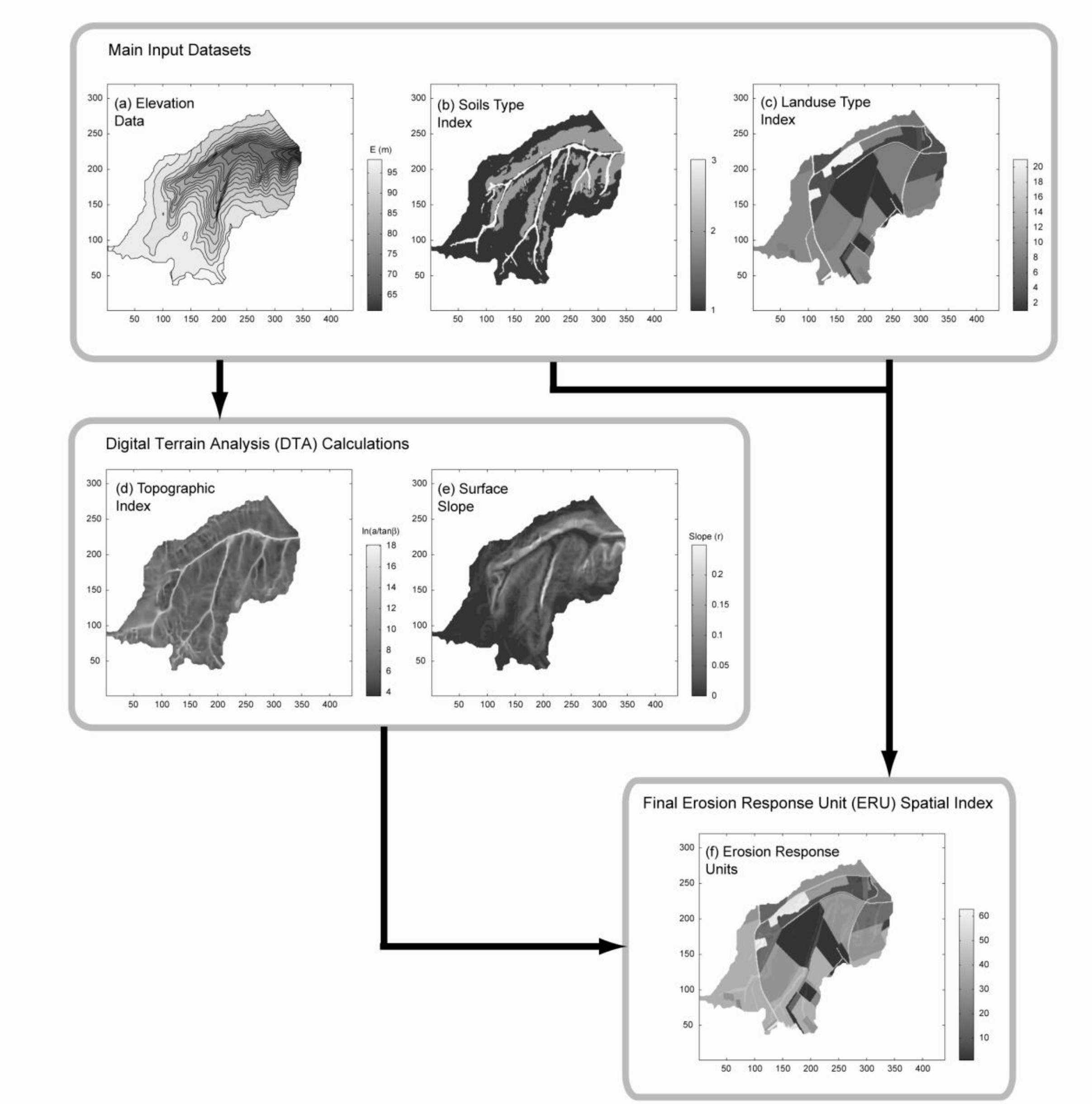


Figure 1. The spatial data sets and Digital Terrain Analysis that is used to calculate and define the final Erosion Response Units. Data from the Ganspoel catchment, was provided by KU Leuven as part of the GTCE erosion model comparison. More details can be found at http://www.geog.uu.nl/lisem/research/intro.html.

elevation data, for which a is the area per unit contour length and $tan\beta$ is the local slope angle. The index identifies areas with greater upslope contributing area, a, and lower gradients, β, as being more likely to saturate during storm events than areas with lower a and higher β. The topographic index is combined with the other spatial coverages (slope, soil type and landuse) to define locally accounted storages, fluxes and ERU characteristics (Figure 2) which are uniquely identified in space (Figure 1f). Using a new suite of DTA programs (see Beven and Freer 2001) downslope flux linkages between ERU are maintained, hence flow/erosion/P transport (using flowpaths derived from the surface topography) are dynamically calculated at each timestep, enabling the sources, sinks and delivery ratios (i.e. material reaching the catchment outlet vs material generated

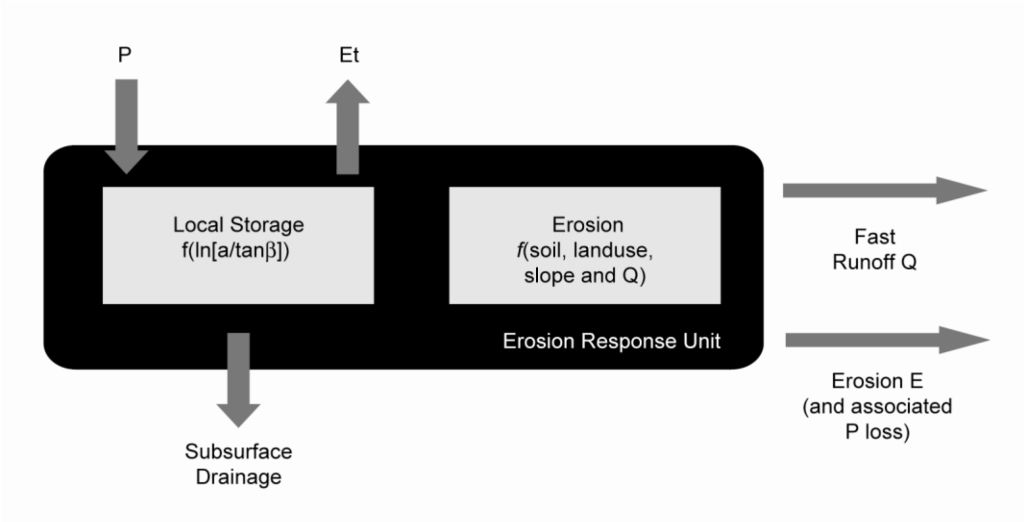


Figure 2. A simple Erosion Response Unit (ERU)

in the catchment) of simulated variables to be mapped back into space. Erosion is controlled by the characteristics of the slope, soil type and landuse coverages using a simple equation taking the form:

$$E = K \times S^{1.5} \times Q \times C^{-0.025} \qquad (1)$$

Where E is the Erosion (g/m2), K is the source erodibility (g/mm), S is the slope energy (radians), Q is the calculated surface discharge (mm) and C is the landuse modifier (fraction). The source erodibility (K) and the landuse modifier (C) are calculated from the soil and landuse coverage units respectfully using standard values adapted from EUROSEM manual (Morgan et al. 1998b).

An example application – Ganspoel Catchment

To demonstrate the spatial dynamics of the ERU model structure the model was applied to the 109ha Ganspoel catchment in Belgium using input/output data from May 1997-98 (3 storm events). Figure 3 shows, for a selected timestep, the spatial simulations of discharge (Figure 3a) and erosion (Figure 3b). Spatial discharg

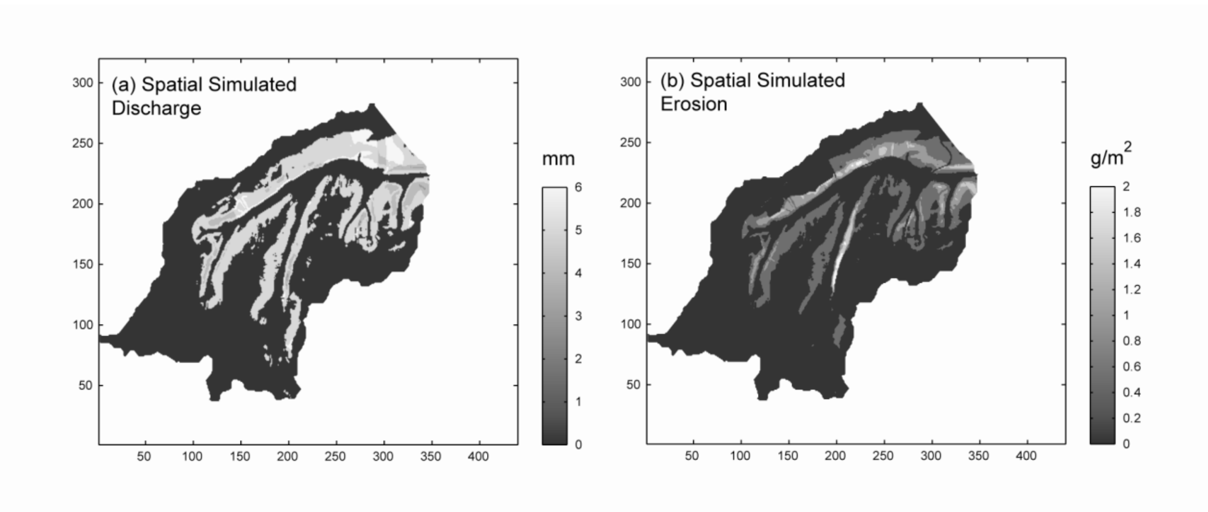


Figure 3. Simulated spatial discharge and erosion for a single timestep during a sample small storm event at Ganspoel catchment, shown for each of the 64 indexed ERU from Figure 1.

is correlated to the *ln(a/tanβ)* and the soils coverage (see Figure 1), both which control the dynamics of the local storage units. However simulated spatial erosion, although clearly related to discharge, is further controlled by the local surface slope and to a lesser extent the landuse type. These results would be expected given the relationships shown in equation 1. Similar spatial variability can also be demonstrated for P losses (data not shown).

Conclusions

We have shown how a simple model of locally accounted storages, expressed through use of a topographically derived index and a simple erosion model, expressed from slope, soil and landuse characteristics, can be used to simulate discharge and erosion/ P loss spatially. These results demonstrate the beginnings of a method which can identify the risk of source areas connecting with streams for the simulated variables. The objectives of this modelling exercise is to develop a spatially connected model structure that is both parsimonious, that has a structural complexity this is commensurate with our understanding of erosion/P loss processes at the catchment scale and requires limited input data.

Acknowledgements

This research has been partly funded from the DESPRAL project (EVK1-CT-199-00007), thanks are given to Victor Jetten the Laboratory for Experimental Geomorphology in Leuven, Olivier Cerdan, and GTCE.

References

Beven, K. J., and J. Freer. 2001. A dynamic TOPMODEL. Hydrological Processes **15**:1993-2011.

Beven, K. J., and M. J. Kirkby. 1979. A physically based, variable contributing area model of basin hydrology. Hydrological Sciences Bulletin-Bulletin Des Sciences Hydrologiques **24**:43-69.

Flanagan, D. C., and M. A. Nearing. 1995. USDA-Water Erosion Prediction project: Hillslope profile and watershed model documentation. NSERL 10, USDA-ARS National Soil Erosion Research Laboratory, West Lafayette, USA.

Heathwaite, A. L., A. N. Sharpley, and M. Bechmann. 2003. The conceptual basis for a decision support framework to assess the risk of phosphorus loss at the field scale across Europe. Journal of Plant Nutr. Soil Science **166**:447-458.

Laflen, J. M., W. J. Elliot, D. C. Flanagan, C. R. Meyer, and M. A. Nearing. 1997. WEPP-Predicting water erosion using a process-based model. Journal of Soil and Water Conservation **52**:96-102.

Meyer, L. D., and W. H. Wischmeier. 1969. Mathematical simulation of the process of soil erosion by water. Transactions of the ASAE **12**:754-758.

Morgan, R. P., and J. N. Quinton. 2001. Erosion modeling. Pages 117-144 *in* W. W. Doe III, editor. Landscape erosion and evolution modeling. Kluwer Academic, New York.

Morgan, R. P., J. N. Quinton, R. E. Smith, G. Govers, J. W. A. Poesen, K. Auerswald, G. Chisci, D. Torri, and M. E. Styczen. 1998a. The European soil erosion model (EUROSEM) : a process-based approach for predicting sediment transport from fields and small catchments. Earth Surface Processes and Landforms **23**:527-544.

Morgan, R. P. C., J. N. Quinton, R. E. Smith, G. Govers, J. W. A. Poesen, K. Auerswald, G. Chisci, D. Torri, M. E. Styczen, and A. J. V. Folly. 1998b. The European soil erosion model (EUROSEM): documentation and user guide. Silsoe College, Cranfield University, Silsoe, Bedford MK45 4DT.

Quinn, P., K. Beven, P. Chevallier, and O. Planchon. 1991. The Prediction of Hillslope Flow Paths for Distributed Hydrological Modelling Using Digital Terrain Models. Hydrological Processes **5**:59-79.

The crop productivity-erosion relationship

Bakker, M.M.[1] – Govers,G.[2] – Rounsevell, M.A.[1]

Introduction

Understanding the response of crop yields to soil erosion is of vital importance in assessing the vulnerability of agriculture to erosion. Correct understanding of the effect of erosion on crop productivity is not only important for soil conservation *per se*: decisions about land use by individual farmers are to some extent determined by the extent to which productivity is affected by erosion. Also the shape of the relationship between crop yield and erosion is important. Crop yield reduction due to erosion may be constant or either increase or decrease with increasing soil loss. The shape of the yield reduction function, therefore, has important economic and management implications: in the case of a convex relationship (i.e. increasing productivity loss with increasing soil loss) priority should be given to protecting eroded soils from further degradation as further erosion on these sites will lead to increasing productivity losses. In the case of a concave relationship, protecting already eroded soils is a less economically viable option, as further erosion will only lead to a relatively minor reduction in crop yield. In this case, preventing erosion of non-degraded topsoil may best preserve the overall production potential.

Over the last 50 years, a significant amount of research has been carried out to study the relationship between erosion and crop productivity. The conclusions of this research appear to be inconsistent. Some studies report a strong response of crop productivity to erosion, others a much weaker effect, if any. The shape of the response curve also appears to be quite variable. In some cases the reported erosion-productivity relationship is convex, sometimes it is linear, yet in other cases it is concave.

In this paper a review is made of research that has been carried out on the erosion-productivity relationship in the context of intensive, mechanized agriculture. The major aim of the paper is to investigate whether general patterns emerge when the numerous experimental results reported in the literature are combined and compared, that can help to explain the variability between studies and provide further insight into the erosion-productivity relationship. The paper tests the hypothesis that the lack of consistency in reported magnitudes of the effects of various studies can be attributed to the experimental method used, and that the inconsistent shapes of the response curves reported can be attributed to the regressor, i.e. the dominant process causing the productivity-reduction.

Methods and Results

The main regressors reported in the literature that are thought to be responsible for yield reductions are (a) root growth hindrance by a clayey subsoil or by a pan or bedrock, (b) water deficit, and (c) nutrient deficit. The methods reported in the literature that were used to asses the impact of erosion on productivity are (a) artificial desurfacing, (b) adding topsoil, (c) comparing yields along a transect, and (d) comparing plots that differ in nothing but erosion degree.

Fig. 1 presents the data that were found in the literature and which could be quantified, i.e. where both the depth of soil loss as well as the yield reduction were given by the authors.

In order to test differences between the methods, the data sets were merged by method. A pair-wise test for parallelism was performed for the four groups of datasets, to see if the slopes of the regression lines through the data sets differed significantly. For testing the difference between regressors, the same method was used on data sets that were created by merging data sets per regressor and per method.

Comparative plot experiments show average reductions of 4.3% per 10 cm of soil loss; transect experiments show reductions of 10.9% per 10 cm soil lost, and desurfacing experiments show reductions of 26.6% per 10 cm soil lost. The differences in yield reduction between the comparative-plot method, the transect method and the desurfacing method are statistically significant.

[1] Département de Géographie, Université Catholique de Louvain, Place Pasteur 3, B-1348 Louvain-la-Neuve, Belgium. E-mail: bakker@geog.ucl.ac.be
[2] Physical and Regional Geography Research Group, Katholieke Universiteit Leuven, Redingenstraat 16, B-3000 Leuven, Belgium

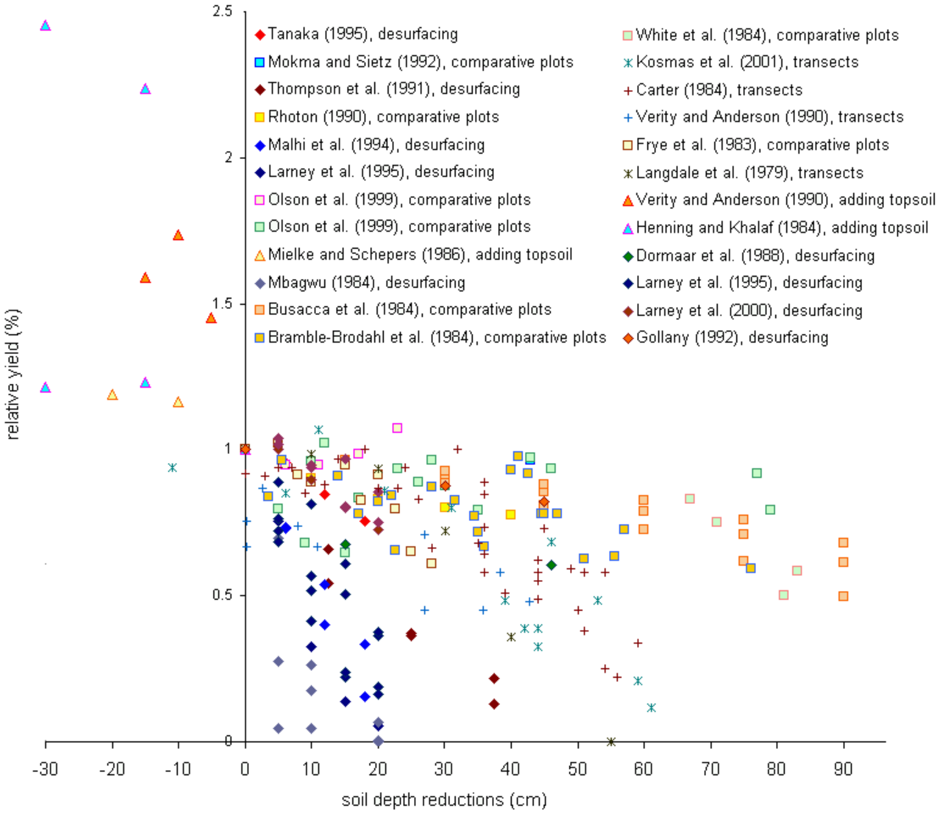


Figure 1. All data that could be quantified in terms of soil depth reductions and relative yield are plotted. Desurfacing experiments are depicted as diamonds, topsoil addition experiments as triangles, transect experiments as crosses and comparative-plot experiments as squares.

Several arguments can be given to support the assumption that *comparative plot* experiments most closely simulate the effects of erosion on productivity under normal agricultural circumstances, and that desurfacing (and to a lesser extent transect studies) lead to a systematic overestimation of the effect of soil erosion on crop productivity. When erosion occurs gradually, a limited amount of subsoil (equivalent to the erosion rate) is mixed with topsoil each year. This causes dilution of the topsoil constituents that are beneficial to crop production such as nutrients and organic matter. Consequently, if erosion occurs again the following year at the same intensity, a smaller absolute amount (same relative amount) of these constituents is removed by erosion. Furthermore, if some of the organic matter in the topsoil is removed by erosion a disequilibrium between organic matter production and mineralisation is created, leading to a net production of soil organic matter, thereby partially compensating for the erosion losses. These processes do not occur in desurfacing experiments, which would cause an overestimate of the impact of erosion on crop productivity.

The transect method also yields a stronger reduction in crop yield with soil depth reductions than the comparative plot method. The main weakness of this approach is that landscape position determines not only erosion, but also the availability of other resources for plant growth. For example, landscape positions where erosion is likely to occur (steep slopes, convexities) often have reduced water availability due to lateral water movement (Stone et al., 1985; Olson et al., 1994; Schumacher et al., 1994). Because of these co-variations between erosion and landscape position, many transect studies describing the effect of soil erosion on crop productivity may not be able to distinguish the effect of landscape position from that of erosion (Stone et al., 1985). Comparison of transect studies with comparative plot studies suggests that the confounding effect is often quite significant, leading to considerable overestimation of the effect of erosion on crop productivity.

With respect to the shape of the yield response curves found by the various researchers, these can be subdivided into four groups: (1) linear relationships; (2) convex relationships, where yield reductions increase with incremental topsoil removal; (3) concave relationships, where yield reductions decrease with incremental topsoil removal; (4) S-shaped curves.

Table 1 shows a relationship between the regressor and the shape of the curve. It can clearly be seen that for experiments where yield reductions were caused by water deficits the response curves are convex, whereas for experiments where the regressor was a nutrient deficit the response curves are linear or concave. Where physical root hindrance or clayey subsoils were the regressor there is a slight dominance of convex curves.

The concave response of crop yield reductions to topsoil removal when nutrient deficit is the regressor, can be explained as follows. Nutrients that originate from organic matter are often situated at or near the surface and decrease in a non-linear way with soil depth. With topsoil removal the highest reductions in nutrient availability occur with removal of the first few centimetres of topsoil and, therefore, yield reductions will also be highest with these initial soil removals. This regressor becomes decreasingly limiting with soil depth, resulting in a concave response curve.

In case of a water deficit, the convex response could be due to the existence of thresholds: both loss of storage capacity and water-holding capacity become critical after a certain threshold has been exceeded. Furthermore, plant responses to water availability involve a threshold: yield reductions due to limited water availability generally become apparent when the ratio of actual versus potential evapo-transpiration falls below 0.75 (Doorenbos and Pruitt, 1977). Also root growth response to increases in bulk density shows non-linear behaviour (Neill, 1979). The combination of these thresholds result in a semi-convex response, although theoretically the curve consists of line segments that become increasingly steeper as each threshold is surpassed.

Table 1. The number of publications reporting shapes of response curves and regressors that caused the response.

	Convex	Linear	Concave	S-shaped
Water Availability	8	-	-	-
Clayey B	7	1		1
Physical hindrance (bedrock or pan)	4	2	1	-
Nutrients	1	2	7	1
Various regressors	-	1	-	-

When root growth is impeded by the presence of a pan or bedrock, reductions in crop yields will start as soon as roots encounter the restrictive layer, and will be strongest when the highest density of roots meets this layer. The response curve can be seen, therefore, as a result of the root morphology of a crop. For most crops root density increases towards the surface (Pierce et al., 1983), which will thus result in a convex response curve. For soils having subsoils with high clay contents, erosion will often result in a combination of limiting factors causing yield reductions. The increase in clays content may lead to physical hindrance for root penetration, resulting in a convex response curve (see above). Furthermore, an increase in clay content also affects nutrient and water availability. Therefore, the presence of a clayey subsoil may lead to more complex response curves. However, since both water availability and physical hindrance result in convex curves, this shape dominates the response curves of clayey soils.

Synthesis and Conclusions

The high variability in magnitudes of crop yield reductions resulting from soil depth changes published in the past decades can largely be attributed to the different research methodologies applied. Yield reductions following desurfacing were on average six times higher than those derived from comparative plot experiments. The transect approach also produced results that were significantly higher than the comparative plot results. It is hypothesized that the comparative plot experiments result in the most reliable estimations of crop yield response to soil erosion. Conversely, desurfacing and, to a lesser extent, transect experiments lead to a significant overestimation of the effect of erosion on crop yield in intensive, mechanized agriculture.

Different response curve shapes can be related to a specific regressor: nutrient deficit leads to linear or concave response curves, water deficit leads to convex response curves, root growth hindrance caused by restricting subsoil also leads to convex response curves. This can be explained by the behaviour of the regressor in the soil profile in combination with the crop response to the regressor: nutrients decrease non-linearly with soil depth and become, therefore, decreasingly limiting with soil removal; water availability decreases more or less linearly with soil depth, but crop growth reduces increasingly with water availability reductions; root restrictions become increasingly limiting as more roots encounter the restricting layer, and since root density generally increases towards the surface, the impact increases with shallower (top)soils.

The results presented in this paper suggest that the development of a general theory about crop yield response to soil erosion is possible. Where erosion occurs gradually and where soil management avoids severe nutrient shortages, the remaining regressors are physical hindrance and water deficit. The shape of the response curve of crop growth to topsoil reductions is generally convex. Yield reductions caused by these regressors are around 4% per 10cm of soil lost. This means that areas suffering from moderate erosion rates (around 10 ton/ha/year) will lose on average 0.4% yield per decade, but for areas suffering from more severe erosion this can easily become ten-fold greater. In general, the reduction in crop yield will become more severe with progressing erosion as root growth becomes increasingly more difficult.

Thus, with respect to land management, attention should be paid to soils with growth-restricting clayey subsoils, pans or bedrock. Even though erosion may not have resulted in severe productivity losses so far, future erosion will show increasingly severe losses with equal erosion rates. As the response of crop yield to erosion is generally convex, specific attention should be paid to soils that have already suffered from erosion, but which are at this stage still productive.

References

Bakker, M.M., Govers, G., Rounsevell, M.A, in press. The crop productivity-erosion relationship: an analysis based on experimental work. Catena.

Doorenbos, J. and Pruitt, W.O., 1977. Crop water requirements, Irrigation and drainage paper. 24, FAO, Rome, Italy.

Neill, L.L., 1979. An evaluation of soil productivity based on root growth and water depletion. M.S. Thesis, Univ. Mo., Columbia.

Olson, K.R., Lal, R. and Norton, L.D., 1994. Evaluation of methods to study soil erosion-productivity relationships. Journal of Soil and Water Conservation, 49(6): 586-590.

Pierce, F.J., Larson, W.E., Dowdy, R.H. and Graham, W., 1983. Productivity of soils: assessing long-term changes due to erosion. Journal of Soil and Water Conservation, 38: 39-44.

Schumacher, T.E., Lindstrom, M.J., Mokma, D.L. and Nelson, W.W., 1994. Corn yield: erosion relationships of representative loess and till soils in the North-Central United States. Journal of Soil and Water Conservation, 49(1): 77-81.

Stone, J.R., Gilliam, J.W., Cassel, D.K., Daniels, R.B., Nelson, L.A. and Kleiss, H.J., 1985. Effect of erosion and landscape position on the productivity of Piedmont soils. Soil Sci. Soc. Am. J., 49: 987-991.

Young, D.L., Taylor, D.B. and Papendick, R.I., 1984. Separating erosion and technology impacts on winter wheat yields in the Palouse: a statistical approach, Erosion and soil productivity. American society of Agricultural engineers, New Orleans, Louisiana.

Properties and sustainable management of cambic arenosols

Szafranek, A.[1] – Skłodowski, P.

Introduction

Land use and land planning are of increasing concern becouse of limited soil resources and their many possible uses. A soil's suitability for particular use often depends on characteristics of its properties. About 29 % of Polish soils is composed of Cambic Arenosols (ARb). In some regions the number is much higher. Cambic Arenosols are infertile, acid with limited water-holding capacity and permanently dry . In many regions Cambic Arenosols are abandoned for crop production.

Since many years we are involved in study which are referring to determine the characteristic and changes taken place in soils with respect to sustainable management.

The main objective of the study was to evaluate physical, chemical and agricultural usefulness of Cambic Arenosols which ocuur within Wysokomazowiecka Upland developed from sand with respect to sustainable agricultural development.

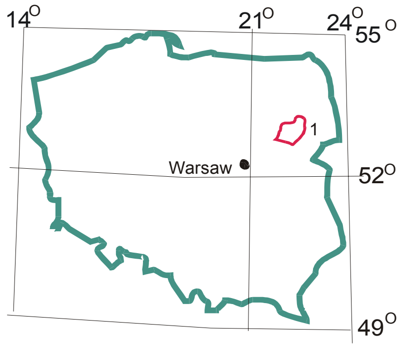


Figure 1. Layout of investigated mezoregion - Wysokomazowiecka Upland

Materials and methods

Two representative complexes of agricultural usefulness of soil were studied – Weak rye complex (complex 6) and Rye – lupinus complex (complex 7).

Soil samples were taken from Ap, Bv, BvC and C horizons. Upper horizons are represented by composit samples taken from many fields representing the same soil unit. The soil material was air dried and passed through a 1 mm sieve. In all samples granulometric composition, pH, Al*exch*, exchangeable acidity, hydrolytic acidity, exchangeable cations – Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} , organic carbon content were determined.The amount of plant available macronutrients were determined as well. Soil pH was determined using a 1:.2.5 soil - water ratio and a 1 : 2.5 1M KCl ratio. Organic carbon was determined by the Tiurin method; exchangeable aluminium were determined by Sokołow method; hydrolytic acidity by Kappen method; Ca^{2+}, Mg^{2+}, $K^{+}$and Na^{+} were extracted with 1M ammonium acetate and determined by AAS , plant available macronutrients - P and K were determined by Egner – Riehm method, Mg - by Schachtschabel metchod . Each soil unit is represented by minimum 4 soil profiles. Selected properties of soils studied are given on figures 2 -16.

Selected properties of Cambic Arenosols (average values)

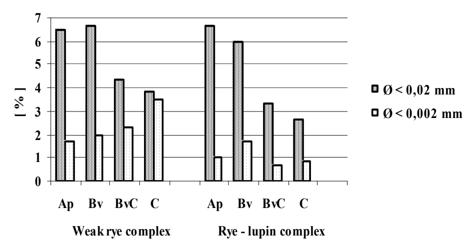


Figure 2. Granulometric composition

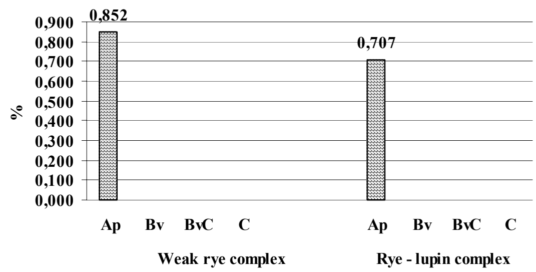


Figure 3.Organic carbon content

[1] Department of Soil Science and Soil Conservation, Warsaw University of Technology, Plac Politechniki 100 - 661 Warszawa, Poland; Tel.: 0048 22 6257142, Fax: 0048 22 6251527, E-mail: a.szafranek@gik.pw.edu.pl

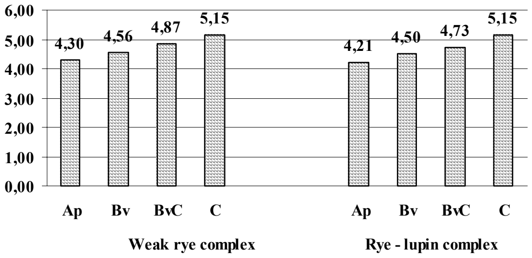


Figure 4. pH (in 1 mol KCl)

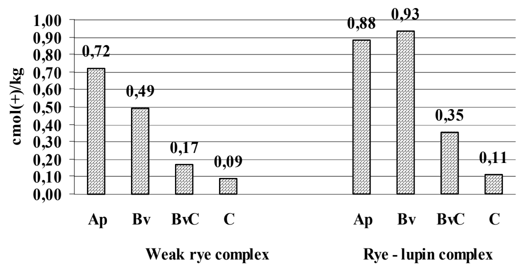


Figure 5. Exchangeable acidity

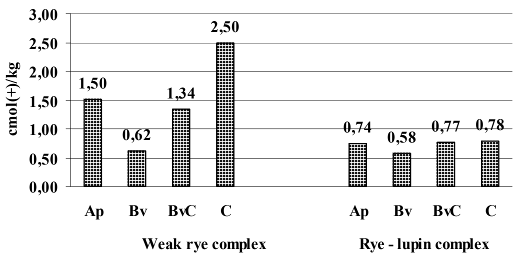


Figure 6. Exchangeable bases – Ca^{++}

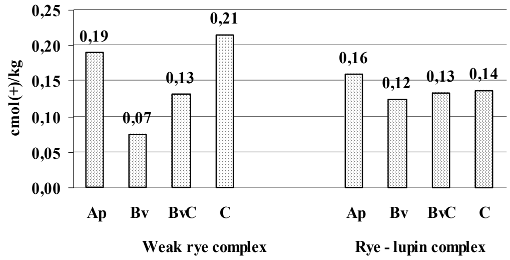


Figure 7. Exchangeable bases - Mg^{++}

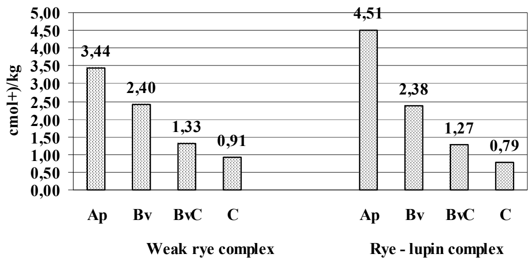


Figure 8. Hydrolytic acidity.

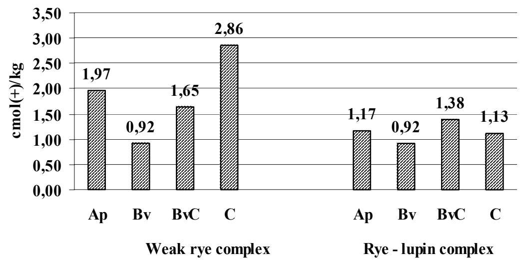


Figure 9. Sum of bases

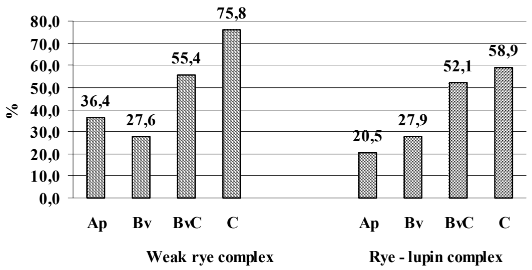


Figure 10. Saturation of bases

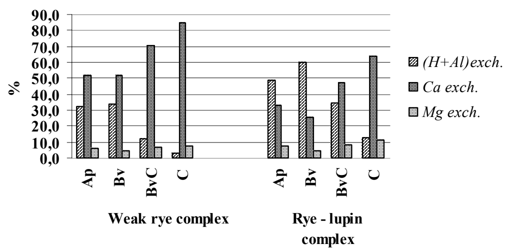


Figure 11. Share of cations in CEC

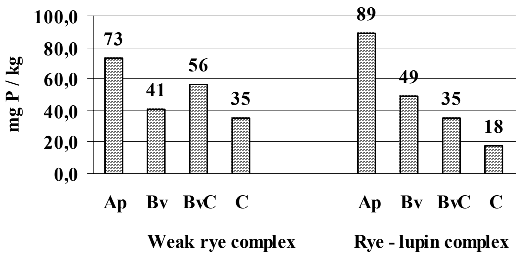


Figure 12. Plant available phosphorus

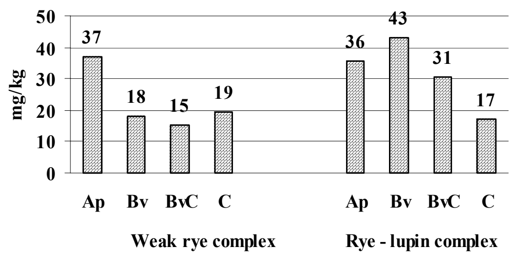


Figure 13. Plant available potassium

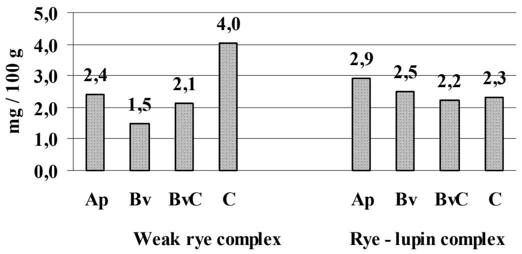


Figure 14. Plant available magnesium – Mg

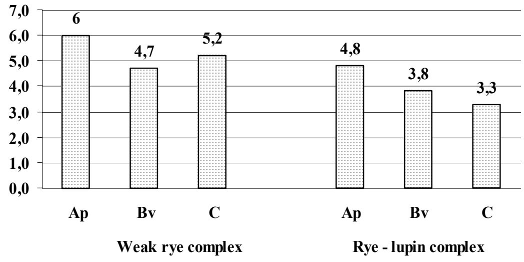


Figure 15. Plant available water (in w.w %)

Discussion and conclusions

Soil agroecological utility complexes for agricultural purposes represents an index, which combine factors of soils like – parent material, texture, lay – out in the relief, water conditions – like water holding capacity or water table. Cambic Arenosols belongs mainly to Weak rye complex (6) and Lupin – rye complex (7). Soils representing weak rye complex are developed from sand with low content of clay and are periodically dry, whereas lupin-rye soils are permanently dry with very deep water table.

The amount of plant available water in investigated soils, decreased together with the decrease of their agricultural usefulness. Bv horizons contained more plant available water, comparing to Ap horizon. It is connected with granulometric composition. The field water capacity of Cambic Arenosols had its highest values in Ap horizons and it was decreasing with the depth.

Obtained results prove, that increase of acidity results in a series of significant changes of sorption properties of soils, namely:

- increase of exchangeable acidity and, first of all increase of the content of exchangeable aluminum in the sorption complex;
- decrease of the content of calcium and magnesium, especially plant available magnesium;
- increase of the content of exchangeable potassium in the sorption complex, in relation to calcium and exchangeable magnesium .

Cambic Arenosols formed from sand containing 3 - 4 % of clay were characterised by the higher sorption of phosphorus, comparing to similar soils formed from loose sand, with very low content of clay. This sorption increased with increase of the content of iron and aluminium in soil.

The quality and agricultural usefulness of Cambic Arenosols, used for agricultural purposes have been lowered within 20 years by : the increase of acidity, decrease of the organic matter content and decrease of plant available magnesium.

Taking into consideration objectives and tasks of sustainable agriculture and sustainable land management, we are coming to conclusions, that the present agrochemical evaluation of soils should be developed by cation sorption capacity in representative units of soils, with consideration of arable-humus and sub-humus horizons.

Cambic Arenosols classified to the 7th (the weakest) rye-lupin complex were characterised by the lowers quality and agricultural usefulness. These soils should be gradually excluded from production and their functions should be changed for other purposes (forests, etc.).

In regards to the needs of sustainable management of soil resources, results of soils evaluation should be presented on a digital soils-agricultural map at the scale of 1:25000. This system enables the creation of any thematic map, which presents phenomena in time and space.

References

Szafranek A., Skłodowski P.1998: Influence of agricultural utilization on physico-chemical properties of rusty soils. Advances on Agricultural Sciences Problem Issues, Issue 460, 303-314.

Szafranek A., Skłodowski P.1998: Possibilities of introduction sustainable agriculture on rusty soils. Advances on Agricultural Sciences Problem Issues, Issue 460, 99 – 111.

Szafranek A.,Bielska A.2003: Influence of acidification on sorptive properties of soils. Advances od Agricultural Sciences Problem Isues, Issue 493, part III, 701-708.

Szafranek A.,Bielska A.Połcik A.2003: Examination of physical and chemical properties of soils by using MapInfo System.26th Congress of the Polish Society of Soil Sciences. SOIL IN THE ENVIRONMENT. Abstracts

The influence of sapropel on the changes of Haplic Luvisols properties and on the productivity of crop rotation

Bakšienė, E.[1]

Abstract

The possibilities to use sapropel for fertilization have been investigated in the Vokė Branch of Lithuanian Institute of Agriculture since 1984. The experiments were carried out on sandy loamy *haplic luvisols*. In the crop rotation with the application of 50, 100, 150, 200 tha^{-1} rates of dry calcareous sapropel.

Summarized results of a long-term experiment showed that by the end of a second and third rotations the influence of sapropel on agrochemical properties of *haplic luvisols* was positive. The usage of calcareous sapropel for fertilization on sandy loamy *haplic luvisols* has shown that sapropel reduced the acidity of sandy loamy soil, increased the amount of absorbed bases, humus, total nitrogen, and mobile phosphorus. The amount of available potassium has decreased.

The results of investigations have shown that the highest rates (150, 200 tha^{-1}) of dry sapropel after 18 years of application increased the productivity of crop rotation. The highest rate of sapropel used (200 tha^{-1}) was almost of the same effectiveness as manure.

Key words: sapropel, soil, conditions, yield.

Introduction

Lithuania is the land of lakes. Their number (of those above 1 ha in area) is as high as 2830. Many lakes are silty, they are decaying and turning into marsh.

As lakes are silting the concentration of phytoplankton increases. Such lakes are suitable neither for recreation nor for pisciculture; they can even become the source of infection diseases. There is plenty of means to reduce lake silting (Kavaliauskiene 2000). However, dealing with the already silted lakes most attention is given to mechanical cleaning – removal of lake sapropel (from the Greek language: sapro – decay, pelos – silt). If they are properly used come costs involved in the cleaning could return. Application of lakes sapropels as fertilisers looks most appropriate. Besides, the highest numbers of silted lake are in the zone with unfertile, fine textured soils where requirement for fertilisation is the highest. In sapropel the amount of bacteria decomposing cellulose is not high; therefore, the functioning of lake sapropel is more prolonged than of other organic fertilisers. It is of utmost importance in cultivated soils.

The lakes sapropel contain 15-90 % of organic matter. Their chemical composition contains all macroelements and line microelements necessary for plants, biologically active substances - vitamins, enzymes, antibiotics (Troels-Smith 1955). Besides in Lithuania the region of the main lake sapropel resources is also the region of poor and erosive soil. So we have organic sapropel there, where need it for soil first of all. The sapropel extracted from lakes can be used for land amelioration. Its mineralization is slow, so it improves the properties of light textured soils for a long time (Encke & Körschens 1988; Gruner & Belau 1990; Liepins 1993; Orlov & Sadovnikova 1996).

All lakes sapropels are subdivided into organic (50-90 % of organic mater), calcareous (30-60 % of calcium carbonate), siliceous (25-45 % of silicon dioxide) and mixed. All kinds of sapropels are used to fertilize infertile soils.

The experiments with the purpose to study the possibilities to use sapropel for fertilization have been carried out in the Vokė Branch of Lithuanian Institute of Agriculture since 1984.

Materials and Methods

The experiments were carried out on sandy loamy *haplic luvisols* (pH – 6.1, P_2O_5 - 230-262, and K_2O - 159-194 $mgkg^{-1}$ soil, humus - 1.81-1.92 %). Maize (*Zea mays L.*), barley (*Hordeum L.*) with undersowing, clover (*Trifolium pratensse L.*), winter rye (*Secale cereale*), potatoes (*Solanum tuberosum* L.), and oats (*Avena sativa L.*) were studied in the rotation with the application of 50, 100, 150, 200 tha^{-1} rates of dry calcareous sapropel (S) from Lake Ilgutis (Vilnius district), which contained N - 1.20, P – 0.041, K - 0.005, Mg - 7.89, $CaCO_3$ - 33.0, organic matter - 30.0 % of the dry matter.

Manure (100 tha^{-1}) (M) was used in order to compare its effect with sapropel. Both were applied to the first crop (maize) in the rotation.

[1] Vokė Branch of the Lithuanian Institute of Agriculture; Žalioji a. 2, Trakų Vokė, LT-02232 Vilnius; Fax.: +370 5 2645 430; E- mail: eugenija.baksiene@voke.lzi.lt

The end of the first and second crop rotations renewed treatment with 100 tha^{-1} manure. Within the rotation further effect of sapropel was observed. Mineral fertilizers ($N_{30\text{-}60\text{-}90\text{-}120}P_{60}K_{60\text{-}90}$) were strewed in soil before sowing each plant of the rotation.

Agrochemical properties of soil were evaluated before the experiments (in 1984-1985) and after the end of first (in 1989-1990), second (in 1995-1996) and third (in 2001-2002) crop rotation from seven treatments and four replications.

All fertilizers, except for the mineral fertilizers, were applied at the beginning of the rotation, before sowing. During the following years the further effect was observed. All rates of sapropel were calculated for dry mass. Minimum rates of mineral fertilizers ($N_{30\text{-}60}P_{30\text{-}40}K_{50\text{-}60}$) were applied annually before sowing.

Data of soil properties and yield were treated according to computer programme ANOVA. Data was evaluated according to Fisher criteria (F) and LSD_{05}.

Results and discussion

The experiments revealed that the use of calcareous sapropel for fertilization has a positive influence on agrochemical properties of sandy loamy *haplic luvisols*.

Fertilizing with various rates of sapropel decreased acidity of soil (fig. 1), pH increased by 1.0 – 1.3. With the increasing rates of sapropel the total amount of absorbed bases increased proportionally by 159 - 380 m-equivkg^{-1} soil. Application of fertilizers increased the content of total nitrogen by 0.003 – 0.036 % units, humus – by 0.56 – 1.19 % units and available phosphorus by 44 - 90 mg kg^{-1} of soil. While the amount of available potassium decreased by 7 - 43 mgkg^{-1} of soil, because there is little amount of it in the sapropel.

By the end of the second crop rotation the influence of sapropel to agrochemical characteristics of sandy loamy *haplic luvisols* remained positive. In comparison with the first crop rotation, the soil acidity did not decrease, pH was 7.2-7.4. At that time the control pH was 6.3. The changes of total amount of absorbed bases also remained increased (in treatments with sapropel - 101-258, and in treatment with manure 34 m-equivkg^{-1} of soil), humus - respectively: 0.15 – 0.30, and 0.40 % and amount of mobile phosphorus was –12 - 50, and -26 mgkg^{-1} of soil of respectively: The amount of mobile potassium was smaller (33 -61 mgkg^{-1} of soil) in treatments with sapropel than in the treatment with manure (83 mgkg^{-1} soil).

Comparing the data of agrochemical indices after third of crop rotation with the data of agrochemical indices after the second crop rotation, we can notice that long-term efficiency of different rates of calcareous sapropel has decreased, but has not achieved an initial data which was before carried out of experience. PH of soil has not changed. Sum of absorbed bases has remained on 74-167 m-equivkg^{-1} soil above than was in the beginning. Also there were major indices of the total nitrogen (0.007 - 0.021 % units) and humus (0.06-0.30% units). Results show that efficiency of manure was finished much faster, than sapropel.

In comparing data of mobile phosphorus and potassium with the data of the previous rotation their amount has increased in all treatments with fertilizing of all rates of sapropel and manure (by 47-125 mgkg^{-1} soil phosphorus and on 19-100 mgkg^{-1} soil potassium).

The introduction of different rates dry sapropel in sandy loamy soil has corresponding influence on the increase of productivity of plants in three crop rotations.

The cumulative curve of the increase of plant productivity (Fig 2) showed that during first four years of crop rotation the efficiency of the smallest rate (50 tha^{-1}) of sapropel was equal to the efficiency of manure. Higher rates (100-200 tha^{-1}) of sapropel proportionally increased the productivity of crop rotation. However during the years when in the crop rotation potatoes and oats were cultivate, all rates of sapropel have reduced the productivity of these plants and the rate from 50 $tha^{-1}$of sapropel has established negative effect.

In the second crop rotation the productivity increased from the repeated introduction of manure and further effect of the largest rate (200 tha^{-1}) of sapropel was even more efficient. However, at repeated cultivation of potatoes and oats, the negative effect of sapropel (50 tha^{-1}) on the productivity reappeared, as in the first crop rotation.

The data show that when began the third crop rotation, the cumulative curve began to rise but in 2001 and 2002 when in the crop rotation were breeding potato and oat the curve, as well as in previous crop rotations has decreased too.

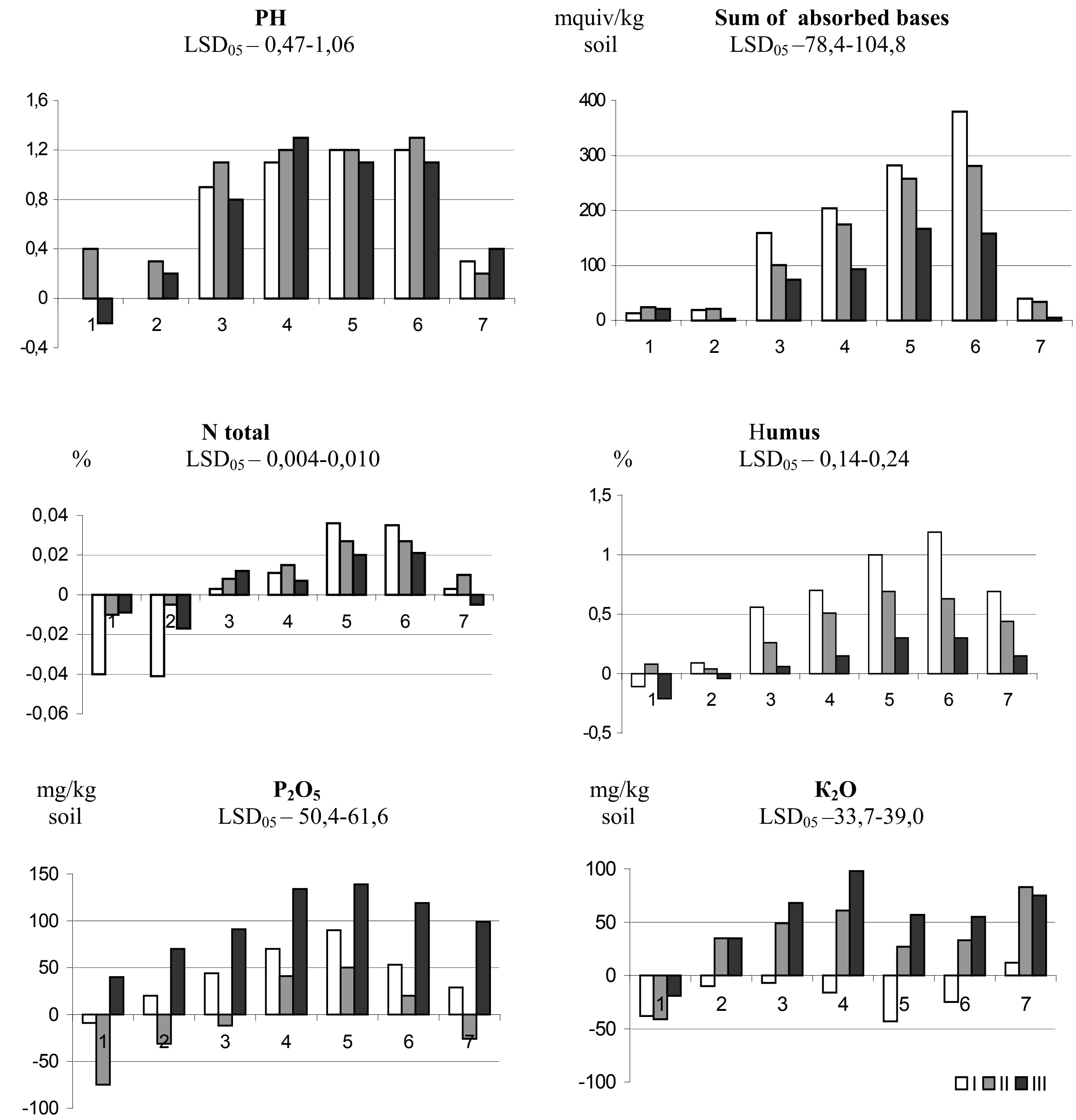


Figure 1. Changes of agrochemical indices after fertilization of sandy loam *haplic luvisols* with calcareous sapropel (I - agrochemical indices after first crop rotation; II - agrochemical indices after second crop rotation; III - agrochemical indices after third crop rotation; 1-7 – treatments of trials).

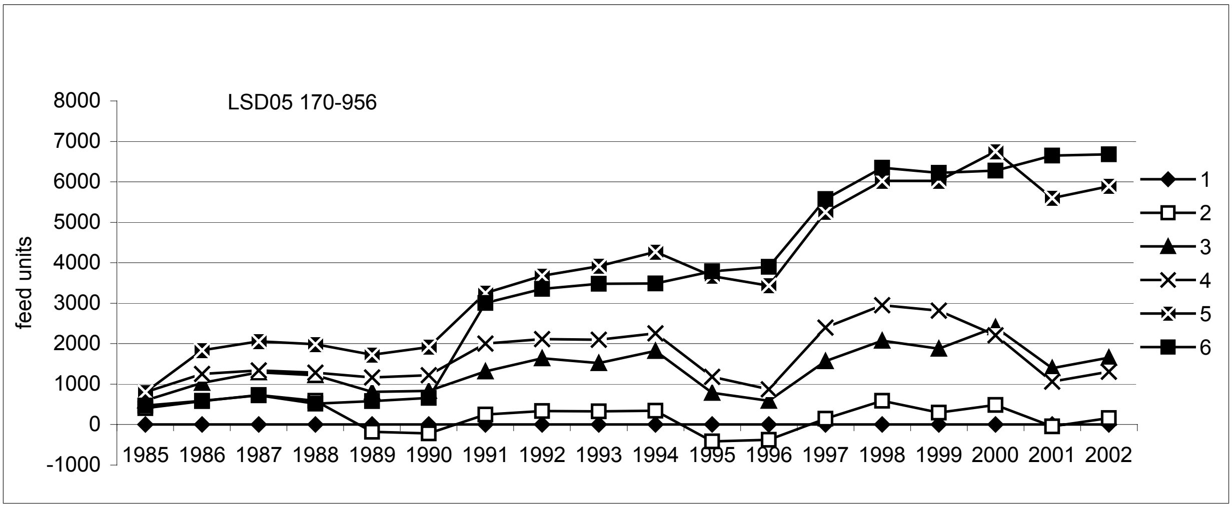


Figure 2. The cumulative curve of yield increase from the different rates of calcareous sapropel.
1 - check; 2 - S 50 tha^{-1} ; 3 - S 100 tha^{-1}; 4 - S 150 tha^{-1}; 5 - S 200 tha^{-1}; 6 - M 100 tha^{-1}.

Conclusion

1. The usage of calcareous sapropel for fertilization on sandy loamy *haplic luvisols* has shown that sapropel reduced the acidity of sandy loamy soil, increased the amount of absorbed bases, humus, total nitrogen, and mobile phosphorus. The amount of available potassium has decreased. By the end of the second and third crop rotation the influence of sapropel on agrochemical properties of sandy loamy *haplic luvisols* was positive.

2. Summarized results of a long-term experiment on sandy loamy soil have shown that the highest rates (150, 200 tha^{-1}) of dry sapropel after 18 years increased the productivity of crop rotation. The highest rate of sapropel used (200 tha^{-1}) was almost of the same effectiveness as manure.

References

Encke OM & Körschens M 1988. Dungung mit Seeschlamm auf humusverarmten Sandbode. Einfluß auf bodenphysikalische Eigenschaftenund Ertag. Arch. Gartebau 36 8 501-508.

Gruner A & Belau L 1990. Zur Dauerwirkung von Schlamen aus Seen und Brackgewassern auf den C- und N-Gehalt des Bodens. Tagungsber, No 295: s.207-214

Kavaliauskienė J 2000. Species composition of phytoplankton in same Lithuanian karst lakes The geographical Yearbook XXXIV(I).

Liepins J 1993. The use of sapropel for soil amelioration. Latvijas Lauksaimniecibas universitetas raksti 277(1) 72-74.

Orlov DS & Sadovnikova LK 1996. Nontraditional ameliorants and organic fertilizers. Euroasian soil science 29(4) 474-479.

Troels-Smith I. 1955. Characterization of unsolidated sediments Danmarks geologicke Undersfgelse Kfbenhvn 3 (10) 44-73

Conventional and conservation tillage from pedological and ecological aspects, The SOWAP project

Kertész, Á.[1]

Introduction

Conservation agriculture is in a way the new discovery of „old fashioned” agriculture, i.e. of the agriculture practised before the discovery and application of high tech machinery in agriculture. Even before the usage of soil cultivation machines cultivation was performed by inverting the soil using the plough or similar tools. According to our understanding conventional agriculture is based on tillage and it is highly mechanised. Conventional agriculture causes severe land degradation problems including soil erosion and pollution as well as other environmental damages like biodiversity and wildlife reduction, low energy efficiency and a contribution to global warming (Boatman et al. 1999).

According to the SOWAP project (Soil and Surface Water Protection Using Conservation Tillage in Northern and Central Europe, 2003) definition *Conservation Tillage (CT)* is understood as tillage practices specifically intended to reduce soil disturbance during seedbed preparation. The objective being to improve soil structure and stability. Conservation tillage encompasses a range of tillage practices up to and including „Zero (no) Tillage”.

Conservation Agriculture (CA) is a holistic approach to crop production, which encompasses „Conservation Tillage”, and also seeks to preserve biodiversity in terms of both flora and fauna. Activities such as Integrated Crop, Weed, and Pest Management form part of Conservation Agriculture. The concept of „As little as possible, as much as is needed” will be the guiding principles for SOWAP in crop production, when it comes to chemical usage.

Sustainable Land Management (SLM). This is one step beyond „Conservation Agriculture” and includes other „non-crop” activities used to promote biodiversity (landscape) historic character in the wider „farmed” landscape.

Conservation tillage is practised on 45 million ha in the world (Holland 2004), first of all in North and South America and with an increasing trend in South Africa, Australia and in other semi-arid areas.

It is interesting that the application of CA in Europe has developed slower than in other parts of the world. Table 1 shows data about CA and direct drilling in different EU countries. Switzerland and the UK are in leading position with 40% and 30% of the agrarian surface.

Table 1. Estimation of surface under Conservation Agriculture and Direct Drilling in different European Countries (data obtained from ECAF National Associations)

	Surface under Conservation Agriculture	% Agrarian Surface	Surface under No-Till	% Agrarian Surface
Belgium	140.000	10%		
Ireland	10.000	4%	100	0,3%
Slovakia	140.000	10%	10.000	1%
Switzerland	120.000	40%	9.000	3%
France	3.000.000	17%	150.000	0,3%
Germany	2.375.000	20%	354.150	3%
Portugal	39.000	1,3%	25.000	0,8%
Denmark	230.000	8%		
United Kingdom	1.440.000	30%	24.000	1%
Spain	2.000.000	14%	300.000	2%
Hungary	500.000	10%	8.000	0%
Italy	560.000	6%	80.000	1%
TOTAL	**10.054.000**		**960.250**	

The reasons why Europe is behind the rest of the world can be summarized as follows (European Conservation Agriculture Federation, 1999). (1) There is less need to take risks because the reduction of costs is

[1] Geographical Research Institute of Hungarian Academy of Sciences, Department for Physical Geography. H-1112 Budapest, Budaörsi út 45. Tel/Fax: 309-2686; E-mail: kertesza@helka.iif.hu

not as important than elsewhere. (2) Lack of technology. (3) Lack of technology transfer. (4) Lack of institutional support.

Soil degradation has not been considered to be a major problem in many European countries until recently. According to Oldeman et al. (1991) in Europe water erosion endangers 12% of the total land area and wind erosion 4%, 16% of the cultivated land is prone to different kinds of soil degradation. Today there is an effort to reduce production costs as well.

Generally it can be said that CA is an important tool in those regions of the world where soil erosion is a major problem and where the retention of soil moisture is an important goal. Keeping the water in the soil is equally important if flood and drought are to be avoided.

Benefits for the soil

The main benefit of CT is that the soil will be preserved more or less in semi-natural conditions as soil disturbance by cultivation in minimized and physical and chemical depletion are reduced.

Soil structure remains very good with drainage, porosity, adsorption capacity and structural stability (Lavier et al. 1997).

Compaction and loss of soil structure can be stopped or reduced by applying CT as well, since there is less traffic on the field and crop residues will not be buried in the soil. It is good for soil organic matter, too.

As it is well known, organic matter influences soil structure, soil stability, buffering capacity, water retention, biological activity and nutrient balance, all of these determining erosion risk as well (Holland 2004). Loosing organic matter can be catastrophic for erosion. If the C content of the soil is below 2% erosion may take place (Evans 1996). The OM content of the soil diminishes under conventional cultivation rather quickly. Kinsella (1995) estimates that most agricultural soil loose 50% of soil C. When CT is applied crop residues remain on the soil surface offering a very good protection against erosion.

The SOWAP project

Recognising the benefits of CA a demonstration project started in 2003, supported by the EU LIFE Programme, involving the organisations listed at the end of this paper. This three-year, 4 million € project is co-funded (50:50) by EU Life and Syngenta.

SOWAP (SOil and WAter Protection) aims to assess the viability of a more "conservation-oriented" agriculture, where fewer tillage practices replace the numerous cultivations carried out under more "conventional" arable farming systems. The use of appropriate chemicals is tested, and their potential for off-site contamination assessed, to ensure that any suggested approaches are environmentally sound.

The main study topics of the project are as follows:

(1) Soil erosion studies are based on erosion plots, which are used to compare conventional, farmer and SOWAP practice and to measure sediment, pesticide and nutrient loss and runoff from these systems.
(2) Aquatic Ecology studies are an important part of the ecology – environment block of SOWAP. Soil disturbance produced by tillage creates high runoff rates and silty water that drains into streams, ditches and ponds. This results in reduced water clarity, enhanced levels of nutrients, organics, pesticides and silty bottom sediments. SOWAP will study the effects of „conservation" tillage on stream biodiversity (fish, invertebrates and plants) water chemistry and sediment loading
(3) Biodiversity – Birds and Terrestrial Ecology. Key biological indicators will assess the impacts of differing land management practices on ecosystem sustainability. Counts of foraging farmland birds in winter and in the breeding season will be undertaken. Of particular interest is the comparison of UK agriculture with the currently, lower intensity agriculture of Hungary. The abundance and availability of seed and invertebrate food resources will also be assessed. Earthworm numbers will be important indicators of soil „health".
(4) Soil Microbiology. The soil microbiology component of the project will complement the physical and chemical measurements of soil undertaken in the erosion topic by monitoring biological indicators. The work will involve micro and macro biological survey recording indicator species and communities/populations thereby indicating levels of bio-diversity in the soil. Details on microbial biomass and community structure and function will add to the complex picture of biological activity in the soil under the different management regimes.
(5) Agronomy. Changes in the way crops grow and are grown in response to different soil management regimes are important to understand and disseminate. To facilitate this understanding, various assessments e.g. crop cover, date of emergence, disease prevalence, weed incidence will be made during the season and over the three year duration of the project, thereby taking into account the farm's crop rotation.
(6) Economics. The economic viability of the practices employed will be key to their successful uptake by farmers inside and outside the project. Project farmers will be encouraged to keep farming

calendars throughout the project duration, noting economic inputs (costs of land preparation, treatment application, cultivations and management practice, harvesting costs, marketing costs, transport, variable and fixed costs, gross margins) and outputs (yields).

Environmental benefits

The environmental benefits of CA include on-site and off-site effects, the latter having local, regional or global importance.

From global aspects carbon and other greenhouse gases have to be mentioned first. CA means the reduction of energy consumption and mechanical work, reducing the emissions of CO_2 and CO gases. CA promotes carbon sequestration in soils. Reduced mechanical activity means less SO_2 emissions from motors mitigating acidification of the atmosphere.

As a consequence of CA, air pollution is also reduced.

Concerning global biodiversity, CA offers better nesting sites and better food supplies (Belmonte 1993). CA fields host higher bird, small mammals and game population (Guedez 2001).

The benefits for soil biodiversity are self-evident. Excellent food and habitat are provided for microorganisms, earthworms and insects, promoting bioactivity and biodiversity of the soil.

As mentioned above, soil moisture conditions are much better, than under conventional agriculture. Better water management of the soil is manifested in reduced runoff by 15-89% (Holland 2004).

Above the positive influence of CA on infiltration, runoff, leaching CA helps to reduce the risk of pollutants to reach surface and groundwater. There is an indirect positive affect of CA on aquatic ecosystems.

Details about the Hungarian sites will be given in the conference papers of Bádonyi – Madarász.

Organisations involved in SOWAP

- Agronomica, U.K.
- Cwi Technical Ltd, U.K.
- FWAG, U.K.
- Harper Adams University College, U.K.
- Geographical Research Institute of Hungarian Academy of Sciences, HU
- National Trust, U.K.
- Cranfield University – NSRI, U.K.
- RSPB, U.K.
- Syngenta, U.K./HU
- The Allerton Trust, U.K.
- The Ponds Conservation Trust, U.K.
- University of Leuven, Belgium
- Vaderstad, U.K./HU
- WOCAT, The Netherlands
- Yara (UK) Ltd, U.K.

References

Belmonte, J. 1993. Estudio comparativo sobre la influencia del laboreo en las poblaciones de vertebrados en la campine de Jerez. Bolentin San. Veg. Plagas, 19. 211-220.

Boatman, N. – Stoate, C. – Gooch, R. – Carvalho, C.R. – Borralho, R. – de Snoo, G. – Eden, P. 1999. The environmental impacts of arable crop production in the European Union: practical options for improvement. A report preperad for Directorate-General XI of the European Commission.

European Conservation Agriculture Federation. 1999. http://www.ecaf.org/Situation.htm web page.

Evans, R. 1996. Soil Erosion and its Impacts in England and Wales. Friends of the Earth. London. 121 p.

Guedez, P-Y. 2001. Environmental aspects of Conservation Agriculture in Europe. I World Congress on Conservation Agriculture. Madrid, 1-5 October, 2001.

Holland, J.M. 2004. The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. Agriculture, Ecosystems and Environment 103. 1-25.

Kinsella, J. 1995. The effects of various tillage systems on soil compaction. In: Farming For a Better Environment: A White Paper. Soil and Water Conservation Society, Ankeny, IA. pp. 15-17.

Lavier, B. – Viaux, P. – Rass, G. 1997. Erosion et travail du sol, bilan en France. Published by ITCF, Monsanto.

Oldeman, L.R. – Hakkeling, R.T.A. – Sombroek, W.G. 1991. World Map of the Status of Human-Induced Soil Degradation. An Explanatory Note (revised ed.). UUEP and ISRIC, Wageningen, The Netherlands. 34 p.

Field evidence of intense tillage erosion

de Alba, S.[1] – Borselli, L. – Torri, D. – Lindstrom, M.J.

Soil redistribution due to tillage practices has been identified as an intensive soil erosion process. During the last decade have been published an important number of papers documenting the mechanics of the process and the rates of soil displacement for different tillage implements and agronomical conditions. Several models of soil translocation and soil redistribution by tillage are being developing and applying in order to simulate the progressive transformation of landscapes and study the derived implications of such landscapes transformation on the water erosion, surface and subsurface hydrology, active geomorphic processes, soil variability, productivity, etc. However, still today part of the soil scientists community do not acknowledge the significance and importance of the consequences of the soil redistribution by tillage in the evolution of the agricultural landscapes. This reveals the need for studies for identifying current landscape features produced by past repeated tillage practices, as well as for documenting the different bio-physical implications. This communication presents several examples of field evidence observed in agricultural fields of Central Spain, Tuscany (Italy) and Central Minnesota (USA). The collection of field evidences are presented grouped according to the nature of the effects, into the following four classes:

1) *Landscape levelling and smoothing:* features of change of the soil surface level;
2) *Modification of morphology of slope profiles:* formation of banks at the lower field edges, landscape benching by the formation of slope profile breaks at borders between adjacent fields located at mid-slope positions;
3) *Spatial variability of soil properties:* patterns of distribution of areas of degraded soils (truncated soils) and of soil accumulations, spatial variability of soil properties in the superficial soil horizons, and variability of soil profiles morphology along the slope profiles; and,
4) *Spatial variability of productivity*: relationships between relieve and spatial variability of soil properties and productivity.

Key words: tillage erosion, soil redistribution, field evidences, slopes morphology, soil variability, productivity.

[1] UCM, F. of Geology, Dpto. of Geodinamics, Ciudad Universitaria s/n, 28040 Madrid, Spain. Tel.: +34-676086764; Fax: +34-913944845; E-mail: Sdealba@geo.ucm.es

A case study of soil and water protection using conservation tillage from the SOWAP project

van Lynden, G.[1] – Jones, C. – Leake, A.

The SOWAP project

SOWAP is an acronym for a project called "**So**il and Surface **Wa**ter **P**rotection using conservation tillage in Northern and Central Europe". SOWAP is a EU-LIFE Environment -supported project jointly implemented by Syngenta, the University of Leuven, ISRIC, Vaderstad (machinery manufacturer), the Geographical Research Institute of the Hungarian Academy of Sciences, and the National Soil Research Institute of Cranfield University, as well as a variety of national partners.

SOWAP aims to assess the viability of a more "conservation-oriented" agriculture, with fewer tillage operations minimising negative impacts on the environment. SOWAP will work at the farm scale, although detailed monitoring will take place at the plot level, allowing sufficient resolution and replication of data.
SOWAP's focus is the UK, Belgium and Hungary. Field sites (farm scale) with collaborative farmers are identified within each country, and the proposed conservation tillage system will be applied at each site. Local variations and farmer/land owner preference will be considered (without losing the potential environmental benefits of that system) and documented. Consultation and participation by all stakeholders is critical to the success of SOWAP. In addition to agronomic and economic aspects, the ecological impacts on wildlife (birds in particular) and aquatic species will be monitored.

SOWAP field sites have been sited in each of the three countries for demonstration purposes. In the UK there are two sites, one in West Somerset and a second on the Leicestershire/ Rutland Border. Single site have been located in Belgium and Hungary. Along with these demonstration sites, other co-operating farmers and farmer organisations have been identified, where demonstrations and comparisons between various land management practices can be tested. The research sites for erosion, aquatic ecology and terrestrial ecology do not necessarily coincide. Each erosion site has a weather station with data being directly accessible from the SOWAP Website. This can be queried for past erosion events or weather data every day or month.

The WOCAT programme

SOWAP will build upon the work of the World Overview of Conservation Approaches and Technologies programme (WOCAT). ISRIC - World Soil Information, as a member of the WOCAT Management Group, represents WOCAT in the SOWAP project and will be responsible for the documentation and dissemination task.

During the past decade WOCAT has developed and tested a standard method to document, monitor and evaluate soil and water conservation (SWC) know-how and to disseminate it around the globe in order to facilitate exchange of experience. A set of three comprehensive questionnaires and a database system have been developed to document all relevant aspects of SWC technologies and approaches, including costs and benefits, uptake, area coverage, etc. A SWC technology is defined by WOCAT as: "the agronomic, vegetative, structural or management measures (or combinations of these) that control soil degradation and enhance productivity in the field. A SWC approach constitutes "the ways and means of support that help to introduce and implement, adapt and apply a SWC technology in the field" (WOCAT, 2004).

At the field level the WOCAT questionnaires offer SWC experts, technicians and extension workers a common framework and methodology to document and evaluate their own experience. One proven benefit of filling in the questionnaires is an in-depth analysis and evaluation of one's own SWC activities. SWC institutions, planners, co-ordinators and decision-makers at the national and regional planning levels need to obtain and maintain an overview of SWC activities. WOCAT helps to efficiently pull together and apply relevant SWC knowledge that is available in their working areas.

The database which contains 300 technology case studies and more than 200 approaches from 40 countries (though not all have been validated or completed) is used worldwide by a variety of government departments, project staff, scientists and extension workers to promote such practices.

Within the SOWAP project the WOCAT method will be used to document and evaluate the tested practices. Other practices not tested on the SOWAP field sites will also be documented and evaluated, resources, time, and funds permitting.

With just three case studies from Switzerland and a few from Serbia, Europe is under-represented in the WOCAT database.

[1] ISRIC World Soil Information; Wageningen, The Netherlands

Dissemination

WOCAT disseminates its information via the Internet, CDs and workshops that facilitate personal contact with other specialists and immediate exchange of experience.

Together with the aforementioned WOCAT channels of dissemination, SOWAP will also independently develop a dissemination - or in more fashionable terms: upscaling - strategy. For such a strategy all target groups have to be identified, as well as the type and contents of the information required by these beneficiaries. The target groups identified in the SOWAP project document cover a very wide range of institutional and professional backgrounds and interests (SOWAP, 2002). Three major levels of dissemination can be distinguished:

- local: farmers, land owners and estate managers, local policy makers and advisory organisations
- national: farmer organisations, agricultural advisory organisations, national policy makers and advisory organisations, researchers and academia, industry.
- EU: policy makers at EU level

These beneficiaries may have different as well as overlapping information needs and interests and need to be addressed through a variety of dissemination means. The latter may include workshops and field visits (for instance for farmers, and field-based organisations), technical documents and scientific papers (technicians, researchers), brochures and leaflets, TV, radio and written press (general public, policy makers), a project Website, electronic newsletter, etc. and of course papers and posters presented at conferences such as ISCO.

The dissemination process will highlight the site-specific elements that need to be considered. This is or at least should be obvious for bio-physical conditions, but is often less so for socio-economic conditions / human environment. Dissemination should therefore be an interactive process with active involvement of the target beneficiaries.

The SOWAP site at Loddington (UK)

The project in the UK has already started to organise workshops and open days for farmers, agronomists and extension workers. Tremendous support has been given to the project in bringing these workshops into being by local organisations such as the National Trust, the Farming Wildlife and Advisory Group (FWAG) and the Allerton Research and Educational Trust.

This paper presents a new case study on "non-inversion tillage" from the SOWAP site at Loddington in the UK. The site is located in Leicestershire and is owned by the Allerton Research and Educational Trust.
The concept of "non-inversion tillage' implies cultivation of the top 10 cm of the soil without complete inversion. Within the SOWAP project, this is designated as conservation tillage. The concept of conservation tillage was originally devised in the US after the notorious "Dust Bowl" in the 1930's. Various forms of conservation tillage have since been developed. The technology described here was introduced into the area some 20 years ago.

Non-inversion tillage includes various methods of preparing a seedbed from the stubble of a previous crop without the use of a mouldboard plough, as used in conventional tillage systems.

Economic benefits include reducing crop establishment cost by making energy and financial savings in terms of fuel and labour. Environmental benefits include the reduction of mineralisation and leaching of soil nitrogen, decreased risk of soil erosion, as well as increased biodiversity as observed in North America and Belgium.[2]

WOCAT has developed a system of "Assessment Indicators" that help users to make an evaluation of a technology. It groups various questions from the questionnaire under a number of general headings which are considered key indicators for success or failure of a technology. These indicators are:

Costs and returns (inputs and outputs)
Economic benefits/disadvantages
Acceptance or adoption
Required / available knowledge
On-site ecological benefits/disadvantages
Off-site ecological benefits/disadvantages

[2] http://www.google.nl/search?q=cache:8ZAwUs28dfIJ:www.harper-adams.ac.uk/research/kchaney/Heidi_280803.ppt+non-inversion+tillage&hl=nl&ie=UTF-8

For the Loddington case study this reveals that rather than production increase which is fairly marginal (5-10%) the key drivers are lowering establishment costs, higher work rate (more hectares per hour) and therefore crops establish earlier prior to heavy winter rain. This has enabled a larger area to be cultivated which reduces unit costs per area. Other (expected) benefits play a role such as soil cover improvement, increase in soil moisture, soil fertility increase, soil loss reduction, efficiency of excess water drainage. Biodiversity and soil biology are enhanced, surface water quality improved, flooding and siltation reduced. The latter issues are not of prime interest to the farmer but have greater societal relevance. In general there is not one clear benefit but rather a mixture of relatively small benefits that combine to make this technology an attractive option for the land user. A number of years of continued treatment may be required before beneficial effects of non-inversion tillage are manifested in improved topsoil tilth[3]. SOWAP aims to further investigate the precise effects of the technology on the aforementioned aspects and provide practical and technical solutions for farmers seeking to adopt this practice. In the UK the spread of minimum tillage has grown from 15 to 40% in the past decade.

Initial investment costs are considerable because the technology requires expensive specialised machinery. The farmers nevertheless implement the technology without subsidies so savings in time and fuel costs for farm operations are providing sufficient motivation, in addition to their environmental responsibility. Whereas most SWC practices often require extra costs because the activities undertaken are additional to "normal" agricultural practice, in the case of conservation tillage the agricultural practice itself is changed.

While in the EU production is subsidised there are no subsidies, which are solely aimed to encourage SWC. However, there are various subsidies to encourage environmental benefits e.g. retention of winter stubbles which, although aimed at encouraging bird populations also reduces soil erosion, or buffer strips which protects water courses. The nature of these subsidies is changing with greater emphasis shifting from production to environmental protection. In the UK soil management will be one option in a range of options that the farmer can choose for his environmental payment.

At the Loddington site the Allerton Educational and Research Trust is experienced in operating workshops which provide technical research input from experts coupled with field demonstrations. The topics covered in the workshops are arranged in response to requests from farmers searching solutions to problems they are experiencing in the field. Such events, tailored to meet the needs of land users, are frequently over-subscribed, highlighting the desire within the farming community for knowledge. The SOWAP demonstration field at Loddington allows for the first time a link to be made between crop establishment costs, crop yields and economics with soil and water protection and other aspects such as soil biological activity and wildlife. These latter benefits are likely to be linked to financial rewards under the reformed CAP regime.

[3] Munkholm, Lars J. and Schjønning, Per and Rasmussen, Karl J. (2001) Non-inversion tillage effects on soil mechanical properties of a humid sandy loam. *Soil and Tillage Research* 62(1-2):1-14.

Tillage erosion under different tillage systems in Croatia

Kisic, I.[1] – Basic, F. – Othmar, N. – Mesic, M.

Abstract

Erosional drift was recorded during the nine-year investigation cycle (1994-2003.) on Stagnic Luvisol, in central Croatia, under common agricultural crops grown in 6 tillage treatments. This work presents the results relating to the total erosional drift, with special reference to the time of occurrence of erosional drifts per USLE crop development stages of the crops grown. The largest erosion in the 9-year period was recorded in the standard variant (black fallow). This was followed by the variant involving conventional up and down the slope ploughing. Erosional drift was much smaller in no-tillage variant and treatments with ploughing across the slope. Much higher erosional drifts were recorded in the growing of spring crops (maize, soybean) than in winter crops (wheat, oil seed rape). Also, in the growing of crops, notably spring crops, erosional drifts were not evenly distributed during crop growing, quite the contrary. The period of seedbed preparation, or the period immediately after sowing spring crops, is the most critical period with the highest risk of erosion. In the growing of spring crops, this is the period when over 80 % of the overall annual erosional drift occurs in all tillage treatments. In the growing of winter crops, crops of high density, no critical periods were observed. Summing up all the advantages and drawbacks of the studied tillage methods for a wide application in crop growing on this soil type, we recommend no-tillage and conventional ploughing across the slope.

Key words: Tillage erosion, Erosional drift, Tillage treatments, Croatia

Introduction and investigation goal

The primary goal of the investigations is to determine the characteristics of erosion on Stagnic Luvisol (ISSS-ISRIC-FAO, 1994) and then to seek for the answer to the question whether it is possible, and to which extent, to reduce erosion to a tolerant level by applying different treatments of soil tillage in the growing of agricultural crops. Based on the results obtained, the optimal tillage has to be determined for Stagnic Luvisol, a soil very prone to erosion. Further goals are to determine the critical crop-stage periods during which the most intensive erosion may be expected, establish the reasons for such intensive erosion, and the way in which erosion is affected by vegetation cover in interaction with the applied tillage. The results should provide elements for recommending the optimal method of tillage on Stagnic Luvisol, as a very widespread soil type in this part of Europe.

Materials and methods

The stationary field trial was set up in the summer of 1994, after the oil-seed rape harvest, on arable land of the farm "Poljodar" in Daruvar, central Croatia. Erosion was measured on 6 enclosed trial plots, according to the USLE (Universal Soil Loss Equation) propositions (*Wischmeier and Smith, 1978*), viz. on a 9% slope, length 22.1 m, width 1.87 m, or a plot area of 41.3 m^2. Plots are enclosed by a sheet-metal fence, which is removed before each tillage practice, and then put up again after the practice is completed. The experimental station consists of the following treatments: **1. Standard plot (black fallow),** tilled up/down the slope. **2. Conventional ploughing up/down the slope 3. No-tillage,** sowing with a special seeder into dead mulch, up-down the slope **4. Conventional ploughing across the slope** 5. **Very deep ploughing across the slope** (to 50 cm deep) **6. Subsoiling to the depth of 60 cm**, with conventional ploughing across the slope to 30 cm deep.

Special equipment enabling separation and filtration of erosional drift has been set up on the lower part of each trial plot of the station, clean water is collected in a separate container while solid drift remains on the cloth serving as filter. In this paper we present results for next crops: 1995 and 2000 - maize (*Zea mays* L.), 1996/97 and 2001/02 - winter wheat (*Triticum aestivum* L.). Crop development is monitored per stages according to USLE (*Wischmeier, 1960*): Period F - rough fallow (primary tillage - plowing to secondary tillage for seeding); Period SB – (seedbed) - secondary tillage for seedbed preparation until the crop has developed 10 % canopy cover; Period 1 – (establishment) – end of SB until crop has developed a 50 % canopy cover - for winter crops includes the winter period; Period 2 (development) – end of period 1 until canopy cover reaches 75 %. Period 3 (maturing crop) – end of period 2 until crop harvest); Period 4 (residue or stubble) - harvest to plowing or new seeding.

[1] Department of Agronomy, Faculty of Agriculture, Zagreb, Croatia. Tel.: 385 1 23 93 959; Fax: 385 1 23 93 981; E-mail: ikisic@agr.hr

Results and discussion

Investigations were conceived so as to obtain the answer to the set investigation goal by applying adequate methods of basic soil tillage and growing of the main field crops. It is assumed that the differences that will occur in surface run-off and erosional drift will be directly dependent on the applied soil tillage methods and growing crops. The obtained results will serve as the basis for determining the tillage method that will most efficiently stop erosional processes, that is, reduce erosion risk in crop growing, protect the environment, at the same time sustaining or increasing the attained growing levels.

Erosion in growing maize

Numerous studies conducted in the world, among which mention is made of only some of the authors: Govers et al. (1994), Tebrüge and Düring (1999), Van Muysen et al. (2002) and de Alba (2003) have proven that up/down the slope ploughing is the least favourable tillage method, since it leads to highest erosional drift, whereas no-tillage and ploughing across the slope are much more efficient in terms of erosion control. This has also been confirmed by our investigations. Spring crop (maize) was grown according to a crop sequence 1995. and 2000. Erosional drift in those years was determined per different stages of crop development according to USLE and is shown in Table 1. It is obvious that the convincingly highest erosional drift (146.32 and 141.39 t ha^{-1}) was recorded in the black fallow. This quantity is several times higher than the tolerant level of erosional drift - T, which for this type of soil amounts to 10 t ha^{-1} y^{-1} (Schwertman et al. 1987). This is followed by the variant involving conventional ploughing up/down the slope with 38.53 and 26.07 t ha^{-1}, respectively, of erosional drift. A smaller quantity of erosional drift was recorded in the no-tillage (22.86 and 0.56 t ha^{-1}) and in very deep ploughing across the slope (21.12 and 6.61 t ha^{-1}, respectively). Reason for very high erosional drift on no-tillage for first year of investigation is first year of used of no-tillage. It is followed by conventional ploughing across the slope with the total annual erosion of 11.66 and 8.35 t ha^{-1}, respectively. Convincingly best results in soil conservation were achieved in the variant with subsoiling with ploughing across the slope, where total erosional drifts were only 2.99 and 6.02 t ha^{-1}, respectively. The results give absolute advantage to ploughing across the slope. Up/down the slope ploughing should be omitted altogether. Maize and other spring row crops are considered to be high risk crops by all the authors studying erosion problems on arable land,

Table 1. Erosional drift in growing of maize

Cropstage	Black fallow	Up/down the slope ploughing	No-tillage	Ploughing	Very deep ploughing	Subsoiling +ploughing
				across of slope		
MAIZE GROWING - October 1994-October 1995.						
Seedbed - SB	34.74	28.86	18.48	9.54	18.80	2.69
% of total drift	23.7	74.9	80.8	81.8	88.9	90.0
Period 1 - establishment	1.37	0.36	0.015	-	-	-
% of total drift	0.9	1.0	0.1	-	-	-
Period 2 - development	50.24	5.22	1.58	0.65	1.13	0.05
% of total drift	34.3	13.5	6.9	5.6	5.4	1.8
Period 3 – maturing	59.97	4.09	2.78	1.47	1.19	0.24
% of total drift	41.1	10.6	12.2	12.6	5.7	8.2
Total erosional drift, t ha^{-1}	**146.32**	**38.53**	**22.86**	**11.66**	**21.12**	**2.99**
MAIZE GROWING - November 1999-October 2000.						
Rough fallow	0.08	0.06	0.01	-	-	-
% of total drift	0.1	0.2	1.4	-	-	-
Seedbed - SB	31.16	15.55	0.30	7.01	6.14	5.75
% of total drift	22.0	59.7	53.5	83.8	92.9	95.6
Period 1 – establishment	14.51	3.64		0,10	0.02	0.01
% of total drift	10.3	14.0		1.2	0.3	0.1
Period 2 - development	8.01	0.10	0.25	1.20	0.45	0.26
% of total drift	5.6	0.4	45.1	14.4	6.8	4.3
Period 3 – maturing	66.83	6.51	-	0.04	-	-
% of total drift	47.2	24.9	-	0.6	-	-
Residue or stuble	20.80	0.21	-	-	-	-
% of total drift	14.8	0.8	-	-	-	-
Total erosional drift, t ha^{-1}	**141.39**	**26.07**	**0.56**	**8.35**	**6.61**	**6.02**

regardless of the direction of tillage (Laflen and Moldenhauer, 1975; Alberts et al. 1985; Govers et al. 1999 and Tebrüge and Düring 1999). Besides, in early sowing at a time when the soil is bare and unprotected of spring crops of low population density, the large intra- and inter-row spacing enables intensified erosion. Therefore, all raw spring crops cannot be fully protected from the direct impact of raindrops even in later stages, which leads to erosion also in its later stages. Ploughing across the slope may reduce erosion to a tolerant level by comparison with the up/down the slope ploughing and sowing. The orientation of furrows in this tillage methods prevents excessive surface run-off and thus reduces erosion. In the treatments with deep tillage, the larger depth of the plough-layer enables stronger descendent movement of water and in this way additionally decreases surface run-off. The results show that the critical period in growing spring raw crops is that of bare soil and the SB. On the black fallow 23.7% or 22.0% of the total annual erosion value was recorded in that period. Essentially different results were obtained in other treatments of tillage. In ploughing up/down the slope, the SB period erosion accounted for 74.9 and 59.7%, respectively, of the total annual erosion while in the no-tillage variant it amounted to 80.8 and 53.5%, respectively. In the variant involving ploughing across the slope, the SB period erosion amounted to 81.8 and 83.8% of annual erosion while in the variant with very deep ploughing across the slope to 88.9 and 92.9%, respectively. In the variant of subsoiling with ploughing across the slope, the SB period erosion accounted to 90.0 and 95.6%, respectively, of the total annual erosion. The reasons for such high values are that this is the period when the soil is bare and unprotected - without any vegetation cover, immediately after sowing. Raindrops of high intensity fall directly on the soil, which leads to surface run-off and occurrence of erosion in all trial treatments.

Erosion in growing winter wheat

In this paper winter crops present winter wheat. This crop was grown on the experimental plots in 1996/97. and in 2001/02.). Erosional drift in those years was determined per different stages of crop development and is shown in Table 2.

Table 2. Erosional drift in growing winter wheat

Cropstage	Black fallow	Up/down the slope ploughing	No-tillage	Ploughing	Very deep ploughing	Subsoiling +ploughing
				across of slope		
WINTER WHEAT GROWING - October 1996-August 1997.						
Seedbed - SB	12.22	0.23	0.03	0.03	0.17	0.10
% of total drift	14.1	41.9	13.6	36.2	56.3	77.0
Period 1 - establishment	9.11	0.21	0.06	0.002	-	0.02
% of total drift	10.5	39.4	28.7	2.5	-	13.8
Period 2 - development	3.95	0.02	0.02	0.01	-	-
% of total drift	4.5	4.6	10.2	11.5	-	-
Period 3 – maturing	52.54	0.07	0.08	0.03	0.10	0.01
% of total drift	60.6	12.9	38.4	46.6	33.2	7.7
Period 4 – residue	8.94	0.01	0.02	0.002	0.03	0.002
% of total drift	10.3	1.2	9.1	3.2	10.5	1.5
Total erosional drift, t ha^{-1}	**86.77**	**0.54**	**0.22**	**0.07**	**0.31**	**0.13**
WINTER WHEAT GROWING - October 2001-August 2002						
Period 1 - establishment	4.3	0.29	-	0.07	0.1	-
% of total drift	7.1	58.0	-	58.3	83.0	-
Period 2 - development	5.23	0.09	0.03	-	-	-
% of total drift	8.6	18.0	100	-	-	-
Period 3 – maturing	42.8	0,1	-	0.05	0.02	0.02
% of total drift	67.2	20.0	-	41.7	17.0	100
Period 4 – residue	10.33	0.02	-	-	-	-
% of total drift	17.1	4.0	-	-	-	-
Total erosional drift, t ha^{-1}	**62.70**	**0.50**	**0.03**	**0.12**	**0.12**	**0.02**

Like in the growing of maize (what is expected), highest erosion was recorded in the black fallow. In winter wheat growing, erosion amounted to 86.77 for first year and 62.07 t ha^{-1}, respectively, in the second year of growing winter wheat. Although total erosional drifts were lower than in the growing of maize, this is still very high erosion, which exceeds the tolerant threshold of soil loss of 10 t ha^{-1} y^{-1} for this soil type. Erosional drifts recorded in all other treatments were well below the tolerant soil loss. As expected, the relatively poorest results in the growing of winter wheat were achieved with ploughing up/down the slope. In this variant, erosional drift amounted to 0.54 t ha^{-1} and to 0.50 t ha^{-1}. The total annual soil loss by erosion in the no-tillage variant amounted to 0.22 and 0.03 t ha^{-1} while in the variant with ploughing across the slope it was 0.07 and 0.12 t ha^{-1}, respectively. In the variant with very deep ploughing across the slope, erosion was 0.31 and 0.12 t ha^{-1}, respectively. The smallest quantity of erosional drift and the highest efficiency of soil protection were recorded in the variant involving subsoiling with ploughing across the slope. The total annual erosional drift in this variant amounted to 0.13 and 0.02 t ha^{-1} of soil particles, respectively. Accordingly, regardless of the ploughing direction, erosional drifts in the growing of winter wheat was much lower than in the first two trial years when spring crop (maize) was grown. This is the reason why in controlling erosional processes we lay greater importance on the crop grown than on the tillage method applied.

In the next few sentences, we will try to answer the question why erosional drifts were much lower in the growing of winter crops. Winter crops were sown towards the end of October (winter wheat, barley) and August (oil-seed rape). Sowing was preceded by a long and dry summer period, during which rather coarse structure aggregates were formed, which reduce or prevent surface run-off. Besides, there are usually no high intensity rains after wheat and oil-seed rape sowing, rain falls on dry soil and the soil can take up large quantities of water for saturation to field capacity. No surface run-off occurs in such conditions. In the winter period of the year when the soil is fully saturated and if it does not get frozen, erosion occurs but the drift quantity is small. In the growing of winter crops there are no critical periods with occurrence of large quantities of erosional drift. Data from Table 2 show a uniform distribution of erosion during the whole growing season of winter wheat. In the period of the highest erosion risk in the studied area (May-June), winter crops fully cover soil surface with a dense cover. This vegetation cover efficiently protects the soil from the direct impact of raindrops (which are often very intensive in this part of the year) and thus contributes to the reduction of the total quantity of erosional drift.

Conclusions

The presented results shows that erosional processes cannot be completely stopped; however they can be reduced to a tolerant level by choosing an appropriate tillage method. Appreciably higher erosional drifts were recorded in the growing of low-density spring crops than in high-density winter crops in the same tillage systems. The time immediately following the sowing of spring crops (SB-seedbed) is the most critical period, that is, the period when highest erosional drifts occur. Spring crops, which are mainly grown at a low crop density, will still be dominant in the crop rotation, however, their growing on sloping terrains will require a balanced tillage system and an appropriate crop sequence. Efficient protection from erosion on Stagnic Luvisol slope can be achieved by no-tillage and all across the slope ploughing variants. Summing up all the advantages and drawbacks of the studied tillage methods for a wide application in crop growing on this soil type, we recommend no-tillage and conventional ploughing across the slope.

Reference

Alberts, E.E., Wendt, R.C., Burwel, R.E. 1985. Corn and Soybean Cropping Effects on Soil Losses and C factors. Soil Sci. Soc. Of Am., J. vol. 49: 721-728.

De Alba, S. 2003. Simulating long-term soil redistribution generated by different paterns of mouldboard ploughing in landscapes of complex topography. Soil & Tillage Res., 71/1: 71-86.

Govers, G., Vandaele, K., Desmet, P., Poesen, J., Bunte, K. 1994. The role of tillage in soil redistribution on hillslopes. European J. of Soil Science, 45/469-478.

Govers, G., Lobb, D.A., Quine, T.A. 1999. Tillage erosion and translocation: emergence of a new paradigmi n soil research. Soil & Tillage Research, vol. 51: 167-174.

ISSS-ISRIC-FAO, 1994. World Reference Base for Soil Resources. Wageningen, Rome.

Laflen, J.M., Moldenhauer, W.C. 1979. Soil and Water Losses from Corn-Soybean Rotations. Soil Sci. Soc. Am. J. 43, 1213-1216.

Schwertmann, U., Vogl, W., Kainz, M. 1987. Bodenerosion durch Wasser. Vorhersage des Abtrags und Bewertung von Gegenmaßnahmen. Stutgart, p. 86.

Tebrüge, F., Düring, R.A. 1999. Reducing tillage intensity – a review of results fom a long-term study in Germany. Soil & Tillage Research, vol. 53/1: 15-28.

Van Muysen, W., Govers, G., Van Oost, K. 2002. Identification of important factors in the process of tillage erosion: the case of mouldboard tillage. Soil & Tillage Res., 65/77-93.

Wischmeier, W.H. 1960. Cropping-management factor for a Universal Soil Loss Equation. Soil Science Society Proceedings, pp. 322-326.

Wischmeier, W.H., Smith, D.D. 1978. A Universal soil-loss equation to guide conservation farm planning. In Int. Congr.Soil Sci.,Trans.,7 Int.Soc.Soil Sci., Madison, 418-425.

Assessment of tillage erosion rates in Tuscany (Italy) studying field features produced by past tillage practices

de Alba, S.[1] – Borselli, L. – Torri, D. – Reina, L. – Bartolini, D.

Mechanical erosion due to the soil redistribution by tillage provokes an important landscape transformation, tends to erode the tops of the fields and convexities, accumulate soil at the bottom of the fields and fill the concavities, while high rates of soil transport with no significant changes in soil surface level take place on the slope sectors of rectilinear morphology. This means that the process tends to make the internal field morphology quite regular. On the contrary, field borders represent impassable lines and are locations of either erosion or accumulation. Any other obstacle to tillage, located inside the field, behaves as a double border, favouring accumulation on one side and erosion on the other. This gives rise to topographic anomalies around the obstacle producing tillage structures sculpted in the landscape. Tillage structures have different shapes according to the combined effect of the obstacle shape, its position in the slope and in the field, and the average direction of tillage with respect to the slope aspect. These structures generally present two shapes: sub-circular structures are common, for example, around isolated trees and electrical or telephone poles; linear structures are typical of field borders. Rows of trees can cause the formation of structures of intermediate characteristics.

This communication present the results of a field survey of the topographic anomalies produced by tillage around electrical poles, in several fields located in the Vall d'Orcia valley in Tuscany (Italy). In Tuscany electrical and telephone poles show the data of placement, so the age of the topographic anomaly could be properly determinate. Soil transport rates derived from surveying field features give us a valuable estimation of the intensity of the process of soil redistribution by tillage as an average effect produced by all the management practices applied in a given field during the period of time from the location of the obstacle. It is not possible to know the details of the management history (sequence and intensity of operations, type of implements, tillage direction and depth, etc.) of each field and consequently it is difficult to use the field surveying data to calibrate soil translocation equations associated to single or combined tillage operations. On the contrary, findings showed that field survey data seems to be the most suitable type of data in order to assess the integrated influence of past soil redistribution by tillage on the landscape evolution and to calibrate simulation models to the local agronomical conditions.

Key words: tillage erosion, soil redistribution, field evidences, field survey, slopes morphology.

[1] UCM, F. of Geology, Dpto. of Geodinamics, Ciudad Universitaria s/n, 28040 Madrid, Spain. Tel.: +34-676086764; Fax: +34-913944845; E-mail: Sdealba@geo.ucm.es

Deriving threshold values for soil compaction from expert knowledge

Tobias, S.[1]

Introduction

Many European countries have enacted their soil protection legislations. However, the execution of these legislations lacks of rules to assess soil health and to decide on sustainable management practices in many aspects. There is a particular lack of criteria and threshold values to assess the state and risk of soil compaction. In the recent past, much effort has been made in sophisticated experiments to describe the processes and effects of soil compaction. However, the specific results of single experiments cannot be applied to any other case in a general way. On the other side, different kinds of experts (scientists, officers, farmers) dispose of personal experience that allows them to judge soil compaction and the feasibility of the experimental data within their working fields. This contribution presents the first results from an elicitation of expert judgment with the Delphi method to derive meaningful and operable criteria and threshold values for the assessment of soil compaction.

Materials and Methods

In the years 2001 and 2002, a Delphi survey was accomplished among the members of the Swiss Soil Science Society. The Delphi survey consisted of three turns with 42 questionnaires returned at the first turn and 24 at the third turn. In the first turn, the experts were asked to mention in their own words the three most important criteria, i.e. physical soil properties, they use to judge soil compaction and susceptibility of compaction.

In the second turn, the experts were asked to group 21 data records with measurements of soil physical parameters from single horizons into 5 classes ranging from not compacted to highly compacted and not susceptible to highly susceptible to compaction, respectively. In addition, they had to mention the parameters that had been crucial for their decisions. The experts were asked to compare the data records in relation to one another. In order to simplify the judging, the data records were randomly grouped into three groups of seven data records each. To control a possible bias resulting from the grouping of the data records, I created two series of random grouping. One half of the experts received the data record combination of the first series; the other half received the combination of the second series.

Table 1. Values of decisive parameters mentioned to judge the state and susceptibility of soil compaction

Classes after 3rd Delphi turn		Bulk density	Coarse pore fraction	Precompression stress
state of compaction	susceptibility of compaction	(g/cm3)	(%)	(kPa)
1	4	1.44	16.4	16.6
1	3	1.32	10.0	72
1	3	1.35	12.5	27.2
1	4	1.26	17.0	13.0
1	4	1.04	12.3	70
2	5	0.91	6.8	40
2	3	1.49	10.9	62
2	3	1.56	7.2	38.5
2	2	1.38	11.5	113
2	4	1.13	8.7	31
3	3	1.52	8.5	64
3	3	1.49	6.9	59
3	3	1.51	6.6	87
3	2	1.57	9.7	140
3	3	1.42	8	106
3	3	1.55	6.4	84
3	2	1.43	5	119
4	3	1.50	5.4	56
4	4	1.5	5.4	47
5	2	1.51	4.2	166
5	2	1.54	2.3	200

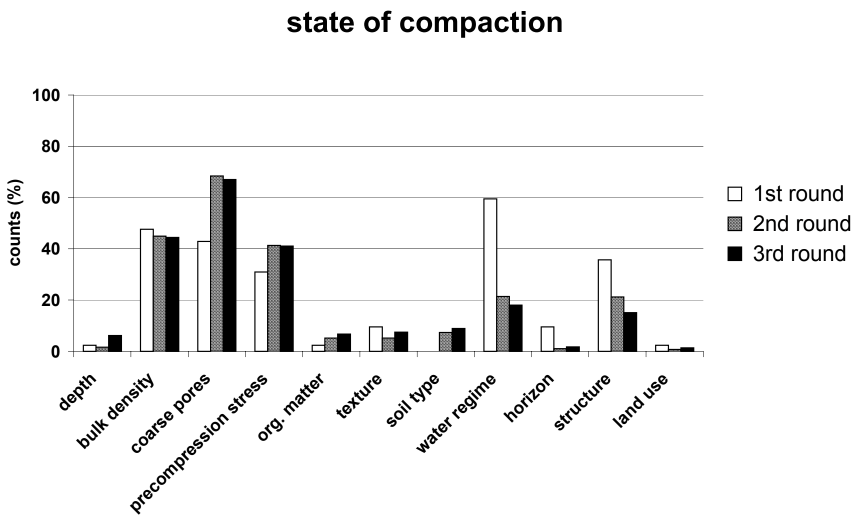
[1] Swiss Federal Institute of Forest, Snow and Landscape Research (WSL), Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland; Tel.: +41-1-739 23 49; Fax: +41-1-739 25 75; E-mail: silvia.tobias@wsl.ch

The third turn of the Delphi survey basically was a replication of the second turn in order to create a convergence in the answers. However, the data records were not grouped any more. Since there were no systematic differences found between the judgments of the two groups of experts, the results of the second Delphi-turn were put together in the same main unit and the median was calculated. For each data record, the experts were presented the distribution of the judgments from the second Delphi-turn as well as their own judgment. They were asked whether they agreed with the median of all the judgments or not.

The soil data were restricted to eutric cambisols with agricultural land use. The experts were given the following parameters (see Fig. 1): depth where sample was taken, bulk density, coarse pore fraction, precompression stress, organic matter, soil texture, soil type, water regime, soil structure, land use. The range of the different soil parameters was chosen as wide as possible, whereas the range of soil type varied between naturally developed and artificially restored eutric cambisols, only. The data records in Tab. 1 show real measurements of those parameters that were mentioned to be most important for judging the state and susceptibility of compaction.

Preliminary results

There was a high convergence in the answers; the grouping of the data records was much sharper in the third turn of the survey than in the second one. There was also a convergence in the criteria the experts mentioned as the basis of their judgments (Fig. 1). In the first turn of the survey, the experts mentioned qualitative parameters (e.g. soil water regime, soil structure) as most important. However, in the second and third turn, most of the experts declared to have mainly used quantitative parameters (e.g. coarse pore fraction, bulk density) to judge the examples given. Quantitative parameters seem to be relied on more in a concrete problem and are possibly more useful as threshold values in soil protection legislation.



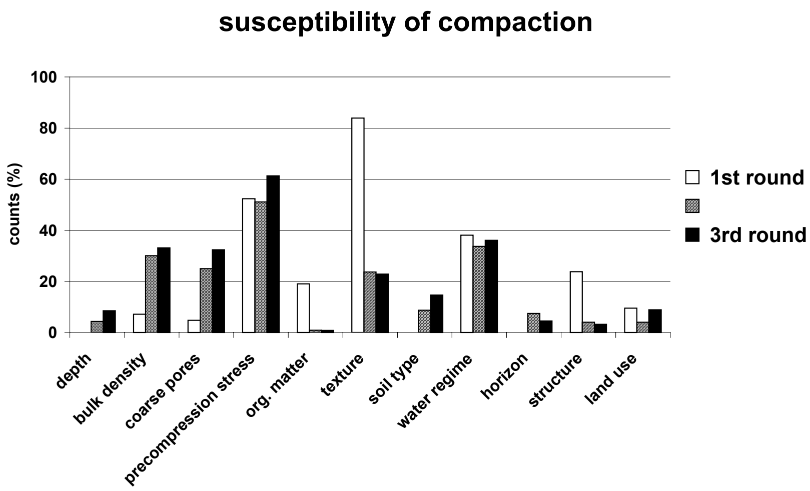


Figure 1. Importance of the different soil parameters to judge the state or the susceptibility of soil compaction as it was mentioned by the experts in the different turns of the Delphi survey

The decisive parameters for grouping the data records in different classes of state of compaction were coarse pore fraction, bulk density and precompression stress. Grouping the data records in classes of susceptibility to compaction, the experts mentioned precompression stress, coarse pore fraction, bulk density, water regime, and clay content as decisive parameters.

A quantitative analysis of the values of the single soil parameters is shown for the state of compaction by the means and standard deviation for each class (Fig. 2). Contrast analysis within a one way anova did not show significant differences between the means of the classes 3 and 4 for any of the parameters. However, significant differences between the means of any other classes were given for the parameters coarse pore fraction and precompression stress. For bulk density, significant mean differences were only given between the first three classes.

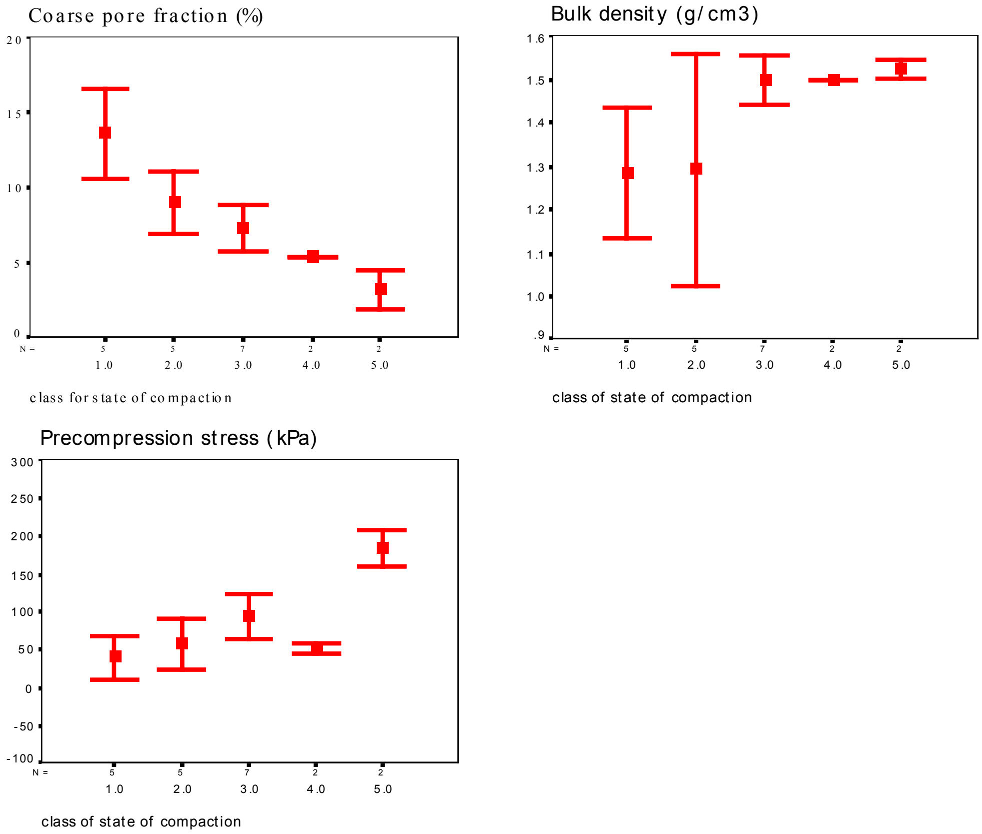


Figure 2. Means +/-1 standard deviation in the different classes of state of compaction for the most decisive parameters in the 3rd turn of the Delphi survey

The thresholds that were implicitly used by the experts to distinguish between compacted and uncompacted soil can be derived from the range of the values in the two classes 3 and 4 together. Hence, we get the following threshold values, while it has to be noted that coarse pore fraction was said to be the most important parameter for the experts' judgments (see Fig. 1):

Soil parameter	Uncompacted soil	Threshold value	Compacted soil
Coarse pore fraction (%)	>	6.87 +/- 1.58	>
Bulk density (g/cm^3)	<	1.50 +/- 0.05	<
Precompression stress (kPa)	<	84.65 +/- 31.66	<

These thresholds are, however, gained from a very simple statistical analysis where, in particular, independence of the variables is supposed. This independence between the different soil parameters holds not true for the experts' judgments. Discriminant analysis revealed more precise distinction, if the data records were grouped by the experts, than if they were grouped by statistical cluster analysis after the most important parameters. Hence, it has to be assumed that the experts account for interdependencies between the soil parameters and also for possible compensatory effects, if not all the decisive parameters show critical values.

The next step in this study is a more comprehensive analysis of the experts' judgments that may allow for interdependencies by applying fuzzy set approaches. The purpose is to check, if the thresholds mentioned above have to be corrected essentially, and to derive evaluation rules that include several parameters.

Control of extreme moisture events and soil degradation processes as priority tasks of soil conservation in the Carpathian Basin

Várallyay, Gy.[1]

The most important element of **sustainable development** in the **Carpathian Basin** is the **rational use and conservation of soil resources and ecosystems** (the geological strata–soil–water–biota–plant–near surface atmosphere continuum), maintaining their favourable „quality" and their desirable **multifunctionality** (Várallyay, 2000c, 2003)**.** This is the main goal of social and agricultural development, soil conservation, water management, environment protection and rural development and the joint responsibility of the state, land owners and land users, requiring priority attention and full support from the whole society.

The natural conditions (climate, water, soil and biological resources) of the Carpathian Basin (particularly the lowlands and plains) are *generally favourable* for rainfed biomass production (Láng et al., 1983). These conditions, however, show extremely high spatial and temporal **variability,** often **extremes,** and sensitively react to various natural or human-induced **stresses.** The generally favourable agro-ecological potential is limited by three soil factors:

(1) Soil degradation processes;
(2) Extreme moisture regime;
(3) Unfavourable biogeochemical cycles of elements (plant nutrients and pollutants).

Limiting factors of soil fertility and soil degradation processes

There are large territories in the Carpathian Basin where the multifunctionality of soil is threatened and its fertility/productivity is limited by various soil properties and unfavourable/harmful soil degradation processes.

The limiting factors of soil fertility are shown in Figure 1, their territorial data are summarized in Table 1 (Szabolcs & Várallyay, 1978).

In the Carpathian Basin the most important soil degradation processes are as follows (Várallyay, 1989, 2000b):

(1) Soil erosion by water or wind.
(2) Soil acidification.
(3) Salinization/alkalization/sodification.
(4) Physical soil degradation, such as structure destruction, com-paction, surface sealing, etc.
(5) Extreme moisture regime: (sometimes) simultaneous hazard of overmoistening, waterlogging and drought-sensitivity;
(6) Biological degradation, such as unfavourable changes in soil biota, decrease in soil organic matter.
(7) Unfavourable changes in the biogeochemical cycles of ele-ments, especially in the regime of plant nutrients, such as leaching; volatilization; biotic and abiotic immobilization.
(8) Decrease in the buffering capacity of soil, soil pollution, environmental toxicity.

In the last years the revolutionary development of in situ and laboratory analytics, remote sensing, informatics, computer technology, GIS/GPS applications, etc. give opportunity for the organization of all available **soil information** into a well-structured up-to-date **soil database.** On this basis the **„environmental sensitivity/susceptibility/vulnerability"** of soils against these soil degradation processes were comrpehensively analyzed and thematic maps were prepared expressing this character (Szabó et al., 1998; Várallyay, 1998, 2000a,b; Várallyay et al., 1979/1980).

Extreme moisture regime

It can be forecasted with high probability that in future water will be the determining (hopefully not limiting) factor of food security and environmental safety in the Carpathian Basin (Somlyódy, 2000; Várallyay, 2001). Consequently, the increase in water use efficiency will be one of the key issues of agricultural production, rural development and environment protection and the control of soil moisture regime will be an imperative task without any other alternatives.

[1] Research Institute for Soil Science and Agricultural Chemistry (RISSAC) of the Hungarian Academy of Sciences, H-1022 Budapest, Herman Ottó út 15. Hungary, Phone/Fax: (36-1) 3564-682; E-mail: g.varallyay@rissac.hu

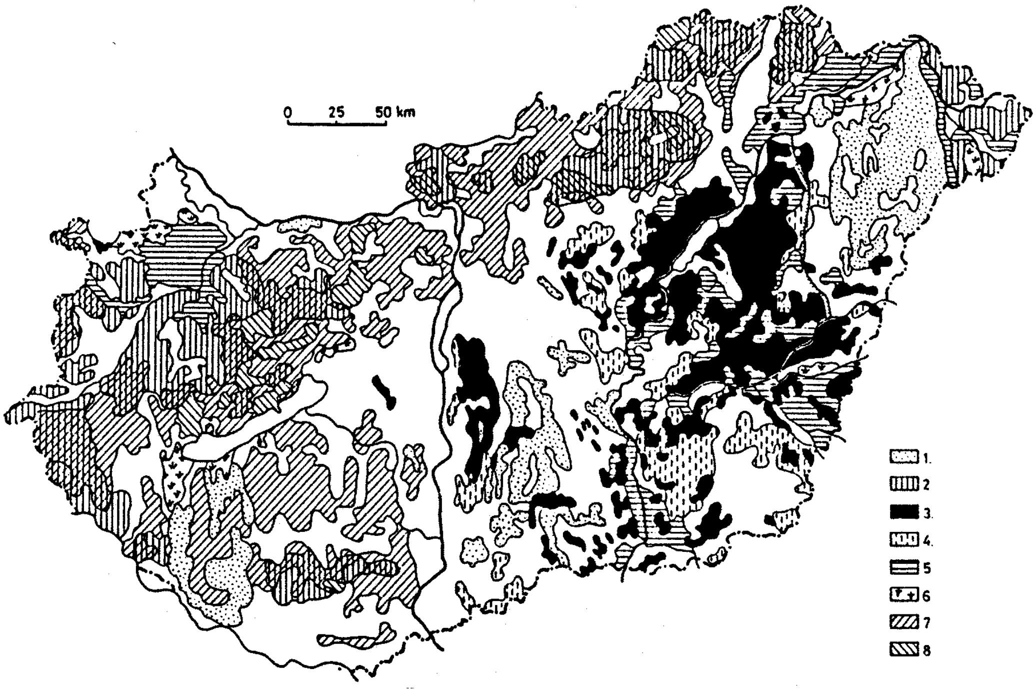


Figure 1. Map of the limiting factors of soil fertility in Hungary.
1. Extremely coarse texture. 2. Acidity. 3. Salinity and/or alkalinity. 4. Salinity and/or alkalinity in the deeper layers. 5. Extremely heavy texture. 6. Waterlogging. 7. Erosion. 8. Shallow depth.

Table 1. Limiting factors of soil fertility and soil degradation processes in Hungary

	Limiting factor of soil fertility	Area, 1000 ha	%		Soil degradation processes
1.	Extremely coarse texture	746	8.0	1.	Soil erosion: - by water
2.	Soil acidity	1200	12.8		- by wind
	- combined with erosion	(348)	(3.7)	2.	Soil acidification
	- combined with shallow depth	(67)	(0.7)	3.	Salinization/alkalization
3.	Salinity/alkalinity	757	8.1	4.	Physical soil degradation
4.	Salinity/alkalinity in the deeper layers	245	2.6		- structure destruction - compaction
5.	Extremely heavy texture	630	6.8		- surface sealing
6.	Peat formation, waterlogging	161	1.7	5.	Extreme moisture regime
7.	Soil erosion	1455	15.6		- overmoistening, waterlogging
	- combined with acidity	(348)	(3.7)		- drought sensitivity
8.	Shallow depth	217	2.3	6.	Biological degradation
	- combined with acidity	(67)	(0.7)		- decrease of organic matter
					- deterioration of soil biota
				7.	Unfavourable changes in the nutrient regime
					- leaching
					- biotic and abiotic immobilization
				8.	Decrease of the buffering capacity, soil pollution, „toxicity”

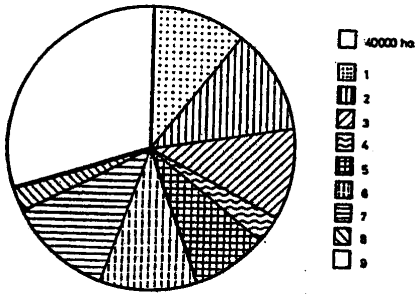
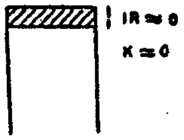


Figure 3. Distribution of soils according to their moisture regimes in Hungary.

1–5 = Soils with unfavourable hydrophysical properties (43%): 1: due to very coarse texture (10.5%); 2: due to very heavy texture (11%); 3: due to strong salinity-alkalinity (10%); 4: due to waterlogging (3%); 5: due to shallow depth (8.5%); 6–8 = Soils with moderately unfavourable hydro-physical properties (26%): 6: due to coarse texture (11%); 7: due to heavy texture or clay accumulation in the B-horizon (12%); 8: due to moderate salinity/ alkalinity in the deeper layers (3%); 9 = Soils with good hydrophysical properties (31%)

1. Limited infiltration, shallow wetting zone

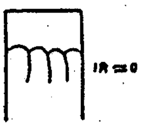
A) Impermable layer (crust) on the soil surface



a) cemented by salts
- Na salts
- gypsum

b) compacted by improper soil manage-ment
- over-tillage, heavy machinery
- improper irrigation methods

B) Impermeable layer near to the soil surface

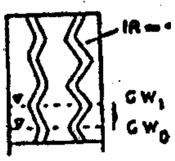


a) solid rock
b) hardpans (fragipans, duripans, orstein,ironpan etc.)
c) layer cemented by exch. Na^+, clay, $CaCO_3$ and other factors (clay-pan, concretionary horizons, petrocalcic horions, etc.)
d) layer compacted by improper soil management (plough pans, etc.)

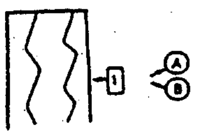
⇒ extreme water regime

[oversaturation (aeration problems) | waterlogging problems
[surface runoff – water erosion
drought sensitivity

2. Cracking (swelling-shrinkage phenomena)



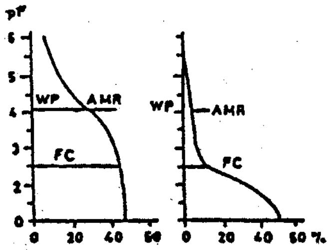
Dry conditions (shrinkage, cracking)
→ filtration losses
→ rising water table
→ too wet conditions (oversatura-tion, water-logging)
→ secondary salinization/alkali-zation from the groundwater (in case of stagnant, saline or alkaline groundwater)
→ evaporation losses (drying of deep layers)



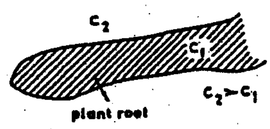
Wet conditions (swelling)

a) high amount of clay
b) high amount of expanding clay minerals
c) high ESP

3. Low availability of soil moisture

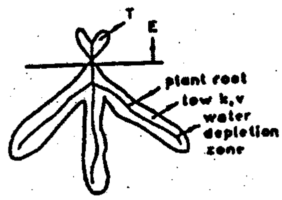


1. Low AMR (FC–WP) (as a result of matrix suction, p)
a) high clay content
b) high rate of dispersion
c) high alkalinity, ESP
d) poor structure
e) too low clay content



2. Low AMR (as a result of high osmotic potential, ψ)

a) high salinity
$\psi_s = 0.32\ (0.8+0.109\ C_l)^{1.03}$
$C_l = Cl^-$ conc., meq/litre



3. Low transmissability coefficients (k, D)

wilting: V < ET

a) low moisture content
b) high water retention
c) high alkalinity, ESP
d) poor structure

Figure 4
The main reasons and consequences of extreme soil moisture regime

Water resources are limited (Somlyódy, 2000; Várallyay, 2001). The increasing water demand must be satisifed from these limited resources. The average 450–600 mm **annual precipitation** may cover the water requirement of the main crops even at high yield levels. But the average shows **extremely high territorial and temporal variability** – even at micro-scale. Under such conditions a considerable part of the precipitation is lost by surface runoff, downward filtration and evaporation. Annual precipitation will not be more in the future (on the contrary, it might be less according to the forecast climate change, characterized by increasing temperature and aridity) and its unfavourable territorial and time distribution will not turn better. On the contrary, an opposite tendency has been forecast: **increasing risk** (frequency, intensity) of extreme weather events and soil moisture situations. The available quantity of **surface waters** (rivers) will not increase, particularly in the critical low-water periods. A considerable part of the **subsurface waters** (especially in the lower parts of the Basin) cannot be used for irrigation because of their poor quality (salinity, alkalinity, sodicity). Another part is not utilizable because of environment control regulations preventing the lowering of the water table and its unfavourable ecological consequences (e.g. the serious „desertification symptoms” in the Danube–Tisza Interfluve sand plateau).

In addition to the hardly predictable atmospheric precipitation pattern, the two additional reasons of **extreme soil moisture regime** (the simultaneous hazard of waterlogging or overmoistening and drought sensitivity) are:

- the heterogeneous microrelief of the „flat” lowland;
- the highly variable, sometimes mosaic-like soil cover and the unfavourable physical and hydrophysical properties of some soils (mainly due to heavy texture, high clay and swelling clay content, or high sodium saturation: ESP).

According to our comprehensive assessment (Várallyay, 1985; Várallyay et al., 1980) 43% of Hungarian soils can be characterized by unfavourable, 26% by moderately (un)favourable and 31% by favourable moisture regime, as illustrated by Figure 3, indicating the main reasons of various moisture conditions.

The main reasons and consequences of **extreme soil moisture regime** are summarized in Figure 4 (Várallyay, 2001).

Because of these reasons sustainable land use and site-specific soil management, yield stability, risk reduction, soil conservation, and the prevention, elimination or moderation of extreme moisture situations have great significance and **soil moisture control** is of primary importance in the Carpathian Basin.

The main possibilities and methods of this moisture control are summarized in Table 2. Most of these „moisture management actions” are – at the same time – efficient environment control measures.

Table 2. Elements and methods of soil moisture control with their environmental impacts

Elements		Methods	Environ-mental impacts*
Reducing	surface runoff	Increase in the duration of infiltration (moderation of slopes; terracing contour ploughing; establishment of permanent and dense vegetation cover; tillage; improvement of infiltration; soil conservation farming system)	1,1a 5a, 8
	evaporation	Helping infiltration (tillage, deep loosening) Prevention of runoff and seepage, water accumulation	2,4
	feeding of ground-water by filtration losses	Increase in the water storage capacity of soil; moderation of cracking (soil reclamation); surface and subsurface water regulation	5b, 7
	rise of the water table	Minimalization of filtration losses (↑); groundwater regulation (horizontal drainage)	2,3 5b,5c
In-creas-ing	infiltration	Minimalization of surface runoff (tillage practices, deep loosening) (↑)	1,4,5a, 7
	water storage in soil in available form	Increase in the water retention of soil; adequate cropping pattern (crop selection)	4,5b,7
Irrigation		Irrigation; groundwater table regulation	4,5c,7, 9,10
Surface } drainage Subsurface		surface } moisture control (drainage) subsurface	1,2,3,5c,6,7 11

Favourable environmental effects	Unfavourable environmental effects
Prevention, elimination, limitation or moderation of: – water erosion (1) – sedimentation (1a) – secondary salinization, alkalization (2) – peat formation, waterlogging, overmoistening (3) – drought sensitivity, cracking (4) – plant nutrient losses by: – surface runoff (→ surface waters eutrophication) (5a) – leaching (→ subsurface waters) (5b) – immobilization (5c) – formation of phytotoxic compounds (6) – "biological degradation" (7) – flood hazard (8)	– overmoistening, waterlogging, peat and swamp formation, secondary salinization/ alkalization (9) – leaching of plant nutrients (10) – drought sensitivity (11)

Conclusions

Sustainable land use and rational soil management, including an up-to-date soil moisture control requires continuous actions. This permanent control may prevent, eliminate or at least reduce undesirable soil processes and their harmful economical/ecological/environmental/social consequences; utilizing the unique soil characteristic, **resilience**, may satisfy the conditions for the „quality maintenance" of this „conditionally" renewable natural resource.

Control can be efficient only on the basis of comprehensive **risk assessments, impact analyses** and exact **prognoses.** These have to be the main research priorities!

The realization of the **sustainability concept** in the rational land use and soil management gives reality for a better life: healthy, good quality food, clean water and pleasant environment.

References

Láng I., Csete L. & Harnos Zs., 1983. [The agro-ecological potential of Hungary]. (H] Mezőgazdasági Kiadó. Budapest.

Somlyódy L., 2000. [Strategy of water management in Hungary]. [H] „Magyarország az ezredfordulón" – Stratégiai kutatások a Magyar Tudományos Akadémián. MTA Vízgazdálkodási Tudományos Kutatócsoportja, Budapest. 370 pp.

Szabó, J., Pásztor, L., Suba, Zs. & Várallyay, Gy., 1998. Integration of remote sensing and GIS techniques in land degradation mapping. Agrokémia és Talajtan. 47. 63–75.

Szabolcs I. & Várallyay Gy., 1978. [Limiting factors of soil fertility in Hungary]. [H, e] Agrokémia és Talajtan. 27. 181–202.

Várallyay Gy., 1985.[Soil moisture and substance regime types in Hungary]. (H, e] Agrokémia és Talajtan. 34. 267–298.

Várallyay, Gy., 1989. Soil degradation processes and their control in Hungary. Land Degradation and Rehabilitation. 1. 171–188.

Várallyay Gy., 2000a. [Scientific control of soil processes] [H] Székfoglalók 1995–1998. III. kötet. 1–32. Magyar Tudományos Akadémia. Budapest.

Várallyay, Gy., 2000b. Risk assessment and prevention of soil degradation processes in Hungary. In: Foresight and Precaution. (Eds.: Cottam, Harvey, Pape & Tait). 563–567. Balkema. Rotterdam.

Várallyay, G., 2000c. Soil quality in relation to the concepts of multifunctionality and sustainable development. In: Wilson, M. J., Maliszewska–Kordybach, B.: Soil quality, Sustainable Agriculture and Environmental Security in Central and Eastern Europe. NATO Sci. Ser. 2. Env. Security. Vol. 69. 17–33. Kluwer Acad. Publishers.

Várallyay Gy., 2001. [Soil water regime and the environment] [H] Magyar Tudomány. XLVI. (7) 799–815.

Várallyay Gy., Szűcs L., Murányi A., Rajkai K. & Zilahy P. 1979. [1:100 000 scale map of the soil factors determining the agro-ecological potential of Hungary] [H, e] I. Agrokémia és Talajtan. 28. 363–384. II. Agrokémia és Talajtan. 29. 35–76.

Várallyay Gy., Szűcs L., Rajkai K., Zilahy P. & Murányi A., 1980. [1:100 000 scale map of the hydrophysical properties of Hungarian soils] [H, e] Agrokémia és Talajtan. 29. 77–112.

Anthropogenic soils originated by severe disturbances due to large scale farming

Dazzi, C.[1] – Monteleone, S. – Scalenghe, R.

Abstract

Due to the anthropic pressure, many areas of the world are concerned by a process of soil "entisolization" that lead to the formation of "anthropogenic soils". Obviously the problem cannot be simply ascribed to consumerist lifestyles but to the energetic availabilities which allow for the use of greater and greater land surfaces. In many cases the activities that more than others threaten pedodiversity are linked to agriculture.
In order to investigate the main physical, chemical and morphological features of "anthropogenic soils" in relation to some adjacent "natural soils", a survey was carried out in a particularly significant area of South-Eastern Sicily where for many years now, there have been wide areas with anthropogenic soils due to large scale farming. Here, in a vineyard area, an anthropogenic soils toposequence was compared with a natural one.

Compared with the natural soils, classified as Entic Haploxerolls and showing a well developed soil profile, the "anthropogenic soils" surveyed show soil profiles in which it is impossible to describe any predictable pattern of organic and mineral elements. Miscic Fragmexerant is a proposal for their tentative classification following the Soil Taxonomy philosophy.

Key-words: anthropogenic soils, Anthrosols classification, Soil Taxonomy, Sicily

Introduction

Traditionally, climate, organisms, relief, parent material and time are the external factors of soil formation that drive the pedogenetic processes within the soil. Human action is considered a soil-forming processes in the sense that man can create new soils and destroy existing ones. In this sense the anthropogenic soil-forming processes can be define as those actions by humans that modify and control soil-forming processes and that can be grouped into physical alteration, hydrologic alterations and geochemical alteration (Bryant & Galbraith, 2003).

From a pedogenetic point of view, the destruction and/or the construction of soil through physical manipulation of "earthy materials", are catastrophic events that reduce the soils to time zero, and the area of the newly created soils is often as large as the area of well developed soils that have been destroyed (Fanning & Fanning, 1989). These are the most remarkable effects of the construction of roads and motorways, or of the burial of various kinds of waste. There are, however, examples which are less striking, but just as dangerous for the protection of the soilscapes such as the case of soils created by large scale farming.

Although many processes related to long-term agricultural use have deeply influenced soil properties over a time scale of a few thousand years, these anthropogenic processes are relatively fast-acting, compared to natural processes of soil formation (Bryant & Galbraith, 2003).

The aims of this study were to i) investigate the main physical, chemical and morphological features of a sequence of "anthropogenic soils" in relation to a comparable sequence of "natural soils"; and ii) propose a tentative classification of such anthropogenic soils, following the Soil Taxonomy philosophy (Soil Survey Staff, 1999).

The study area

The study area is located within the Mazzarrone city limits. Mazzarrone is a small town, in the South-East of Sicily, Italy (37.0849°N, 14.5590°E), in an internal zone with an altitude ranging between 115 and 335 meters a.s.l.. The landscape is characterized by a quite level morphology, in which it is possible to point out the superimposition of the anthropic effects on natural processes. Pleistocene and Holocene rocks outcropping (Dazzi & Monteleone, 2002), are made up of less than 10 meters of clay and sandy-clays; 20 meters of fossiliferous yellowish sandstones; 15 meters of fine quartzose sands with intercalations of well-cemented arenaceous levels; and finally 8 meters of bad cemented sands with intercalations of gravels and clays. These lithologies were deposited in a marine paleo-environment and covered by a continental deposit made up of lacustrin deposits less than 5 meters thick and fluvial deposits found along the main river beds.

On these substrata developed soils which, on the more stable surfaces, were made up of Calcic, Inceptic, Mollic and Typic Haploxeralfs together with Entic Haploxerolls. The less stable surfaces on moderately steep slopes, showed Calcic, Humic and Typic Haploxerepts. The steeper surfaces and the slope side of the stream valleys, were (and in some cases still are), characterized by Typic Xerorthents. The bottom valleys were

[1] Dipartimento di Agronomia Ambientale e Territoriale - Università di Palermo, Viale delle Scienze, Palermo 90128, Italia. Tel.: +39.0916650247; Fax: +39.0916650229; E-mail: dazzi@unipa.it

characterized by Typic and Vertic Xerofluvents and by Typic Haploxererts. Nowadays most of these soils do not exist at all, substituted by anthropogenic soils due to farming management for vineyard cultivations (Dazzi & Monteleone, 2002).

In this environment vineyards have spread copiously between 1981 and 1987, producing a large increase of the *pro capite* income. At present, most of the farms in that area, are vine growing, favored also by the climate that highlighting (data recorded in Vittoria, south of Mazzarrone) average monthly temperature that reaches a maximum of 25,5°C in August and a minimum of 10,3° in January, with average rainfalls of 452 mm, can be defined Mediterranean.

Anthropic action in land transformation

In the Mazzarrone area, land evolution and the elements that characterize it (particularly the soil), have to be considered on the basis of a comprehensive analysis of the factors that influence the environment. For this reason, we must consider man's action as a pedogenetic factor that, in the social and economic context of the area, directly modifies and alters the landscape and the soils.

From the data available and according to the Potential Vegetation Map of Sicily (Gentile, 1968), it can be reasonably supposed that a great part of the Mazzarrone area was once covered by oak and maquis (dominated by *Ceratonia siliqua*, *Pistacia lentiscus*, *Laurus nobilis*, *Olea europaea*, *Rhamnus alaternus* and *Pistacia terebinthus*). Statistical data and aerial photos show that land use in the 60's was mainly arable land and olive groves. Wine growing spread rapidly during the 70's, while the period of economic explosion was in the 80's, when cultivation started to be converted everywhere (Lo Verde, 1995). Arable land, almond-yards, olive groves and natural grazing were replaced by vineyards with a frequency not easily measurable and with a consistent and evident transformation of the landscape. Such large scale farming was achieved through very deep ploughing, excavations, land levelings and trenchings. In many cases, big amounts of "white earthy materials", that allow for a qualitative improvement of the grapes, (Sottile, pers. com.) were spread over by trucks.

Materials and methods

For the purposes of this study, two fields were selected in North-East Mazzarrone. The first, 200 by 40 meters, had been uncultivated for many decades as is testified not only by the presence of old carob and olive trees but also by the owners. The second, 200 by 60 meters, was converted to vineyards in the 80s. In each of these areas a soil sequence made up of three pedons was investigated. The soil sequences were South-East North-West oriented. The pedons were described to a depth of 100/140 cm and sampled according to USDA-NRCS (2002) and to the ICOMANTH circular letter n° 4 (2003). Samples were air dried and 2 mm sieved for laboratory analysis.

Results

Main features of pedons

In tables 1a and 1b the main morphological features of the pedons surveyed are listed. In general in the anthropogenic pedons the evidence of human activity is often expressed in the lack of horizonation, altered chemistry or difference in landform relative to surrounding parent material.

Table 1a. Main morphological features of natural pedons

Pedon	horizon	cm	[1]MC	[2]S	[3]C	[4]R	[5]RF	[6]$CaCO_3$	[7]B
10	A	0-20	10YR3/3	sb,fm, 4	eh-sh	c, fi	c, me, r	2a	cl
	A&C	20-35	10YR4/2	sb, fm, 4	eh-sh	c, fi	c, me, r	2a	cl, s
	C	> 35	2.5Y8/2	-	-	-	-	-	-
11	A1	0-28	10YR3/2	sb, mc, 4	sh,	c, fi	f, b, r	-	gr, s
	A2	28-45	7.5YR3/2	sb, mc, 4	f, sh	c, fi	-	-	cl, s
	Bw	45-58	7.5YR4/2	sb-ab, m, 4	eh	f, fi	-	4b	cl, s
	BCk	58-68	10YR6/3	sb-ab, fm, 3	sh	-	-	4b	cl, s
	C	> 68	10YR8/3	-	-	-	-	-	-
12	A	0-25	10YR4/2	sb, fm, 4	eh	c, fi	f, me, r	2a	cl, s
	AC	25-40	10YR6/2	sb, fm, 3	sh	c, fi	f, me, r	4b	ab, w
	C	> 40	2.5Y8/2	-	-	-	-	-	-

[1]**MC** Munsell dry color; [2]**S** structure: g=granular; sb=subangular blocky, ab=angular blocky, pr=prismatic, p=platy, sg=single grains; ma=massive; f=fine, m=medium, c=coarse; 2=weak; 3=moderate; 4=strong; [3]**C** consistence: f= friable; sh= slightly hard, eh=extremely hard; fi=firm; vf=very firm; ef=extremely firm, [4]**R** roots: a=absent; f=few; c=common; fi=fine, [5]**RF** rock fragments: a=absent; f=few; c=common, me=medium; c=coarse; s=small; fl=flat, r=rounded, [6]**$CaCO_3$** concretions: 1=absent, 2=few, 3=common, 4=abundant; a=fine, b=medium, C=coarse; [7]**B** boundary: ab=abrupt, cl=clear, gr=gradual; s=smooth, w=wavy, ir=irregular.

Only some of the chemical properties (data not shown) differentiate the natural and anthropogenic soils. The clay, ranging from 15 to 38%, if seen as mean weighed over horizon depth, is similar in anthropogenic (24%) and natural (21%) soils. Soil reaction was totally unaffected: anthropogenic/natural covariance accounts for 0.00, in both pH (H_2O and $CaCl_2$). Human disturbances considerably affect organic carbon and carbonates: organic C, ranging from 0.01 to 1.87 g kg^{-1}, results in a mean weighed over horizon depth, respectively 0.18 g kg^{-1} (anthropogenic) and 1.39 g kg^{-1} (natural) while total carbonates 593 g kg^{-1} (anthropogenic) and 377 g kg^{-1} (natural). The active carbonates/total carbonates ratio which would indicate an increased Ca^{2+} availability, is not affected if considered as weighted over horizon depth. The CEC is lowered by anthropic activities from 23 to 16 $cmol_c^+$ kg^{-1} and the exchangeable Na^+ ratio increases (from 0.9 to 1.3).

Table 1b. Main morphological features of anthropogenic pedons

Pedon	horizon	cm	[1]MC	[2]S	[3]C	[4]R	[5]RF	[6]$CaCO_3$	[7]B
	HA1	0-20	2.5Y8/2	ab, m,3	fi	f, m	a	4a	cl, s
	HA2	20-50/70	5Y7/4	ab, m,3	fi	f, m	a	4b	gr, ir
7	2Apb1	70-100	10YR5/2	g&sb, fmc, 3	f	c, fim	c, s, r	2a	cl, ir
	2Apb2	100-140	10YR6/4	sb, mc, 3	f	c, fim	c, me&c, r	2a	cl, ir
	2C	> 140	10YR3/3	sb-ma, mc, 2	f	-	a	4c	cl, s
	HA1	0-20	2.5Y7/4	ab-sb, mc, 3	sh.eh	f,fi	a	4c	cl, s
	HA2	20-45	2.5Y7/2	p,fm,2	f	f,fi	a	4c	ab,ir
8	HA3	45-70	2.5Y7/2	ab, fm, 2	f	f,fi	a	4c	ab,s
	2HA	70-90	10YR5/4	ab, m,4	eh	c, fim	a	4c	ab,ir
	3HA	90-130	2.5Y7/4	ab, f, 2/3	f, sh	f, fi	f,me,r	4c	ab, ir
	C	> 130	-	-	-	-	-	4c	-
	HA1	0-27	2.5Y7/2	ab, mc, 3	ch	a	c, me	3	ab, m
	HA2	27-45	2.5Y8/2	sg, f, 2	f	a	c, me	3	ab,s
9	2HA1	45-90	10YR4/2	ab, fm, 2	f	fi	c, me	4b	gr, s
	2HA2	90-130	10YR5/3	ab, fm, 2	f	fi	c, me	4b	gr, s
	3Bk	> 130	10YR5/3	ab, fm, 3	fi	fi	c, cm	4b	-

[1]**MC** Munsell dry color; [2]**S** structure: g=granular; sb=subangular blocky, ab=angular blocky, pr=prismatic, p=platy, sg=single grains; ma=massive; f=fine, m=medium, c=coarse; 2=weak; 3=moderate; 4=strong; [3]**C** consistence: f= friable; sh= slightly hard, eh=extremely hard; fi=firm; vf=very firm; ef=extremely firm, [4]**R** roots: a=absent; f=few; c=common; fi=fine, [5]**RF** rock fragments: a=absent; f=few; c=common, me=medium; c=coarse; s=small; fl=flat, r=rounded, [6]**$CaCO_3$** concretions: 1=absent, 2=few, 3=common, 4=abundant; a=fine, b=medium, C=coarse; [7]**B** boundary: ab=abrupt, cl=clear, gr=gradual; s=smooth, w=wavy, ir=irregular.

Taxonomic aspects

Following Soil Taxonomy (Soil Survey Staff, 1999), the "natural soils" we studied, can be classified as Entic Haploxerolls. Really, all the pedons that form the sequence of the natural soils, which evolve in a xeric environment, show a surface horizon that meet all the requirements of a mollic epipedon. Moreover (Soil Survey Staff, 1999) they are characterized by little development in the subsoil, lie on late-Pleistocene deposits and have free carbonates throughout the cambic horizon (as in pedon 11) or in all parts of the mollic epipedon below a depth of 25 cm from the mineral surface (as in pedons 10 and 12).

The question that arose when considering the anthropogenic soils was: "are these soils to be regarded as Anthrosols or should they be considered as Entisols"?

According to the sixth attribute of Soil Taxonomy (Soil Survey Staff, 1999, pag. 16b), "*significant changes in the nature of the soil by humans cannot be ignored*". This is particularly true in our case where the soils prepared for the vineyard cultivation were so deeply disturbed not only putting a *stratum* (30-50 cm) of marly limestone on a pre-existing deeply ploughed anthropogenic soil but, also, mixing again with the aid of heavy machinery the so-constructed soil to a depth of 110/120 centimeters.

This way of soil-building excludes the possibility of classifying such soils as Arents. Soil Taxonomy states that Arents are soils which have fragments (3 percent or more) of diagnostic horizons that are not arranged in any discernible order and in our case this requirement is not met.

As a consequence and following the criteria of Soil Taxonomy, the anthropogenic soils we surveyed, should be classified in a new soil order (Table 2). We propose they be called ***Anthrosols***, as in another well known soil classification system (FAO/ISRIC/ISSS, 1998).

If we consider "*ant*" as the "formative element" in the name of this new soil order (ant, from Greek *anthropos*=man) and bearing in mind that the pedoclimatic features of our study area are of Mediterranean type, at suborder level we can classify our soils as ***Xerants***.

Moreover, considering that such soils are made up of a mixture of inorganic materials (mainly marly limestone) transported and deposited through earth excavations which cover a pre-existing very deeply anthropoturbated material, ***Fragmexerant*** could be the most suitable name at Great Group level (from Latin *fragmenta*=spoils). Finally, considering that, before the vineyard plantation, the soils are mixing to a depth of 110-120 cm with the aid of heavy machinery, at Sub-Group level they can be regarded as ***Miscic Fragmexerant*** (from Latin *miscere*=to mix) meaning that such anthropogenic soils are characterized by anthropoturbated materials in the whole profile (ICOMANTH circular letter n° 2, 1997).

Table 2. Proposed nomenclature with formative elements for the anthropogenic soils surveyed.

Category	Name	Formative element	Connotation
Order	ANTHROSOLS (from Gr. *anthropos*, meaning man)	Ant	Soils built or strongly influenced by human activity
Suborder	XER-ANT	Xer (from Gr. *xeros*, meaning dry)	Anthrosols with a xeric moisture regime
Great Group	FRAGME-XERANT	Fragme (from L. *fragmenta*, meaning spoils)	Anthrosols formed on or with mineral materials that have been moved by earthmoving equipment. Landscapes are human formed.
Subgroup	MISCIC FRAGMEXERANT	Miscic (from L. *miscere*, meaning to mix)	Anthrosols formed on or with mineral materials that have been moved by earthmoving equipment and that have been deeply mixed with heavy machinery for farming purposes.

Conclusion

Due to the anthropic pressure, many areas of the world are affected by a process of soil "entisolization" that leads to the formation of "anthropogenic soils". In many areas of the Southern Mediterranean basin such a process is linked to large scale farming for vineyard cultivation. In central and South-East Sicily, in particular, the farmers create anthropogenic soils by radically reshaping the landscape in order to obtain new areas for vineyard cultivation.

According to the ICOMANTH circular letter n° 1 (1995), the processes that influence the anthropogenic soils we surveyed could be seen as "anthropogeomorphic processes" because the human activity on the soils is constructive in that pre-existing anthropogenic soils set aside for vineyards, are first covered with a 30-50 cm stratum of white marly limestone and then deeply ploughed to a depth of 110-120 cm. For these reasons it is impossible to describe any logical pattern of organic and mineral elements along the profile and their chemical-physical features are very variable.

Following the rules of Soil Taxonomy they can be tentatively classified as Miscic Fragmexerants meaning that such soils are Anthrosols, in a xeric environment, formed on or with mineral materials that have been moved by earthmoving equipment and that have been deeply mixed with heavy machinery for farming purposes.

Acknowledgements

This work was funded by MIUR "Indicatori chimici, fisici, mineralogici e biologici della qualità e dell'evoluzione dei suoli antropogenici" (COFIN 2002). The authors wish to thank L. Badalucco, V.A. Laudicina, G. Lo Papa, S. Parisi, M. Sabatino and C. Territo for their valuable help during the field work and E. Bazan, E. Palazzolo, M. Panno for the analytical work.

References

Bryant R.B., Galbraith J.M. (2003) - *Incorporating anthropogenic processes in soil classification*. In: Eswaran, et al. (Eds) Soil Classification. A global desk reference. CRC Press, Boca Raton,FL-USA

Dazzi C., Monteleone S. (2002) - *Emergenza suolo e antropizzazione del territorio: un esempio di perdita della pedodiversità per entisolizzazione*. Atti del Convegno "L'emergenza suolo". Boll. SISS, n°51, pp. 557-570.

Fanning D.S., Fanning M.C. (1989) – *Soil: Morphology, Genesis and Classification*. Wiley & son, Chicester UK

FAO/ISRIC/ISSS (1998) - *World Reference Base for Soil Resources*. World Soil Resources Rep. n.84, Roma

Gentile S. (1968) - *Memoria illustrativa della Carta della Vegetazione Naturale Potenziale della Sicilia* (1ª appross.). Quaderno 40. Ist. Bot. Univ. Lab. Crittog., Pavia

ICOMANTH (1995-1999) - *Circular letters n°1-3*, clic.cses.vt.edu/icomanth/03-AS_Circulars.pdf [verified on February 18, 2004]

ICOMANTH (2003) - *Circular letter n°4*, clic.cses.vt.edu/icomanth/circlet4.pdf [verified on February 18, 2004]

Lo Verde M.F. (1995) - *Agricoltura e mutamento sociale. Analisi di un caso siciliano*. Harmattan

Soil Survey Staff (1999) - *Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys.* 2nd ed. Agriculture handbook n° 436, Washington D.C.-USA

USDA-NRCS (2002) – *Field book for describing and sampling soils*, Version 2.0. Schoeneberger et al. (Eds). Lincoln, NE-USA.

Soil inorganic carbon in benchmark forest soils of Mediterranean environment: a case study from Sicily

Laudicina, V.A.[1] – Pisciotta, A. – Territo, C.

Abstract

Authors report on soil carbon distribution and pools of inorganic carbon in benchmark forest soils of a Mediterranean environment. The study was carried out in a representative forest ecosystem of internal hilly clayey area of central Sicily. Along a slope 100 minipit were described, sampled and analyzed to surveyed inorganic and organic carbon. Moreover, for three selected soil profiles, isotopic analysis were carried out to differentiate pedogenic and lithogenic inorganic carbon. Results show a great variability along the slope of inorganic and organic carbon. Soil inorganic carbon concentrations are higher in the central part of the slope where clays and marly clays constitute the parent materials, while soil organic carbon concentration, that is higher at the top and at the bottom of the slope, may be correlated to vegetation type. Moreover, results from isotopic analysis show that the amount of pedogenic and lithogenic inorganic carbon is different among surveyed pedons, reasonably due to different parent materials and landforms.

Keywords: pedogenic and lithogenic soil carbon, stable C isotope, Mediterranean environment, Sicily.

Introduction

Soil carbon has been traditionally studied due to its role in functioning of soils. Recently such studies have been complemented by others related to biogeochemical processes affecting carbon fluxes (Schlesinger, 1997).

Soil carbon is the greatest reserve of carbon in the terrestrial ecosystem. There are two types of soil carbon pools: soil organic carbon (SOC) and soil inorganic carbon (SIC). The SOC is the predominant pool in soils of humid regions, whereas SIC is the most common form of C in arid and semi-arid climates. Many studies suggest that SIC exceeds organic carbon by a factor of >10 in arid regions and of >2-5 in semiarid regions (Lal et al., 2000). While the importance of SOC in global carbon cycling and the dynamics with the changing environment have been recognized (Bajracharya et al., 1996), few studies have been performed on SIC. SIC significance in terrestrial carbon transfer and its role in soil carbon sequestration has been poorly understood (Pan and Guo, 2000). This is due not only to the lack of data but also to the inability to differentiate (mainly in calcareous soils) between the presence of primary and secondary origin of carbonate, i.e. lithogenic and pedogenic carbon respectively. The aims of this work were (i) to estimate the SIC amount and its distribution in benchmark forest soils and (ii) to differentiate lithogenic and pedogenic SIC.

Materials and methods

Study area

The survey was carried out in a representative forest ecosystems of an internal hilly clayey area of central Sicily. Within it was choosen a hillslope of about 200 hectares and facing S.E. (fig. 1), showing an average gradient of about 10 % and rising from 250 m to 485 m a.s.l.. Its land use is represented by woodland, mainly with *Eucalyptus camaldulensis* but also with *Eucalyptus occidentalis*, *Pinus halepensis*, *Pinus pinea* and *Cupressus sempervirens*. The climate is characterized as Mediterranean with cool to cold, wet winters and warm to hot, dry summers. Climatic data from 1985 to 2003 (climatic records in the area started in 1985), show a mean annual air temperature of 17.3 °C and a mean annual rainfall of 460 mm. Considering the "normal year" as defined in Soil Taxonomy (Soil Survey Staff, 1999), only for the eighteen years of climatic records which are available for the area, the soil udometric regime is "xeric" and the thermometric regime is "thermic".

In this area, deposits from Tortonian to Holocene in age outcrop. The oldest are sand-clays and marl-clays from Tortonian "Terravecchia" Fm. To these follow selenitic gypsum and laminitic gypsum gradually passing to gypsarenites of the Messinian "Gessoso-Solfifera" Fm.. The youngest deposits (Holocene in age) outcrop at the top of the slope and are colluvial deposits made up by clays, marly-clays and silts, accumulated on gypsum in a continental environment (Dazzi and Monteleone, 2001).

b. Laboratory methods

On the basis of a technique of optimizated sampling, called "annealing sampling strategy" (Ferreyra et al., 2002), along the slope, 100 mini-pit have been selected. This technique allows to optimize the sampling using

[1] Dipartimento di Agronomia Ambientale e Territoriale, Università di Palermo. Viale delle Scienze, 90128 Palermo, Italy. ph. +39-091-6650249; fax +39-091-6650229; laudicina@katamail.com.

punctual information, already available, for the study area. In particular chemical and physical results from a preview survey (Fierotti et al., 1995) have been used.

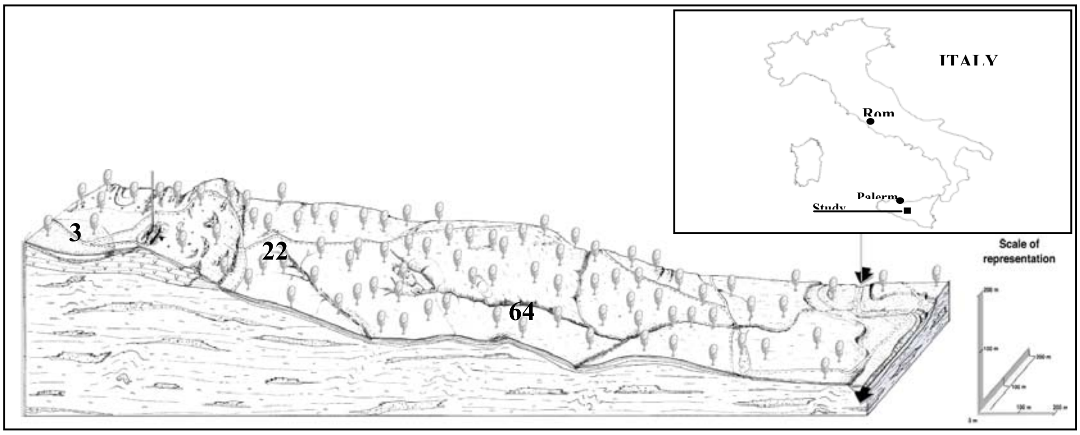


Figure 1. Study area and location of soils profiles along the slope.

Soil samples were analyzed to investigate inorganic and organic (only for the topsoils) carbon. Inorganic carbon was calculated on the basis of total calcium carbonate measured by gas-volumetric method. Organic carbon was calculated as the difference in total carbon determined by dry combustion and inorganic carbon. SIC and SOC contour maps of estimated kriging data were obtained using the software SURFER 7.0 (Golden Software, 1999). This procedure has allowed to estimate the value of the regionalized variable at points that have not been sampled to estimate the trend of SIC along the surveyed hillslope. Moreover, for pedons 3, 22 and 64, (for which in table 1 are reported the selected soil forming factors and soil classification) each genetic horizon have been investigated to differentiate lithogenic and pedogenic carbonates by stable carbon isotopes.

Table 1. Soils and selected soil forming factors.

Pedon	Parent material	Altitude (m a.s.l.)	Slope (%)	Vegetation at sampling site	Classification (Soil Survey Staff, 1999)	Classification (WRB, 1998)
3	Colluvial deposits	475	4	*Eucalyptus camaldulensis*, *Pinus halepensis*, *Cupressus sempervirens*	Typic Calcixerert	Calcic Vertisol
22	Clays and marly clays	390	15	*Eucalyptus occidentalis*	Gypsic Calcic Vertic Haploxerept	Vertic Gypsic Calcisol
64	Sandy clays	330	6	*Eucalyptus camaldulensis*	Gypsic Vertic Haploxerept	Vertic Gypsisol

To determine the isotopic composition of inorganic carbon, soils were roasted at 380°C under vacuum and treated with 100% H_3PO_4 in an evacuated reaction vessel. The isotopic composition of the CO_2 was determined by mass spectrometry. To determine the isotopic composition of soil organic carbon, an aliquot of each soil was treated with 1 N HCl to remove carbonates and combusted at 850°C in sealed quartz tubes (Boutton, 1991). Isotopic measurements were made on a mass spectrometer FINIGANN-MAT DELTA S and expressed as $\delta^{13}C$ (‰) values relative to the international PDB standard (Craig, 1957). Precision was 0.1‰ for both inorganic and organic carbon measurements. The amount of pedogenic carbonate (PC) is calculated using the isotopic mass balance equation of Salomons and Mook (1976):

$$PC\ (\%) = (\delta^{13}C_{bulk} - \delta^{13}C_{\text{parent material}} / \delta^{13}C_{\text{pedogenic}} - \delta^{13}C_{\text{parent material}}) \times 100 \qquad (1)$$

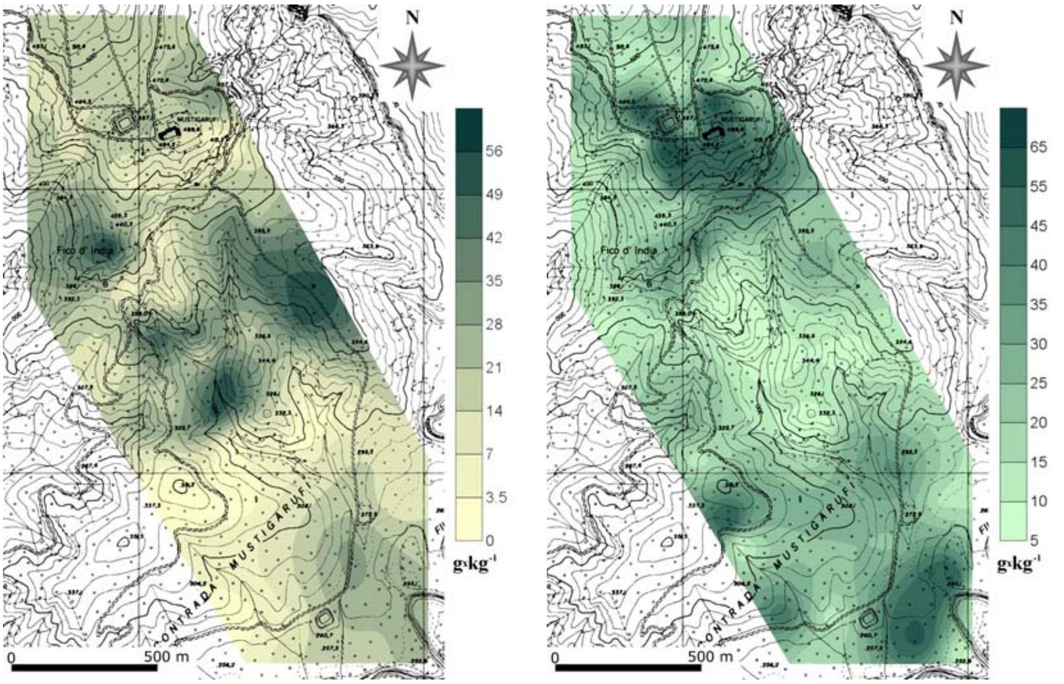
where $\delta^{13}C_{bulk}$ is measured on each soil horizon, which normally contains a mixture of lithogenic and pedogenic carbonate; $\delta^{13}C_{\text{parent material}}$ is measured on an assumed parent material and $\delta^{13}C_{pedogenic}$ is calculated according to diffusional model of Cerling (1984) and Quade et al. (1989):

$$\delta^{13}C_{pedogenic} = \delta^{13}C_{\text{organic carbon}} + \Delta CO_{2\ \text{diffusion}} + \Delta CO_2\text{-}CaCO_3 \qquad (2)$$

in (2) $\delta^{13}C_{\text{organic carbon}}$ is measured on soil organic matter; $\Delta CO_{2\ \text{diffusion}}$ is the $\delta^{13}C$ difference between soil CO_2 and soil-respired CO_2 and ΔCO_2-$CaCO_3$ is the $\delta^{13}C$ difference between C in carbonate and CO_2 occurring during equilibria reactions. Pedogenic carbon was calculated as the 12% of pedogenic carbonates. Statistical analysis was performed using the "Statistica 5.0" software (Statsoft Inc., USA, 1997).

Results and conclusions

Results show a great variability of inorganic and organic carbon concentrations along the slope. In figure 1, SIC and SOC distribution, along the slope, are showed.



(a) (b)

Figure 1. SIC (a) and SOC (b) distribution in the topsoil along the slope.

SIC concentrations are higher (ranging from 10.8 to 62.4 g·kg-1) in the central part of the slope where clays and marly clays costitute the parent materials and lower (ranging from 1.9 to 7.1 $g{\cdot}kg^{-1}$) near the bottom of the slope where parent material is made up by sandy clays. In the subsoils SIC show a similar trend. SIC concentrations did not show any association level with elevation ($r = 0.03$) and, from field observations, no strong correlation appear with relief or other state factor of pedogenesis. SOC concentrations are higher near to the top (ranging from 8.6 to 70.5 $g{\cdot}kg^{-1}$) in soils developed on gypsum and gypsarenites and at the bottom of the slope (ranging from 10.2 to 40.7 $g{\cdot}kg^{-1}$) in soils developed on marly clays. In the central part of the slope, where soils developed on clays and marly clays, SOC show a lower concentration. Such SOC distribution, reasonably, depends on vegetation type (*Pinus halepensis* instead of *Eucalyptus camaldulensis*) and landform.

Table 2. Total, pedogenic and lithogenic inorganic carbon in pedon 3, 22 and 64.

Pedon	Horizons	Depth	Total inorganic C	Pedogenic inorganic C	Lithogenic inorganic C
		cm		gkg-1	
3	Ap	0-12	13.4	13.4	0
	ABss	12-50	14.9	14.9	0
	Bkss1	50-90	19.4	17.3	2.2
	Bkss2	>90	21.4	19.3	2.0
22	A	0-7	22.7	3.4	1.3
	Bk	7-45	19.9	2.5	1.4
	Byss	45-75	21.8	0.6	2.2
	BCy	75-115	11.2	0.4	1.8
	C	>115	18.6	0.0	1.6
64	A	0-10	1.8	1.7	0.1
	AB	10-20	5.2	4.9	0.2
	Bwss	20-50	6.5	6.2	0.2
	Byss	50-80	4.6	3.7	0.8
	BCy	80-105	6.5	3.2	3.2
	C	>105	5.3	0.8	4.4

Also SOC concentrations did not show any association level with elevation (r = 0.12). As regards SIC concentration in the three surveyed pedons (table 2), it is higher in pedons 3 and 22 (that develop on colluvial deposits and clays and marly clays, rispectively), than in pedon 64 (that develops on sandy clays). In particular, pedon 3 and 22 show similar SIC concentrations along the profile being in average 17.3 ± 3.7 and 18.8 ± 4.6 $g\cdot kg^{-1}$, respectively, while pedon 64 has a much lower concentration of SIC (5.0 ± 1.7 $g\cdot kg^{-1}$). Even if pedon 3 and 22 show similar concentrations of total inorganic carbon, results of isotopic analysis show that the amount of pedogenic and lithogenic inorganic carbon between pedon 3 and pedon 22 is different.

In pedon 3, pedogenic carbon is the most abundant form of inorganic carbon, while in pedon 22 lithogenic carbon is the predominant form of inorganic carbon. In pedon 64, the two forms of inorganic carbon show a trend linked to depth and consequently to pedogenesis (Laudicina, 2003). In the upper horizons are present more pedogenic than lithogenic carbon, while in the deeper horizons the trend is inverted.

References

Bajracharya R.M., Lal R., Kimble J., 1996. *Soil organic carbon distribution in aggregates and primary particle fractions as influenced by erosion phases and landscape position*. In Proceedings of Carbon Sequestration in Soils, An International Symposium, July 22-26, 1996, Columbus, Oh, USA. The Ohio State University, National Soil Survey Center, NRCS and USDA-ARS.

Boutton T.W., 1991. *Stable carbon isotopes ratios of natural materials, I.* Sample preparation and mass spectrometry analysis. In Coleman D.C., Fry, B. (Eds.), Carbon Isotope Techniques. Academic Press, New York, pp.155-171.

Cerling T.E., 1984. *The stable isotopic composition of modern soil carbonate and its relationship to climate*. Earth Planetary Science letters 71: 229-240.

Craig H., 1957. *Isotopic standards for carbon and oxygen and correction for mass spectrometric analysis of carbon dioxide*. Geochimica et Cosmochimica Acta, 12: 133-149.

Dazzi C., Monteleone S., 2001. *Soils and soil-landform relationships along an elevational transect in a gypsiferous hilly area in central Sicily, Italy*. Proceedings 7th International Meeting of Soils with Mediterranean Type of Climate, Valenzano, Bari.

FAO-ISRIC-ISSS, 1998. *World Reference base for Soil Resources.* World Soil Resources Rep. n.84, Roma.

Ferreyra R.A., Apeztegua H.P., Sereno R., and J.W. Jones, 2002. *Reduction of soil water spatial sampling density using scaled semivariograms and simulated annealing.* Geoderma. Vol. 110:265-289.

Fierotti G., Dazzi C., Raimondi S., Bellanca A., Monteleone S., Neri R., Pipitone G., 1995. *I suoli del complesso boscato Mustigarufi (CL) e la loro adattabilità all'Eucalyptus camaldulensis.* Azienda Foreste Demaniali Regione Siciliana, Palermo 1995.

Lal R., Kimble J. M., Eswaran H., Stewart B. A., 2000. *Global climate change and pedogenic carbonate.* Lewis Publishers, Boca Raton, Florida.

Laudicina V.A., 2003. *Carbonati primari e secondari in suoli forestali: genesi e significato ambientale.* Ph.D. thesis. University of Palermo.

Pan G., Guo T., 2000. *Pedogenic carbonate of aridic soils in China and its significance in carbon sequestration in terrestrial systems.* In In: Lal R., Kimble J. M., Eswaran H., Stewart B. A., Global climate change and pedogenic carbonate. Lewis Publishers, Boca Raton, Florida.

Quade J., Cerling T. E., Bowman J. R., 1989. *Systematic variations in the stable carbon and oxigen isotopic composition of pedogenic carbonate along elevation transacts in the southern Great Basin*. USA Geol. Soc. Amer. Bull. 101:464-475.

Salomons W., Mook W. G., 1976. *Isotope geochemestry of carbonate dissolution and reprecipitation in soils*. Soil Science, 122:15-24.

Schlesinger W. H., 1997. *Biogeochemestry: an analysis of global change.* 2nd Edition, Accademic Press, San Diego.

Soil Survey Staff, 1999. *Soil Taxonomy, a basic system of soil classification for making and interpreting soil surveys*. 2nd ed. Agriculture handbook N° 436, Washington D.C..

Heavy metal contamination of urban soils: a case study (Nuoro/Sardinia, Italy)

Vacca, S.[1] – Capra, G.F. – Muntau, H.W. – Loi, A. – Biagioli, M.

Background

Systematic soil quality monitoring has been performed in Italy since only a few years. The National Environmental Protection Agency and the National Thematic Committee "Soil and Contaminated Sites", in particular, published quite recently an information dossier on the soil contamination in some provinces [Buondonno et al. 1996], clearly demonstrating that the Italian soils fit largely in the general variability observed in other European countries. With regard to contaminated sites, however, we have to admit that, according to the last census in the year 2000, more then 10500 contaminated sites have been recorded, Sardinia occupying the seventh position in the national ranking with 410 sites., according to the 2000 census is known.

Objectives of the study

The present study wants to offer the first contribution to the knowledge on urban soils in Sardinia and more specifically on heavy metal contamination of the urban soils of Nuoro. The tree-lined alleys of the city, exposed to heavy traffic, have been selected for soil sampling and the spatial distribution of the elements lead, nickel, copper, zinc and cadmium has been investigated and compared to the threshold values given by the Italian law (DM 25 of October 1999, No. 471). Further element of decision in the process of establishing the sampling station network were the data obtained from analysis of traffic flow and density [General Survey on Urban Traffic, 2001].

The distribution of the mentioned metals shall be analyzed using Geographic Information System techniques with the major aim to characterize particularly polluted areas inside the city perimeter.

Materials and Methods

The sampling station network comprised both the areas of maximum traffic and the "green lungs" of the city. Surface core samples of maximum depth of 10 cm were taken by using an Edelman corer. Altogether 52 samples have been collected.

Following to drying, sieving (2 mm) and homogenization, subsamples of 1 g were mineralized following the AQUA REGIA procedure [DM 471/99] and analyzed by Electrothermal Atomic Absorption Spectrometry.

Results and Discussion

The obtained metal concentrations correlate positively with traffic densities (table 2). The mean metal concentrations encountered, and lead and Zinc in particular exceed largely the Italian norm as laid down in DM of 25 October 1999 (table 1, figure 1). The concentrations in the most heavily polluted city areas reach values as high as 810 and 570 mg/kg of lead and zinc, respectively. Cadmium exceeds the assumed geochemical backgound values of the Nuoro geological setting of 0.2 mg/kg [Bowen, 1966] for a factor 250.

The spatial distribution of lead throughout the city (Figure 2-3), evaluated on the basis of the Geographical Information System (GIS) highlights the high risk areas and indicates possible ways of intervention

Element correlation analysis (Pearson) does not offer too much insight in the mechanisms, which led to the observed metal accumulation. While lead-zinc (r=0.75) might be traffic-induced (lead from gasoline and zinc from tyres), lead-copper (r=0.75), as well as copper-cadmium (r=0.70) do not find an easy explanation. On the other hand, the classical zinc-cadmium correlation, arising from the corrosion of zinc-protected steel and iron construction elements, appears unusually weak (r=0.44). All that could be due to the fact that urban soil composition reflects in a much lesser way the geological and geochemical aspects of their genesis, but the history of city development and related material displacements.

The here presented study is but a first step towards a systematic mapping of environmental contaminants in urban soil. The authors are aware of the needs to add additional elements and compounds to the research set-up, but also to develop sampling strategies which take into account the basic differences between geochemically governed environments and urban environments and the manifold civilizational influences acting on them – in the past and in the presence.

[1]University of Sassari, Department of Botany and Plant Ecology, Section of Pedology, Nuoro, Tel.: 0784/214948; Fax: 0784/205292, E-mail: pedolnu@uniss.it

References
Aitchinson G,D., 1973 – Twenty-five years of application of soil survey principles in the practice of fundation engineering, Geoderma.
Alloway B. J., 1990 – Heavy metals in soils, Blackie Academic & Professional, Glasgow.
Bettini V., 1996 – Elementi di ecologia urbana, Einaudi, Torino.
Blum W.E.H., 1998 – Soil Degradation Caused by Industrialization and Urbanization,H.-P. Blume et al. (eds.) Reiskirchen, Catena Verlag.
Bowen, H.J.M., 1966 – Trace Elements in Biochemistry, Academic Press, London
Blume H.P., 1989 – Classification of soils in urban agglomerations, Catena.
Bretzel F., 1997 – Il suolo: un aspetto trascurato nell'ecosistema urbano, in: Siti Contaminati, a cura di A. Frigerio & M. Schieppati.
Bretzel F., Lubrano L., Petruzzelli G., 1997 – La qualità del suolo in ambiente urbano, Congr. Naz. Chimica Ambientale, Gallipoli.
Bretzel F., Lubrano L., Petruzzelli G., 1997 – La qualità del suolo in ambiente urbano. Studio preliminare nella città di Pisa, Qualità del suolo.
Buondonno C. Previtali F. Resuloviç H. Buondonno A. Comolli R. Ermice A. Murolo M. Pugliano M.l., Suoli Antropogenici., 1998 - Problemi di classificazione: rassegna e proposte di tassonomie, in Convegno SISS, Napoli.
Rutigliano F.A., Alfani A., Bartoli G., Fierro A. R., Castaldi S., Cortruffo M. F., Virzo De Santo A., 1993 – Carico di metalli pesanti e attività enzimatica in suoli dell'area urbana di Napoli, Ann. Fac. Agr. Univ. Sassari.
Wolf U., 1999 – Suoli degli ambienti urbani e periurbani (SAUP), Ecologia Urbana, pag. 63-129.

Table 1. Limit values given by Italian norm (DM 471/99, expressed in mg/Kg)

Metallo	Valore soglia (mg/Kg)
cadmio	2
rame	120
nichel	120
piombo	100
zinco	150

Table 2. Index of correlation of Pearson applied to analysis on the heavy metals (in **bold** the values for r>0,7)

	Cadmio	Rame	Nichel	Piombo	Zinco
Cadmio		**0,70**	0,47	0,38	0,44
Rame			**0,73**	**0,75**	0,81
Nichel				0,63	0,66
Piombo					**0,75**
Zinco					

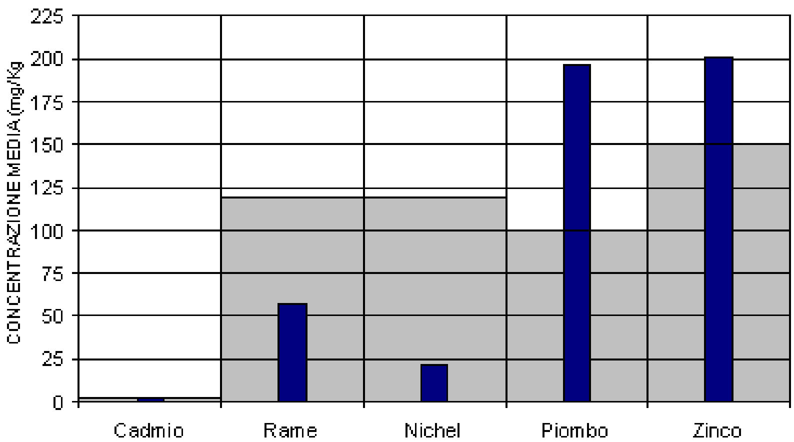


Figure 1. Average values of heavy metals concentrations (grey area represented the limit values given by Italian norm, DM 471/99)

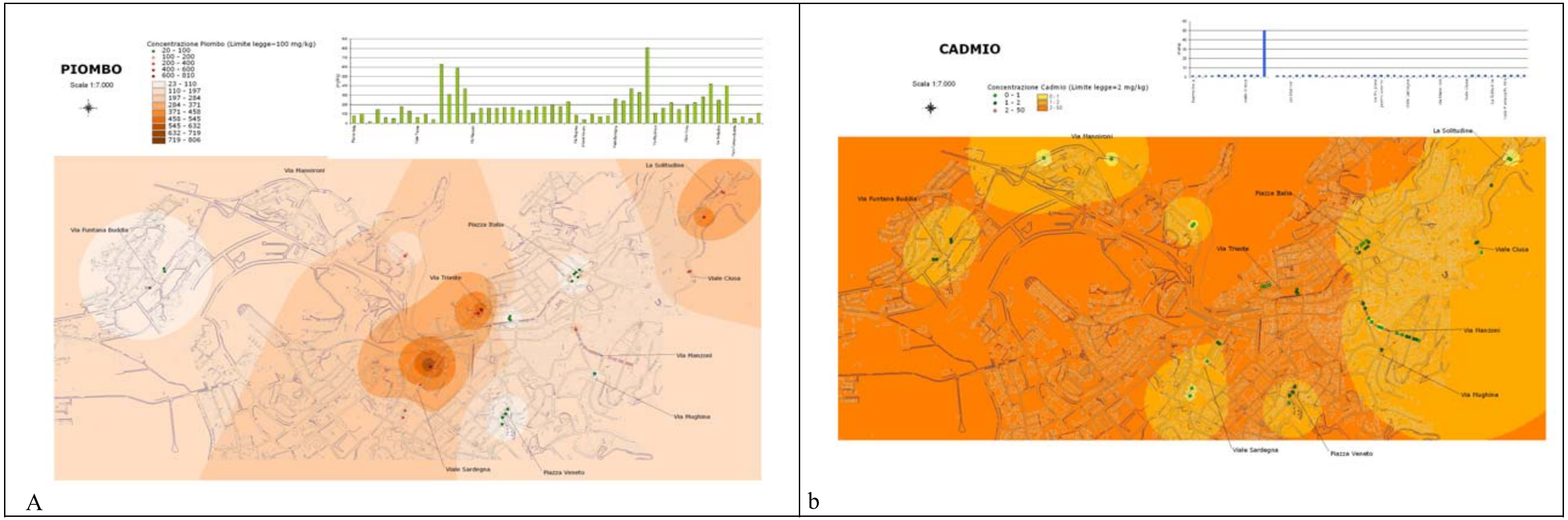


Figure 2. Spatial elaboration by softweare G.I.S. with the interpolation of the single values (a-lead; b-cadmium).

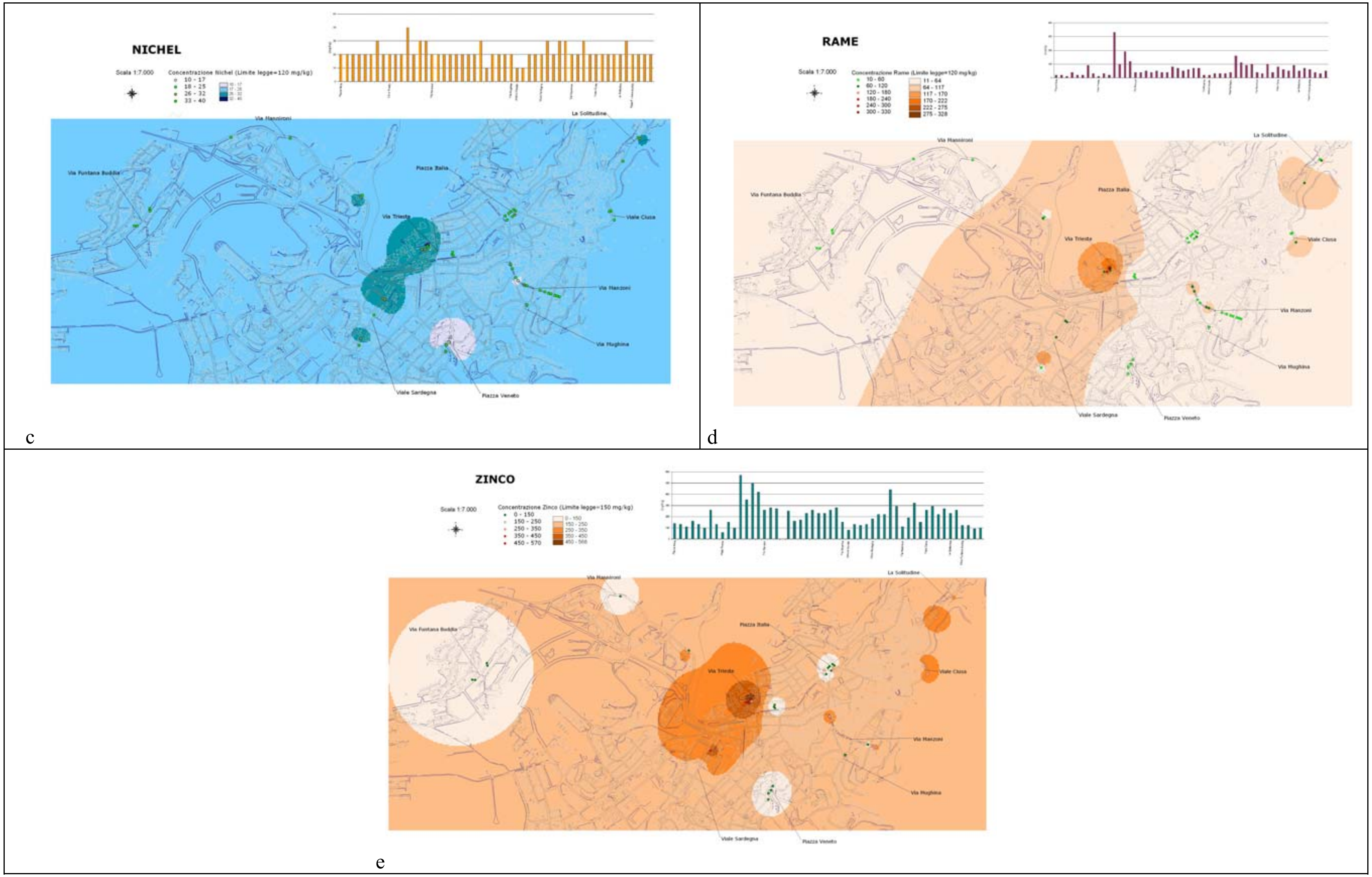


Figure 3. Spatial elaboration by softweare G.I.S. with the interpolation of the single values (c-nickel; d-copper; e-zinc).

Factors influencing the properties and productivity of acid arable soils in the Tirnavos area, Central Greece

Karyotis, Th.[1] – Argyropoulos, G. – Toulios, M. – Haroulis, A. – Mitsimponas, Th. – Katsilouli, E. – Georgiou, Th.

Abstract

Soil survey was conducted in the area of Tyrnavos (about 26.000 ha) in Central Greece, within the framework of the National Project for Soil Mapping. According to Soil Taxonomy (1999) the soils of the present study have been classified as *Alfisols*, they belong to the suborder of *Xeralfs*, and more precisely to the great groups of *Haploxeralfs* and *Palexeralfs*.Soil and thematic maps concerning the distribution of soil properties were compiled by using a Geographical Information System. Acording to data provided by the National Meteorological Service in Larissa, mean annual rainfall ranges between 450 and 550 mm/year. The main crops of the studied area are winter wheat, cotton, vineyard and peach trees. Thirty-three surface samples from the examined *Alfisols* were collected and the fine earth fraction (<2 mm) was used for laboratory determinations. Soils varied significantly in texture, soil acidity, cation exchange capacity (CEC), organic carbon content, plant available phosphorous (P), micronutrients, drainage conditions, thickness and depth of argillic horizons. Organic matter ranged between 1.0 and 31.0 mg/kg, CEC varied from 7.8 to 50.2 cmol/kg, and available P was between 6.0 and 67.0 mg/kg. Moreover, the status of micronutrients at certain samples was found at deficiency level. Deep plowing, monocultivation, excessive use of fertilizers, soil levelling and artificial drainage had affected soil properties. Regardless of the different degree of soil development, the similarities among the studied soils, were: formation of argillic and/or calcic horizons, organic matter translocation to deeper horizons and low pH in the subsurface horizons. Soil management and productivity may be controlled by practices that decrease the negative impact of problems relevant to: crusting of Ap horizons, hardness of argillic horizons, inadequate or excess infiltration and secondary salinization of Ap horizons. It should be taken into account that low organic matter, man induced nutrients disorders and climate factors have seriously affected soil properties. It is expected that deep plowing, application of proper irrigation schemes, liming and selection of suitable fertilizers may enhance soil fertility.

Materials and methods

Surface soil samples were collected from thirty-three representative *Alfisols* of the studied district. Soil Survey Manual and Soil Taxonomy were used for description and classification, while thematic map concerning the soil units distribution of the acid soils was compiled by using a Geographical Information System. The examined samples were air–dried, ground and sieved (<2 mm). Particle size distribution was determined by the Bouyoucos hydrometer method (Gee and Bauder, 1986). The pH values were measured in a 1:1 soil–H_2O suspension (McLean, 1982) and the ammonium acetate (1 N at pH=7) method was used for measuring the exchangeable cations (Thomas, 1982). The exchangeable K^+ and Na^+ were determined using a flame photometer, and both Ca^{++} and Mg^{++} were measured with an atomic absorption spectrophotometer. Soil carbonates were determined by the volumetric calcimeter method (Allison, 1965). Available phosphorous was extracted from acid soils by a Bray method (Kuo, 1996) and from alkaline soils by the Olsen method (Olsen and Sommers, 1982). A modified wet digestion, Walkley and Black method (Allison, 1965), was used for the organic matter determination. The plant-available Fe, Cu, Zn and Mn were extracted in soil samples with 0.005 M (Lindsay and Norvell, 1978). The contents were determined by atomic absorption spectro–photometry.

Results and discussion

The studied soils are located on alluvial terraces and/or fans in the district of Tyrnavos, Central Greece (Fig. 1 and Fig. 2) and have been classified as *Alfisols.* A number of the Ap horizon commonly has resulted from the mixing of eluvial horizons and of the upper part of the argillic horizon. The organic matter was low, varied greatly amongst the examined samples and ranged between 1.0 and 31.0 mg/kg. Parent material, topography, hydrology aand human activities have influenced soil properties (Table 1). Cation exchange capacity ranged between 3.4 and 50.2 cmol/kg and was linearly related to clay content by the following relationship:

$Y_{CEC} = 8.54 + 0.38X_{clay}$ (r = 0.34, P<0.5)

Concerning the exchangeable cations, the following order (Table 1) was observed: Ca>Mg>K>Na and in certain sites, only potassium seems to be at deficient level (Table 1). The slightly alkaline surface layers contain $CaCO_3$ from secondary enrichment. The pH values ranged between 4.7 and 8.1 and 25 out of 33 surface soil samples were acid. In eight surface horizons the pH value was higher than 7.0 and can be attributed to

[1] National Agricultural Research Foundation, Inst. for Soil Mapping and Classification, 1 Theophrastou Str., 41 335 Larissa – GREECE. Tel.: + 30 2410 671297, Fax +30 2410 660 571; E-mail: karyotis@nagref.gr

secondary enrichement by $CaCO_3$. The distribution of trace elements greatly varied and a wide range of the elements extracted by DTPA was as follows: Fe 3.4–162 (mean 31.5) mg kg $^{-1}$, Mn 11.-201.1 (mean 37.1), Cu 1.4 –16.8 (mean 5.5) mg kg $^{-1}$, and Zn 0.5 – 19.7 (mean 3.3) mg kg $^{-1}$ (Table 1).

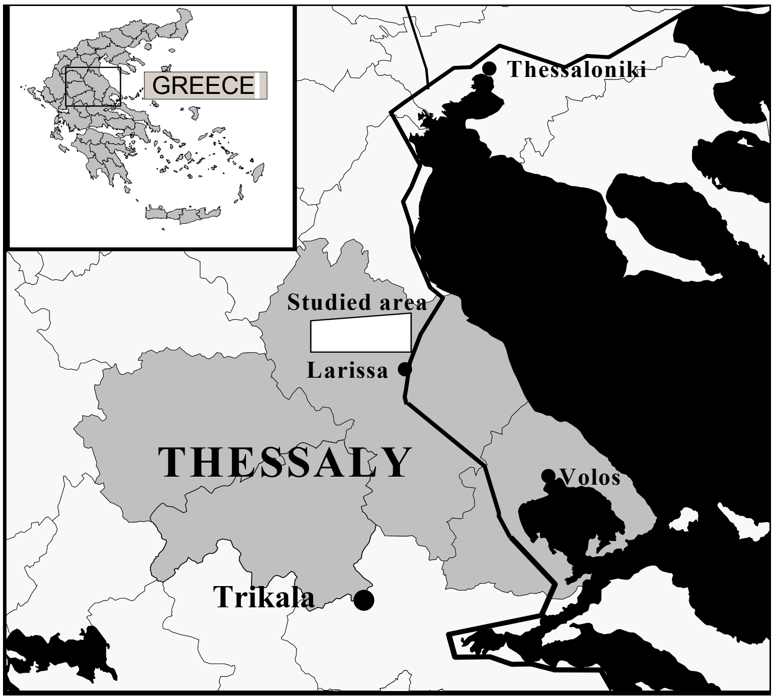


Figure 1. Simplified map of the studied area in Thessaly, C. Greece

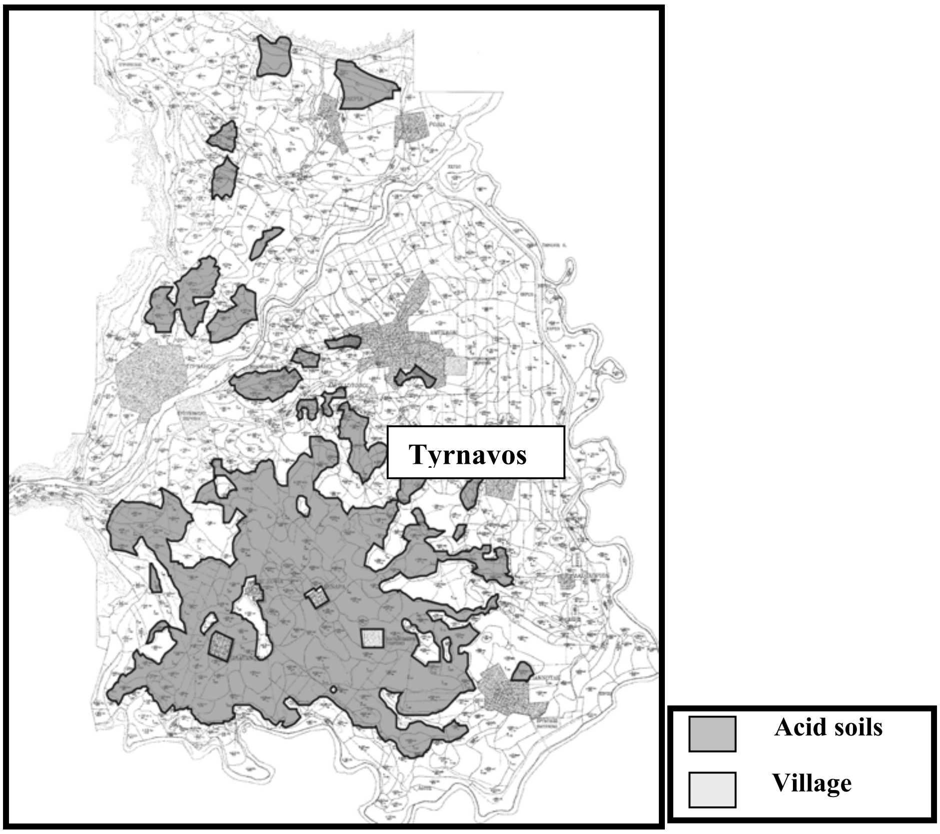


Figure 2. Grouped mapping units of the acid soils

Based on average concentration, the following decreasing order was found: Mn>Fe>Cu>Zn. These differences of the available form of nutrients, may be attributed to parent material heredity and man activities by means of fertilization, irrigation and tillage practices. Iron deficiency symptoms observed in peach trees, these are restricted in some limited areas and can be ascribed either to the parent material heredity or to the presence of calcium carbonate, which decreases the plant availability. Manganese deficiency was limited and its mobility may be due to the oxidation of this element during the dry and warm growing period. Only one sample was very rich in Mn (>200 mg/kg) and the risk of toxicity is high. The increased mean Cu content may be related to parent material and to application of fungicides by the farmers. Zinc was low in several soils and visual deficiency symptoms are frequently observed in arable crops. The available phosphorus content ranged between 6.0 and 67.0 mg kg^{-1} (mean 25.0 mg kg^{-1}), although in some locations the P level was low. It can be argued that these soils are vulnerable to management, which strongly affects their properties. Rational water management and proper fertilization could contribute to the soil quality, without any yield reduction. Potassium exhibits deficiency levels at specific locations, mainly due to empirical application of fertilizers. Soil organic matter content was low, as a result of the dry soil conditions and tillage practices. Over-liming of acid soils may be avoided in order to reduce binding of micronutrients that lead to deficiency symptoms.

Table 1. Descriptive statistics of the selected soil properties (n=33)

	S	Si	C	$CaCO_3$	OM	pH 1:1	P	CEC	Na	Ca	Mg	K	Fe	Cu	Zn	Mn
	(%)				g/kg		mg/kg	cmol/kg					mg/kg			
Mean	41	29	30	1.1	1.0	6.3	25.0	20.1	0.5	13.9	5.9	0.7	31.5	5.5	3.3	37.1
STD	8.1	6.8	9.7	3.0	0.5	0.9	15.5	10.8	1.6	10.3	4.1	0.3	31.1	3.7	4.1	38.2
Min	28	13	16	0.0	0.1	4.7	6.0	7.8	0.05	3.4	1.4	0.0	3.4	1.4	0.5	1.1
Max.	61	41	53	15.4	3.1	8.1	67.0	50.2	9.1	50.7	19.2	1.6	162	16.8	19.7	201.1

Acknowledgements

This research was part of a Soil Survey Project of the Greek Ministry of Agriculture. We wish to thank the Competent Authorities for their financial support.

References

Allison, L. E. (1965). Organic carbon. In A. L. Page (ed.). Methods of soil analysis. American Society of Agronomy, No 9.

Allison, L.E.; C.D. Moodie. (1965). Carbonate. In: *Methods of soil analysis. Part 2*; Black et al. (ed.) American Society of Agronomy, Madison, Wisconsin, Monogr. 9, 1379–1400.

Gee, G.W. and J.W. Bauder. (1986). Particle size analysis. In: Klute, A. (Ed.), Methods of soil analyses, Part 2, 2nd edn. Agronomy monograph 9. ASA and SSSA, Madison, WI, USA, pp. 383–411.

Kuo, S. (1996). Phosphorus. In: *Methods of soil analysis. Part 3. Chemical methods– Soil Science Society of America, Book Series 5*, Madison, Wisc., USA, pp. 869–960 .

Lindsay, W. and W. Norvell. (1978). Development of a DTPA Soil Test Zinc, Iron, Manganese and Copper. Soil Sci. Am. J., *42,* 421–428.

McLean, F. (1982). Soil pH and lime requirement. In: Page, A. L. eds.. *Methods of soil analysis, Part 2. Chemical and Microbiological Properties*. American Society of Agronomy., Agr. Series Monograph No 9, Madison, Wisconsin, pp. 199–223

Olsen, S.R.; L.E. Sommers. (1982). Phosphorus. In: *Methods of soil analysis.* Part 2, 2nd ed.; A.L. Page et al. (ed). Agron. Monogr. 9; ASA and SSSA, Madison, Wisc., USA, 403-430.

Soil Taxonomy (1999). *A Basic System of Soil Classification for Making and Interpreting Soil Surveys*. USDA, NRCS, Agricultural Handbook, No 436, Washington, DC 20402.

Thomas, G. Exchangeable cations. (1982). In A. L. Page eds. *Methods of soil analysis Part 2. Chemical and Microbiological Properties*. Agronomy 9, pp. 159–164.

Reforestation of degraded shrublands for combating desertification in SE Spain: effects on soil properties

Castillo, V.M.[1] – Barberá, G.G. – Navarro, J.A. – Mosch, W. – Martínez-Mena M. – Albaladejo, J.

Reforestation has been advocated as an important tool to reduce erosion, to control runoff and to improve soils, and, especially in the Mediterranean areas, to combat desertification. The extended use of terracing in the 60s and 70s with the purpose of improving water supply has been severely criticized because of promoting erosion, reducing soil quality and disrupting natural landscapes. This paper describes results from a study of the effects of reforestation works on major physical (texture, bulk density, soil water retention characteristics, hydraulic conductivity) and chemical (total organic carbon, nitrogen, phosphorus and potassium content, pH and electrical conductivity) soil properties. 50 sampling plots were selected to compared soil properties under reforested stands with Aleppo pine (*P. halepensis* Mill) with those on adjacent degraded shrublands at two watersheds in which several forest restoration projects have been carried out since 1970.

After 30 years of the plantation, results showed that concentration of organic carbon under trees were similar compared with contiguous areas covered by shrubs. On the other hand, concentrations of nitrogen, phosphorus and potassium were significantly lower in forested stands than in shrublands. No significant differences were found in physical soil properties. Only bulk density and hydraulic conductivity were slightly improved by site preparation

These findings confirmed the initial negative effect of terracing on soil fertility has not been recovered by tree growth, except for carbon content. These negative effects are only partially counteracted by the improvement of soil hydraulic properties which lead to a greater water availability.

[1] Department of Soil and Water Conservation, CEBAS-CSIC. Murcia (Spain). Tel.: 34-968396349 ; Fax: 34-968396213; E-mail: victor@cebas.csic.es

GIS evaluation of a long-term experiment on salinization processing

Blaskó, L.[1]

Introduction

The leaching and accumulation of sodium are strongly related to the soil water regime and to the micro morphological features of the of the soil surface (groundwater level, infiltration of rainfall, evaporation, micro-sins with/without outlet etc.).

According to Bíró and Thyll (1999) by re-classification of digital maps describing the spatially relatively stable characteristics contributing to water inundations (hydraulic conductivity and maximum water holding capacity of the topsoil, convexity of the soil surface, size of micro-watersheds, critical groundwater level, land use) category maps can be created. Using the serial overlaps of them maps can be drawn indicating the threat of water inundations.

On a certain soil spot many combinations of factors causing Na-accumulation or leaching can occur. The great variety of the affecting factors is manifested by the extreme spatial and temporal heterogenety of soil features. Beyond the different forms of Na-accumulation, the spatial pattern (mosaic-like characteristic) is also an inseparable feature of salt affected soils. This great spatial and temporal heterogenety rises special methodological problems in case of plot experiments (Colibaş, 1978).

Theoretically the disadvantages of heterogenety could be moderated by the increase of the number of the replication, but this method is practically not applicable in the case of soil reclamation or amelioration experiments due to the limited capacities.

To improve the assessment technique we used a specific methodology for unfavourably heterogeneous soils. The amelioration experiment is set without real plot replications and within the plots the soil samples are taken at surveyed points. These points are the bases of a soil property monitoring. Hence the soil reclamation treatments are not compared to a control, but to the state of the certain point before the reclamation.

The up-to –date GIS methods ensure the joint evaluation of the reliability and the uncertainly of a state survey (Kertész, 1997). The conventional statistical methods do not take the positions of the sampling points related to one another and spatial link system of the measured values into account. By means of geo-statistical methods linked to GIS point-like sampling data can be evaluated. In this paper the GIS methods of the system setup and the evaluation of a long-term experiment are presented.

Material and method

The investigated complex amelioration model site at Karcagpuszta was set up by László Nyíri in 1977. The detailed introduction of the experiment carried out at that model site was published by Nyiri and Fehér, 1977. The pedological and plant production results – evaluated with conventional methods – can be found in the publications of Nyiri and Fehér (1981), Nyiri (1988) and Blaskó (2001). The soil type of the experimental site is a meadow Solonetz with structural B-horizon, the parent material has clay-clay loam texture. The characteristic groundwater depth varies between 1,5 and 2 meters.

Juhász et al. (1997) also emphasized the advantage of GIS as it connects the digital and topological graphic models to the data base systems, hence the actual analysis techniques can be completed with spatial geo-statistical analyses. In accordance with this during data collection we gave preference on secondary data gain, partly because of its lower costs, partly because of our limited hardware- and software capacities. Although primary data gain provides better quality, but it is more time- and cost consuming. Nevertheless the data gain quality must be examined and certified at the design of data gain and also at the control of the created data base (Detrekői et al., 2000).

My logical GIS model was originally published by Tamas and also used his recommendations to integrate the field GIS (ArcPAD) data sources with web mapping technology and prepare precision agriculture in this fields. Tamas earlier published his large scale digital elevation modelling results also about salt affected water accumulation processes and emphasised the importance of micro relief. He applied a special TIN algorithm to treat the local depressions and sinks in digital model which is need to reduce local error.

During data collection we applied the analogue cadastre and topographical maps of 1:4000 and 1:10 000 scale got from the regional Land Office at Törökszentmiklós. The digitalisation, the insertion into EOV system, the cut of frames and the rotation of the analogue cadastre map sections were done by means of „Erdas Imagine 8.4" and „ArcView 8.1" Software (Table 1.). The location of the experimental site mentioned above is shown in Fig. 3.

[1] Debrecen University CAS Karcag Research Institute, H-5301 Karcag, P.O.Box 11. Hungary. Tel.: 36-59 311-255; Fax: 36-59 311-036; E-mail: blasko@dateki.hu

Table 1. Basic data of the used maps

Basic maps	Format	Scale	Number of map section	No. of map section
Cadastral map	.tif, .geotif	1: 4000	1	58-141-4
Topographical map	.sid	1: 10 000	1	58-141b

The scan of the basic maps was done at 300 dpi resolution that amounts to 3 m reference value. During the rectification linear affin transformation was done, where the final horizontal accuracy was +-0,65 m. the vertical accuracy of basic point levelling was +-0,02 cm. The transformation of the relative altitudes into elevation above Baltic see level is ensured. During data processing the raster data served as the basis for the vectorize of the examined objects. The object- and layer distribution determined in the logical model was the basis of the digital graphic model, for which the attributive data (the data base of the investigated four years) were needed to be ranged by means of the primary and secondary identification keys.

To determine the change of the soil properties[2] samples were taken from 112 surveyed points of 16 plots in 1977, 1981, 1989 and 1995. The soil was sampled to the depth of 110 cm by each 20 cm deep layer. Beyond the sampling points 224 elevation reference points were also surveyed, hence the „z" co-ordinates provide the possibility of 3-D modelling (DTM).

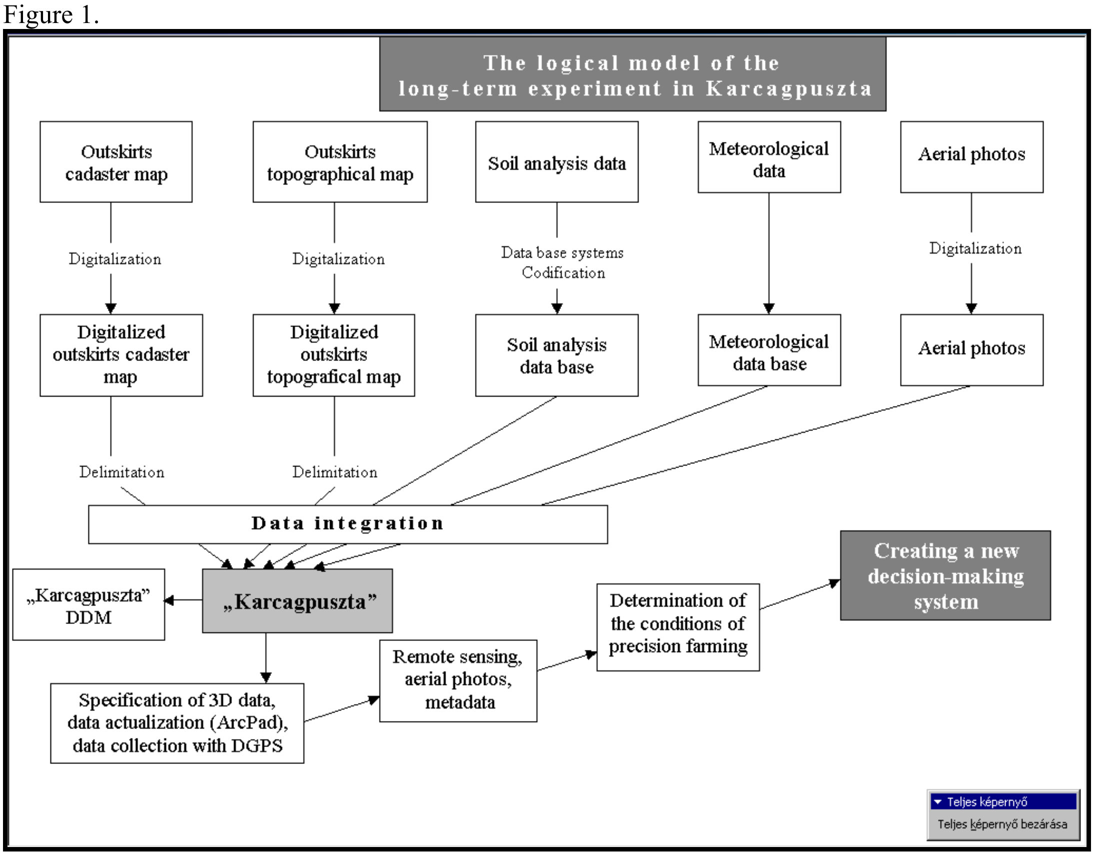
The climatic conditions, the salt balances and the plant production possibilities related to the experiment has been carried out since 1977 are described in the study of Karuczka (2001).

Results

On the base of the logical- and physical models of the investigation (Fig. 1-2.) the data bases were made in convertable forms by dBase and Excel.

The logical model includes the future steps to create the decision making system as well. On the base of the data of the physical model the necessary data bases could be created and the implementation of analysis could be initiated (Fig. 2.).

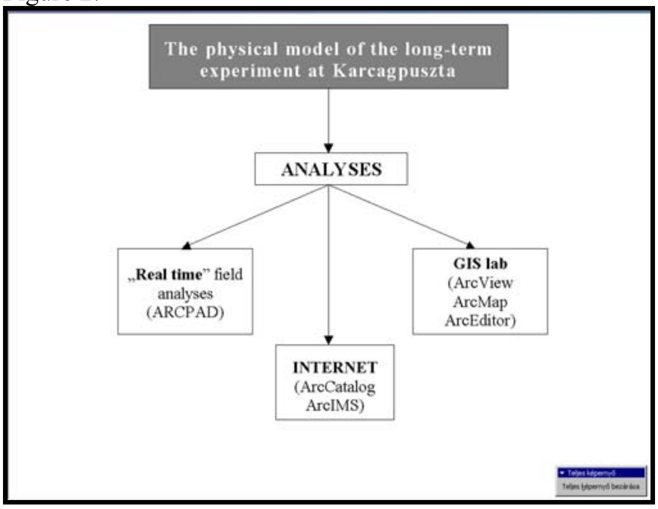
Figure 1.



[2] The examined soil properties: pH (H_2O), pH (KCL), Y1, $CaCO_3$, Na_2CO_3, KA, exchangeable Ca-, Mg-, K-, and Na, salt (%).

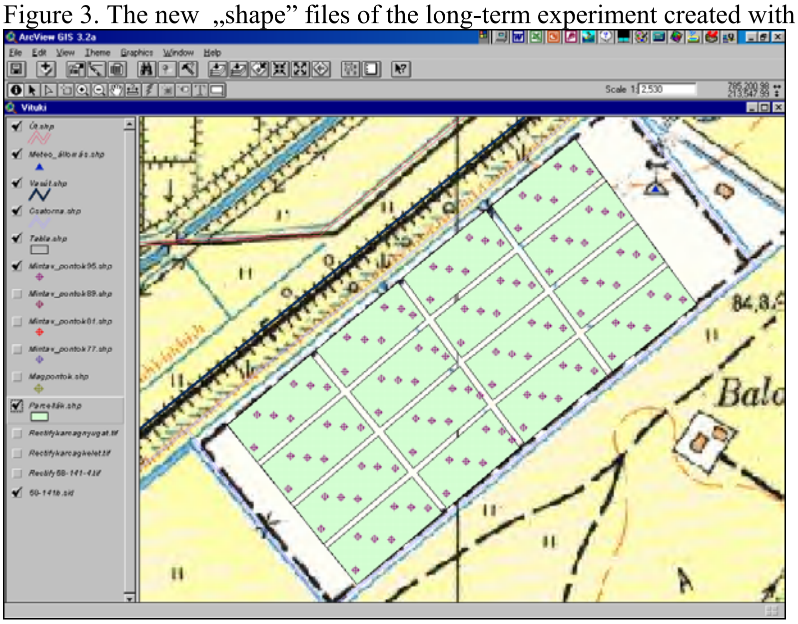
The geostatistical analyses were made by means of „Genstat 6.0” and „Surfer 8.0” software. The symmetrical quadratic grid was created. The grid points values change in the function of the interpolation technique and sample spatial density and their values but grid size results was geostatistically optimized by Tamas (1999, 2004) large scale DTM methodology. If this method is used the model parameters must be treated very accurately and proper variogram models must be chosen and interactively up scaling the meshes of grids sizes. During the DTM optimization analysis approximate (with low nugget value) kriging was used to create surface of the investigated area. Based on Tamas (2001), the acceptable optimal nugget value was below 20% of the total sill value.

Figure 2.



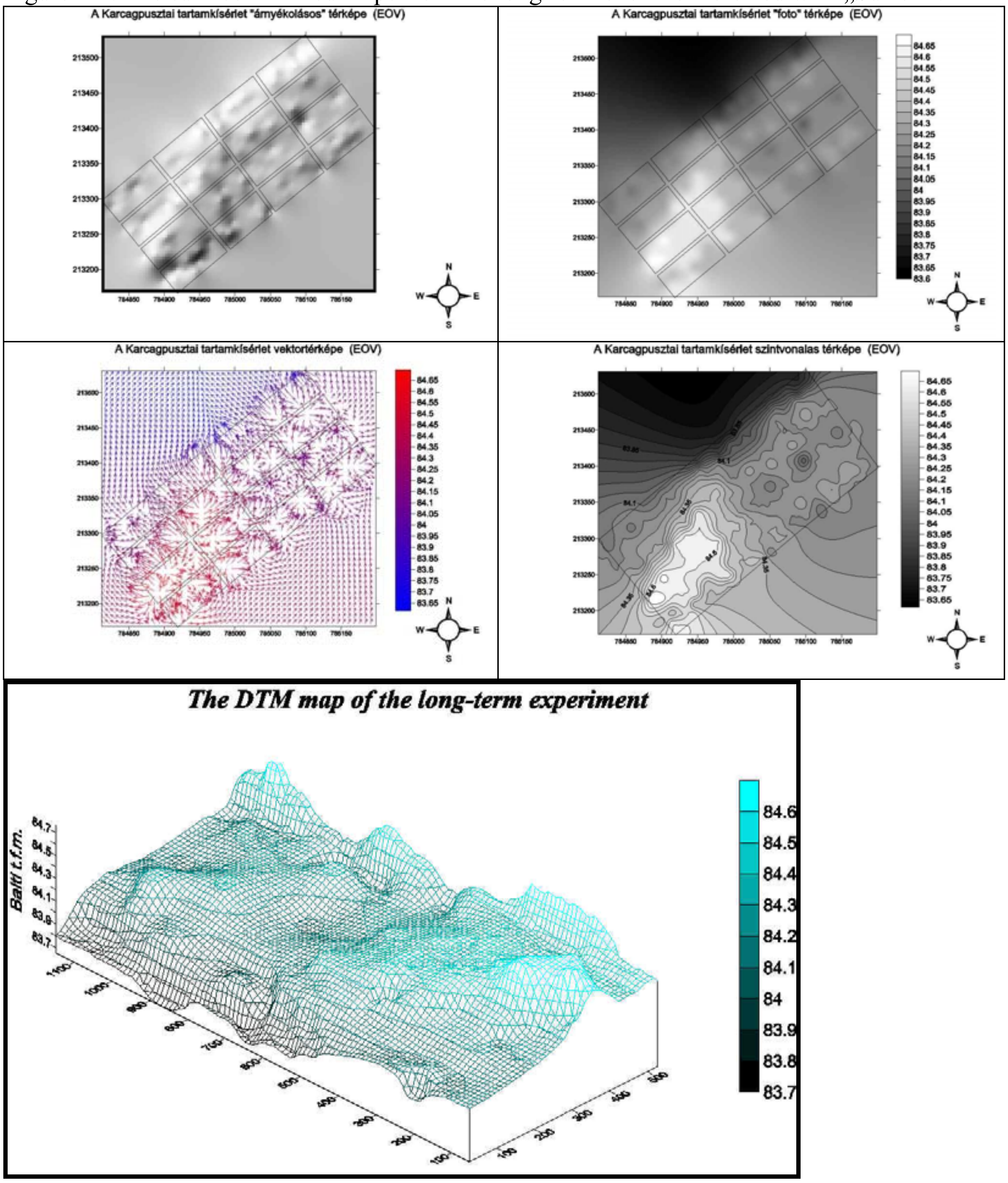
For the GIS analyses „ArcView 3.2-8.2” versions were used. Using the cadaster and topographical map sections we generated different ovelapping shapes (Fig. 3.) for that the soil properties were linked as attributive data. The sampling points involve the main information in the structure of the data base. For this we created a coding system. On the base of this system each investigated parameter and its change can be reproduced and analysed for each year and sampling point. Furthermore coding precludes the possibility of data redundancy and errors. By using the logical shapes shown in Fig. 2.

Figure 3. The new „shape” files of the long-term experiment created with „ArcView”



The 3-D surface of the investigated area could be displayed (Fig. 4-5.). The aim of modelling is to aid decission making processes. After the DTM delineation can be spatially isolate the salt accumulated places and analyse the correlation with elevation model and land use and cultivation practice. Beyond the models created on the base of the elevation points, the analysis and spatial display of the temporal dynamics of the soil properties are of great importance. For the introduction of precision agricultural management on this area the preconditions (thorough survey, correction and update of co-ordinates, more elevation points) are already given. This will ensure the compatibility of the up-to-date machinary park, wich is already at our disposal, with the „AgGPS" computing system.

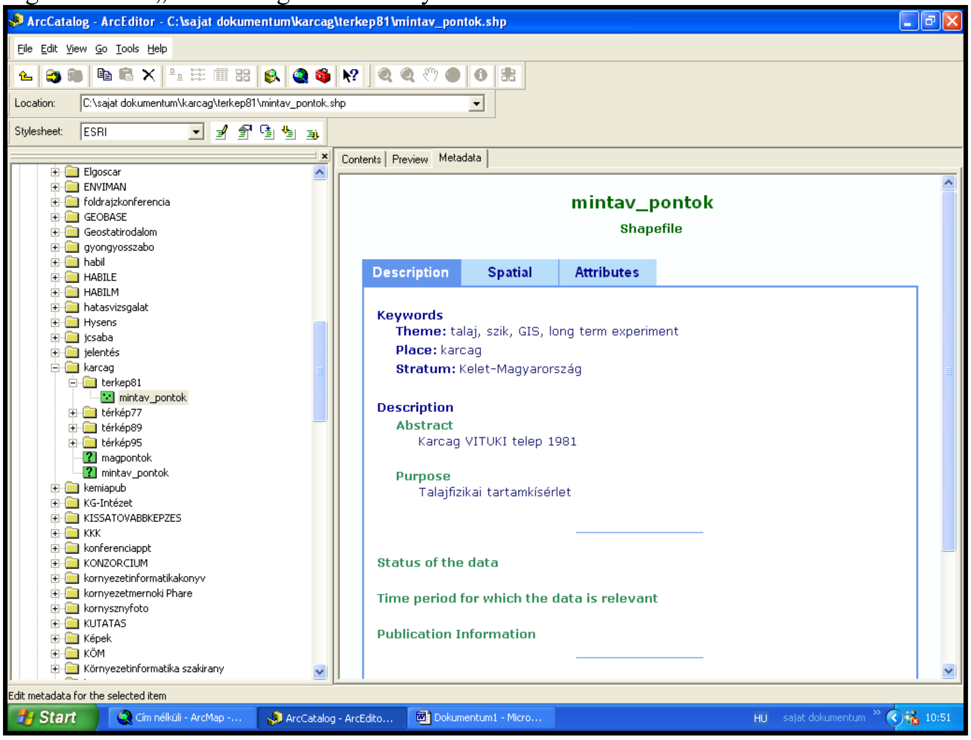
Figure 4-5. The surface-analized maps from the long-term exeriment created with „Surfer 8.0"



For the publication of the research achievements we used the web-based „ArcCatalog", „ArcIMS" systems (Fig. 6.). The map- and attributive data are accessable through special mapping webservers[3] as meta-data by anybody who is searching for literature or data bases by means of the given keywords (soil, sodic soil, GIS, long-term experiment etc). WEB mapping also effective tools to remote analysis of salt risk. Tamas (1995) Tamás et al. (1998) published powerful combined GIS based Fuzzy and Boolean risk management methods to evaluate Environmental Buffering Capacity which methods can be used after modification on the web to treat salt affected risk.

[3] FGDC = Federal Geographic Data Committee meta data base – URL: http://www.fgdc.gov /metadata/metadata.html –

Figure 6. The „ArcCatalog” software by ESRI



References

BÍRÓ T. – THYLL Sz. :(1999) A belvíz-veszélyeztetettség térképezése. Vízügyi Közlemények, LXXXI évfolyam, 1999. évi 4 füzet. 709-718.

BLASKÓ L.: (2001) Réti szolonyec talajon folyó talajjavítási tartamkísérlet. Sustainable Agriculture and Rural Development. Paper presented at the plenarí section of conference held in Debrecen and Nyíregyháza on Long-term field experiments in Carpathian Region. Nyíregyháza. 55-89.

COLIBAŞ, I. – COLIBAŞ, M.: (1978) Mintavételi módszer szolonyecek tulajdonságai közötti kölcsönhatások és variációk megállapítására. Agrokémia és Talajtan, Tom. 27. No. 3-4. 379-390.

DETREKŐI Á.-SZABÓ GY.: (2000) Bevezetés s térinformatikába. Nemzeti Tankönyvkiadó, Budapest, 250.

JUHÁSZ CS. – TAMÁS J. – BLASKÓ L. – ZSEMBELI J.: (1997) A Tisza tó talajvíz emelő hatásának elemzése integrált számítógépes modellek alapján. Debreceni Agrártudományi Egyetem Tudományos Közleményei, Tom. 33. No. 31. 143-152.

KARUCZKA A.: (2001) A talajok víz- és sómérlegének vizsgálata liziméteres kísérletben. Sustanaible agriculture and rural development. Paper presented at the plenarí section of conference held in Debrecen and Nyíregyháza on Long-term field experiments in Carpathian Region. Nyíregyháza. 43-54.

KERTÉSZ Á.:(1997) A térinformatika és alkalmazásai. Holnap Kiadó. Budapest

NYIRI L. – FEHÉR F.: (1977) Tájékoztató a Karcagpusztai komplex meliorációs modelltelepen folyó kutatómunkáról. Kézirat. DATE KI, Karcag.

NYIRI L. – FEHÉR F.: (1981) Effects of chemical amelioration and soil moisture regulation on various types of salt affected soils. Agrokémia és Talajtan. 30. (Suppl.) 139-147.

NYIRI L.: (1988) A talajjavítás fejlesztésének lehetőségei. Doktori tézisek. Karcag. 27.

TAMÁS J.: (1955) A környezeti pufferkapacitás változása szennyvíziszapokkal terhelt talajokon, Agrokémia és Talajtan, Budapest, 44, 3-4, 403-408.

TAMÁS J.: (1999) Analysis of uncertaintinity in the design of sampling strategy. In: Analele Universitatii din Oradea, Fascicula Agricultura si Horticultura, 5. 7-14.

TAMÁS J.: (2001) Precíziós mezőgazdaság. Mezőgazdasági Szaktudás Kiadó, Budapest

TAMÁS J. – Csillag J. – Murányi A.: (1998) Risk mapping of potentially toxic elements pollution by modelling combined effects of pH, clay mineral and organic matter. In Filep Gy. (ed.) Soil Pollution Wageningen - Debrecen. 225-238.

TAMÁS J, TAKÁCS P, JUHÁSZ Cs,: (2004) Integrated field scale water management technology In: Proc. III. Alps-Adria Scientific Workshop, Dubrovnik, Croatia. 112-117.

Conceptual and methodical bases of preservation physically soil degradation

Jigeu, G.[1] – Konishesku, A. – Jolondkovski, A.

Processes of modern evolution of a soil cover put forward on the first place alongside with erosion the problems of physical degradation of soil. The reasons of this phenomenon are discovered in the process of replacement biosenozes by agrosenozes. Last assumes carrying out of processing's with a view of creation of favorable conditions for an input and growth of plants. Thus this process proceeded during all historical times and in connection with intensification influences of the man on land resources constantly amplified, and the last 40 – 45 years from a local problem has turned in global which studying borrows scientists of all world.

In Europe the first data concerning physical degradation of soil have appeared in beginning XX of century but appropriate attention began to give by these processes only in the beginning of the seventieth years of the last century when began to be shown as limiting factors. Now in this or other form (over ramming of soil, destruction of soil, crusty, slitization, colmatage and etc.) physical degradation proceeds in all regions of Europe. It is caused by interaction and interrinfluence of natural and anthropogenous factors and leads to reduction or destruction of efficiency eko – and agroekosistem, to easing their biological features and obstructs economic activities of the man. It strengthens necessity of research of the phenomenon for which studying combined efforts scientific of different regions and the countries are necessary, called to elaborate measures for prevention or reduction of negative consequences. Simultaneously we mark that by present time in Europe the rich experimental material concerning factors and mechanisms of physical degradation of soil is accumulated. At the same time in a number of the countries of region (Germany, Hungary, Netherlands, England, Russia, Romania, Moldova, Ukraine, etc.) were formed a number of science centers of the processes of physical degradation borrowed with researches of soil and possessing by an infrastructure necessary for these researches as scientific bases and permanent experiments. The first stage of studying of processes of physical degradation of soil in various has in our opinion ended with it is soil – climatic conditions and conditions for development of the all-European uniform strategy of soil preservation and prevention or decrease to a minimum of consequences of physical degradation are created. In this context the maintenance of the term preservation of soil is reduced to one thesis: the general influence on a soil cover should not exceed limits behind which its destabilization begins, transition in a unstable condition, and then follows also irreversible processes of transition to a new stationary condition. In such definition development of uniform all-European strategy of preservation of soil assumes creation uniform networks of monitoring capable to provide an estimation of a modern condition and monitorizaion the basic processes and mechanisms of evolution of a soil cover and potential productivity of soil.

Experience of teamwork with colleagues from Romania, Ukraine, Belgium, etc. the European countries shows, that the main obstacle in a way of the decision of problems of physical soil degradation are unequal methods of identification and an estimation of processes of physical degradation. Unequal methods of research and estimation of processes of physical degradation interferes with creation of models of steady use of soil and the forecast of evolution of processes of pedogenesis and functioning of a soil cover and also to carry and introduction new soil – and energosaving technologies. In this connection unification of methods of identification and an estimation of processes of physical degradation are paramount condition for recessing integration in present district

Other important condition inextricably related with the first is unification of a theoretical basis of a regional network monitorization a physical soil condition .

In this context in view of modern achievements of various soil schools of the European countries we consider, that the most comprehensible is the principle of the system approach to concept about soil as about very complex system with indefinitely big variety of the internal and external functional communications having very complex multilevel structural organization. From these positions at research of soil as natural solid it is necessary to distinguish a hierarchical series of consecutive levels of its structural organization, each of which demands specific methods and approaches of research, the control and management.

All structural levels of the organization of soil are in constant development and close genetic, and consequently also a causal relationship as among themselves, and with factors of pedogenesis as test for itself influence of features of pedogenesis. The concept of hierarchy of levels of the structural organization of soil has not only the important methodological value, confirming independence of soil as natural solid, but also plays the big role both at studying of soil, and at their practical use. She indicates that for knowledge of properties and functions of soil as a whole and managements of not enough what studying of them or one level, and is necessary research of interaction of all levels of the soil organization. This concept allows to choose correctly objects and to establish ways and methods of research, and also the directed change of soil properties and processes proceeding in them.

[1] Research and Production Centre of Agricultural Chemistry Service, Republic of Moldova

– POSTER PRESENTATIONS –

Soil disturbance surveys in pine tree plantations of the Basque Country

González-Arias, A.[1] – Martínez de Arano, I. – Gartzia, N. – Aizpurua, A.

Forests are known to be the ecosystems that best protect soils and watercourses (Horswell & Quinn 2003). Nevertheless, in commercially managed forests where stands are clear-cut and heavy machinery is used for harvesting and site preparation, the maintenance of forest soils sustainability is greatly questioned because plant cover is disturbed and the risk of erosion intensifies. Nevertheless, forestry areas are exposed to disturbance at lower frequency than traditional agriculture, although the disturbance is more severe. Inter-rotation period is defined as the period between clear felling of a mature plantation and the complete re-establishment of the next rotation (Constantini *et al*. 1997).

Pinus radiata plantations that are harvested every 30-40 years account for 60% of the forest surface in the Basque Country. Besides, the steep and mountainous terrain which is characteristic of the Atlantic part of the Basque Country along with the high precipitation that is distributed all year round (1500-2000 mm year^{-1}) makes erosion hazard to be very high in this region, mostly during inter-rotation period. The forestry practices that are used more in this region are: i) clear-cut with chain saws; ii) harvesting using skidders and iii) site preparation using the following techniques: a) clearing harvest residues and understorey vegetation with the front blade of a bulldozer followed by b) ripping in order to facilitate plantation and to improve the physical structure of the soil. If the slopes are steeper (>30%) site preparation is usually fulfilled without machinery and residues are pushed into windrows manually. There are neither reliable statistics about the practices involved in forestry operations nor about the surface treated with these practices. Nevertheless, almost all the harvesting and over 50% of site preparation involve the use of heavy machinery (foresters Confederation, personal communication). The socioeconomic structure of the forest sector and the increasing demand for wood and paper products have led to increased mechanisation and use of heavy machinery in forest operations in the Basque Country, and this fact is going to increase in the following decades.

During the inter-rotation period the plant cover disappears leaving the mineral soil exposed to rainfall for periods of time with different lengths depending on site characteristics and on the forest practices used (Olarieta et al. 1997). In the Basque Country the effect of mechanisation during the first year may lead erosion to change from 8 tn/ha when site preparation is done manually to 60 tn/ha when machinery is used for this purpose (Olarieta et al. 1999). The effect of machinery can also be seen in terms of a 50% reduction of organic matter in forest soils and significant reductions of other essential nutrients (Merino et al 1998; Merino & Edeso, 1999; Olarieta et al. 1999).

Thus, it is important to develop a quick and easy procedure to measure the disturbance of the soil caused by forest practices during harvesting and site preparation in the Basque Country in order to asses the effects of the use of heavy machinery and to evaluate forest practices themselves. This is the main aim of the present study.

Soil Disturbance Evaluation Procedure

A soil survey recording form (an electronic counterpart has also been developed using FileMaker Pro 6.0 database) has been designed in order to standardise data recording and processing. In the front cover of it some general data about the stand (Owner, surface, mean slope, prescription…) have to be recorded. It has to be also recorded, if possible, some parameters about previous harvesting such as harvested species, mean height of harvested trees, dominant height, mean diameter, total harvested volume, tree density when harvested. Afterwards, data about the practices involved must be recorded; practices done by, machinery used, date when forest practices are done and if possible, soil moisture status when practices are done. Another set of data that has to be reported is the one that has to deal with harvest residues and protection of watercourses. This set of data includes the following items: Kind of riparian buffer zone (natural riparian forest, planted riparian forest, shrub-land area, grass-land area, no buffer area, not relevant), number of crosses between roads and watercourses, minimum distance to a riparian buffer zone/river from a road, length of a road that lies parallel to a water course and maximum slope to it. The harvesting residues are recorded as chopped (chopped and evenly spread through the entire surface of the planted area), piled, burnt, windrows and removed (removed from the planted area of the stand). Windrows are recorded in a different way. If distance from windrow to windrow is just enough to plant 3 rows of trees (around 10 m with the nowadays forest management for radiata pine in the Basque Country), and thus, erosion prevention is maximised these windrows are recorded as windrows/erosion;

[1] Forestry Unit. Neiker: Basque Institute for Agricultural Research and Development. Derio Centre**.** Zamudio Technology Park, Plot 812. Berreaga, 1 Derio 48160 (Bizkaia); Tel.: +34-94-4034328; Fax: +34-94-4034310; E-mail: agonzalez@neiker.net

if the distance between them is larger or if they are just pushed perpendicular to the slope they are recorded as windrows.

Soil Disturbance Categories Definition

The procedure developed in this study is based on the Soil Conservation Surveys Guidebook published by the British Columbia Ministry of Forests (2001). This survey method takes the stand as the unity for carrying out the procedure because forests operations are mainly done at this landscape level, and because of operational feasibility. In the procedure proposed in this study, stand level surveys will also be done.

In the first place, the soil disturbance categories defined by BC Ministry of forests (2001) were revised and modified in order to be useful for the particular case of the Basque Country.

The first soil disturbance category to take into account is the one called "Unplanted Structures". This category involves structures in the stand that will be left unplanted in the future. There are two subset of structures counting for this category: 1) lineal structures as access structures (roads), fire-brakes, electrical laying, gas pipelines… and 2) non lineal structures as landing areas, backspar trails… These unplanted structures must be built or considered under prescription. This category will be used to estimate the stand surface occupied by this kind of structures and thus, the surface that is going to be left unplanted in order to evaluate the correct technical prescription and to estimate the losses of productive surface. For structures (roads, paths…) constructed for machinery travelling or left unplanted crossing a watercourse it will be noted in the front cover. If the structure runs parallel to a watercourse the minimum distance to it or to the buffer riparian forest (if it is smaller than 50 m), the length of the structure that is parallel to the river and the slope to it will be measured.

The following disturbance categories are the ones evaluated in the area to be reforested. These disturbance categories are mainly due to i) the incorrect use of the machinery during forest operations e.g. travelling around the whole area, passing by many times on the same place, pushing the shovel into the mineral soil forming gouges… ii) because machinery is used under improper moisture contents of the soil. These categories are grouped from severe disturbance to no disturbance at all the following way: Gouges/dislodged soil; compacted areas; wheel or track ruts; scalps and not disturbed.

Gouges/dislodged soil

These disturbance categories are those that deal with improper use of the machinery. The front blade of bulldozers and skidders have to be operated some centimetres above forest soil to encompass clearing of harvesting residues but sometimes these blades are pushed into the mineral soil for several meters removing the upper part of mineral soil.

a) Deep gouges (**D**). Excavations into mineral soil deeper than 30 cm measured from undisturbed mineral soil or to bedrock at the survey point.
b) Wide gouges (**W**): Excavations into mineral soil that are i) deeper than 5 cm measured from undisturbed mineral soil at the survey point and ii) deeper than 5 cm or to bedrock, on at least 80% of an area of 3 m^2.
c) Long gouges (**L**): Excavations into mineral soil that are i) deeper than 5 cm measured from undisturbed mineral soil at the survey point and ii) deeper than 5 cm or to bedrock on at least 80% of an area 1 x 3 m.
d) Ripping furrows (**S**): Furrow generated during site preparation using a ripper or similar equipment at the survey point. The angle deviation from the horizontal line is also measured at the bottom of the trench. If ripping is a prescribed operation, the category where the furrow trench at the survey point lies is also recorded.
e) Ripping mounds (rest-balk) (**N**). Rest-balk generated during site preparation using a ripper or similar equipment at the survey point. If ripping is a prescribed operation the category where the mound lies at the survey point is also noted.
f) Dislodged soil (**E**). Accumulations of dislodged mineral soil (mounds) with or without harvest residues that are i) higher than 5 cm at the survey point and ii) higher than 5 cm on at least 80% of an area of $3m^2$.
g) Removed stumps (**T**): Stumps that have been pushed out from the soil by the machinery. It may be the stump itself or the hole left when the stump was removed.

Compacted areas

Due to repeated machine traffic, or because logging areas are not properly designed and the area to be reforested is used for this purpose, some areas of the area to be reforested may get compacted. Prior fulfilling the survey, a quick determination is done in an adjacent and mature forest in order to have forest floor depth and compaction reference values for the evaluation. Compaction is assessed with a hand penetrometre easily. This is achieved selecting two points in the middle of the mature stand, 100 m away from access structures. From these points 15 points are randomly selected using 2 different randomly generated number lists: one (from 0 to 360) for compass bearing and the other one (from 0 to 25) for distance from the centre point. In each of these 30 points forest floor depth to mineral soil is measured and soil strength (as resistance to penetration) are measured. Compaction is assessed relative to the 90th percentile of the values estimated this way. When resistance to penetration in the survey point and the area surrounding is bigger or equal this figure, then the soil is considered as compacted.

a) Big Compacted Areas (**A**): Compaction estimated as explained before i) at the survey point and ii) compaction on 100% of an area of 100m^2.
b) Small Compacted Areas (**C**): Compaction estimated as explained before i) at the survey point and ii) compaction on at least 80% of an area of 3 m^2.

Wheel or track ruts

Wheel or track ruts are impressions or ruts in the soil caused by heavy equipment traffic. They are mainly done when the soil is wet (close to field capacity). This category does not require the survey point to be assessed for evidence of compaction.

a) Deep Ruts (**H**): Impressions in the soil with a width of 30 cm and a minimum depth of 15 cm from the forest floor or 5 cm from the mineral soil at the deepest point in the perpendicular cross-section, over the entire length of 2 m. Depth is measured from the surface of the undisturbed forest floor or from the mineral soil to either the forest floor surface in the bottom of the rut or the mineral soil surface in the bottom of the rut if a forest floor is not present.
b) Superficial Ruts (**G**): Impressions in the soil with a width of 20 cm and a minimum depth of 5 cm measured from the mineral soil at the deepest point in the perpendicular cross-section, on at least 50% of a length of 2 m. Depth is measured from the surface of the undisturbed forest floor or from the mineral soil to either the forest floor surface in the bottom of the rut or the mineral soil surface in the bottom of the rut if a forest floor is not present.

Scalps

Scalps are areas where the forest floor has been removed either by the improper use of the front blade or by the pushed trunks when logging is done.

Forest floor is considered removed when the underlying mineral soil is exposed or it is covered by:

1) Fine woody slash, undecomposed needles, or dislodged rotten wood.
2) Dislodged forest floor that is less than half the depth of the undisturbed forest floor (reference value estimated as commented above).

Forest floor is not considered as removed when it is:

1) Intact forest floor of any depth, typically showing roots growing into the mineral soil.
2) Exposed mineral soil covered by dislodged forest floor that is at least half the depth of the undisturbed forest floor (dislodged forest floor must be similar to the adjacent undisturbed forest floor to be acceptable).

a) Very Wide Scalps (**B**): Areas where the forest floor has been removed i) at the survey point and ii) forest floor removed at least 80% on an area 9 m^2.
b) Wide Scalps (**M**): Areas where the forest floor has been removed i) at the survey point and ii) forest floor removed at least 80% on an area 3 m^2. This category is not considered when the prescription allows the use of machinery.

Harvest Residues

Harvest residues with neither mineral soil nor forest floor that have been piled in the area to be reforested either to minimise the erosion hazard or to facilitate planting operations. They will not be counted as disturbance category as it will be impossible to assess for soil condition underneath them unless they are burnt.

It will be positively taken into account and it will be noted as such in the front cover if:

1) Residues are pushed into windrows following the contour of the land and allowing 3 rows of trees to be planted (around 10 m for radiata pine) to minimise erosion risk.
2) Residues are chopped and spread uniformly all over the stand to minimise raindrop impact and to provide for organic matter and nutrients for the next rotation.

It will be negatively taken into account and it will be noted in the front cover if:

1) Residues are burnt although the soil has no visible damage as defined in the category "Burnt Harvest Residues"
2) Harvest Residues are removed from the area to be reforested even if they are pushed to the bottom of the stand or to an Unplanted Structure.

a) Wide Harvest Residues (**R**): Piles of harvest residues higher than 30 cm i) at the survey point and ii) piles occupying at least 80% of an area of 9 m^2.
b) Harvest Residues. Windrows (**K**): Harvest residues piled on strips i) at the survey point and ii) residues on at least 80% of an area of 4 x 0.5 m.
c) Burnt Harvest Residues (**I**): Piles of burnt harvest residues i) at the survey point and ii) burnt residues occupying an area of 3 m^2. Burnt residues will be considered if the underlying soil shows a

massive and oxidised structure different from undisturbed soil. If residues are burnt but no clear affection to soil is recorded, it will be noted in front cover but these areas will be considered as scalps.

Not evaluated

Not Evaluated (**X**): The survey point falls on a stone, a stump, or other element that cannot be evaluated.

Not disturbed

Not disturbed (—): The survey point falls on not disturbed soil or on a disturbance category smaller than the ones mentioned above.

Forest Floor Absence

Forest floor absence (**O**): The survey point falls on whichever category defined above (with the exception of X) but the forest floor is not present. The category is reported as the symbol that represents it and it will be encircled.

Survey Methods

Estimation of the riparian buffer system

If the stand is close to a watercourse the type of riparian buffer system (e.g. riparian forest, shrubs, grassland, not present…) must be recorded in the front cover. To estimate the area occupied by it or the mean width that it has, the lineal structure surveying is carried out (see below). The width and its slope are also measured at ten intervals. The width is considered as the distance from the top part of the riverbank to the imaginary line that connects the trunks of the outer trees or to the end of the vegetation. Calculations are also done as in the "Lineal Structure Surveying".

Lineal Structure Surveying

A different survey for different lineal structures must be made; for example roads, fire-brakes or electrical lines. If different roads differ in width more than 2 m they are also be considered as different structures, and as such they are surveyed. For each structure the whole horizontal length and at least ten horizontal widths will be measured to estimate the area occupied by it. A visual estimation of the length of the structure to be surveyed is done and this is divided into at least ten intervals in order to estimate the length at which the width is going to be measured. The width is measured as the distance from the outer points of it considering as part of the structure the upper part of the cut and the end of the horizontal plane unless if there is a the fill that is 2 m wide. If this happens, and if the fill is left unplanted the fill is also considered as part of the structure. The length of this interval and its slope is then recorded along with the width of the structure at that point and its slope. The first width to be measured is set up at half of this interval and afterwards the measures are done on the interval basis. The slopes are recorded in order to estimate the horizontal area of the structure and to be able to estimate the percentage of the stand's surface that is covered by such structures. When the interval for width measurement falls in a landing area it is not recorded and the length that falls in the landing area is not considered for lineal structure calculation. If it falls on a junction of structures the point for width measure is moved until the junction finishes and the width is measured there. The next width is the measure at the point where the interval falls. When the structure is close to a watercourse (less than 50m) it is also recorded with a "V". With the width values measured this way and the t table (one sided, 90% or 95%, depending on the accuracy needed for the survey) the width confidence interval can be calculated and thus the area error for the surface that each structure occupies. Besides, the proportion of structures that are close to watercourses can be assessed. Roads are supposed to be one of the most important elements for erosion and for sediment delivery to rivers.

Non-Lineal structures

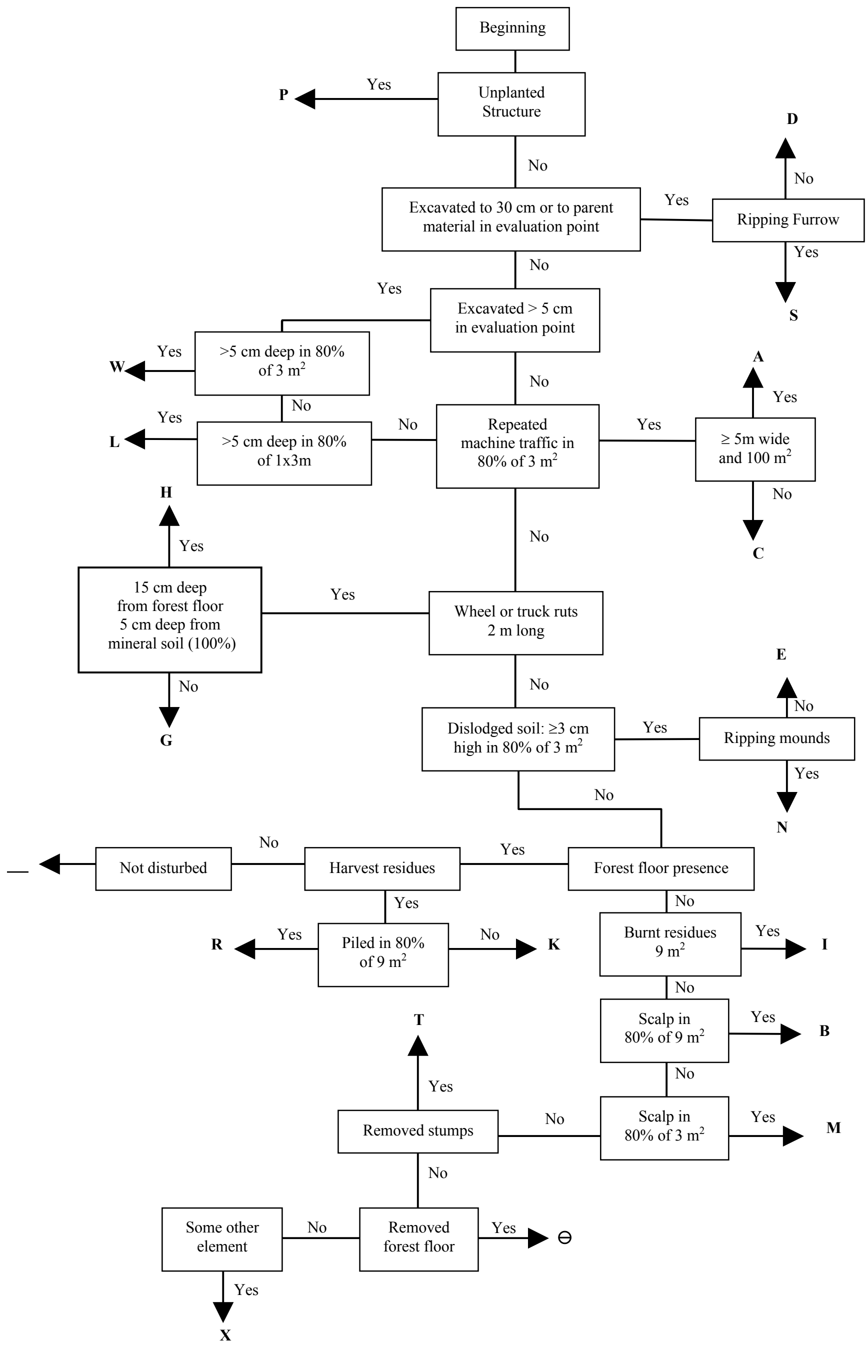
Non-lineal structures are landing areas, logging areas… that are left unplanted. To estimate the area occupied by these structures, four measures are taken in each of them. The length of the structure is divided into quarters and the width at the first and third quarter along with their slopes are measured. The width of the area is also divided into quarters and the length of the area and their respective slopes at the first and the third quarter are measured. The mean of the horizontal lengths and of the horizontal widths are calculated and the area is estimated as the product of these figures for each of them, that can afterwards be added up to estimate the percentage area occupied by these structures.

The percentage of the occupied by unplanted structures is calculated as the horizontal surface of roads and landing areas to the total area of the stand and the area to be reforested is considered as the subtraction of the stand area from the sum of the areas of roads and landing areas and the percentage for the rest of lineal structures are referred to this area to be reforested.

Transect surveys for disturbances categories in the area to be reforested

A regular grid of points to be surveyed are laid out in the area to be reforested using parallel transect lines. They are laid out perpendicular to the maximum disturbance assessed visually. Normally, and taking into account the practices used for forest operations in the Basque Country, this maximum disturbance coincides with the slope. Distance between transects and between the points that are going to be surveyed are calculated depending upon the surface of the area to be reforested. If the surface is smaller than 1.0 ha distance from point to point in each transect is 4 m and distance form transect to transect will be calculated to survey 100 points regularly. From 1 ha onwards the distance between points will be 5 metres and the distance between transects will be calculated to be 200 points to 2 ha, 300 points to 5 ha and 500 to areas to be reforested bigger than 5 ha. The first transect is laid out using a randomly generated number list from 0 to 100, and this figure will be used as the percentage of the distance between transects calculated before. Once the grid of points is laid out in field the survey is done recording a disturbance category as defined before to each point following the guide presented below. In order to evaluate each point the maximum disturbed surface around the point will be considered. With these figures and with the Remig tables for probabilities (90 or 95 % depending on the accuracy needed for the estimation) for the binomial distribution the percentage of the surface of the area to be reforested and its confidence limits can be assessed.

Guide for assessing disturbance categories.
The following dichotomous guide (fig 1) is used to assign a disturbance category to each surveyed point.



Results

Fifteen different stands were surveyed last year. All the stands are located in the Basque province of Bizkaia. The maximum distance between stands is around 40 km. Harvesting, logging and site preparation had been done the same year. None of the stands were harvested by hand and skidder was always used for this operation. Site preparation was done by machinery in 40% of the sites, whereas in the rest of the stands plantation was achieved manually. Harvesting and site preparation was done in the end of 2002 or the beginning of 2003 and soil moisture was high when these operations were carried out. The results from these surveys are presented in table 1.

Table 1. Results from forest soil disturbance surveys carried out during 2003 in 15 stands in the Basque Country. Stands are divided by site preparation practice. All of them were harvested with skidder. The name of the locality served as code for each stand. "Unplanted structures" is the percentage of the area occupied by these structures referred to the whole stand minus the confidence interval for the one sided t distribution at 90% probability in brackets). "Disturbed area" and "forest floor removal" are the percentage of the area occupied by these categories referred to the planted area (stand surface *minus* unplanted area). Confidence interval for the binomial distribution at the 90% probability is shown in brackets. Ripping furrows is the percentage of furrows in slopes >30% referred to the total number of furrows surveyed. Mean slope of these furrows in brackets.

	Surface (ha)	**Mean slope (%)**	**Harvest residues**	**Unplanted Area (%)**	**Disturbed Area (%)**	**Forest floor Removal (%)**	**Ripping furrows in slopes > 30%**
Manual site preparation							
Aretxabalagane	0.5	15	Windrows	7.51–0.32	59–5.5	47–5.6	NR*
Autzagane	1.5	14	Removed	2.29–0.14	47–6.9	57–3.8	NR*
Astei	1.5	39	Removed	9.53–0.63	74–6.1	70–5.7	NR*
Egia	1.5	25	Removed	3.13–0.21	21–5.7	22–5.8	NR*
Etxaso 1	0.25	10	Windrows	7.5–0.46	75–6.1	73–5.9	NR*
Santa Lucia 1	1.5	30	Burnt	20.66–1.1	83–4.3	77–5.0	NR*
Sarasolalde	2.5	10	Removed	1.56–0.09	55–4.8	49–4.8	NR*
Xaibiko Landa 1	0.6	20	Removed	9.50–0.75	41–6.8	40–6.8	NR*
Xaibiko Landa 2	0.5	10	Removed	9.20–0.66	38–6.8	31–6.5	NR*
Mean (sd.)	1.2 (0.7)	19.2 (10.2)		7.8 (5.7)	55 (20.2)	52 (19.1)	
Mechanical site preparation							
Baluga	5.0	25	Piled	22.43–2.11	87–2.9	91–4.2	21.7 [38.33]
Etxaso 2	0.75	10	Windrows	1.73–0.11	40–6.8	44–6.9	0 [0]
Maiaga	0.4	14	Removed	5.64–0.33	62–6.8	64–5.0	0 [0]
Santa Lucia 2	0.8	46	Removed	6.63–0.48	97–2.7	97–6.9	66.7 [52.36]
Txareta	0.7	31.5	Removed	10.14–0.78	81–4.5	85–5.3	27.8 [42.71]
Txorierrota	1.5	12	Removed	8.37–0.42	74–6.1	75–6.1	5.9 [32.49]
Mean (sd.)	1.5 (1.7)	23.1 (14.0)		9.2 (7.1)	73 (20.2)	76 (19.6)	20.4 (25.5)

*NR: Not relevant

Stands were relatively small, but private owners mainly own forest plantations in the Basque Country, and most of the properties are around 1 ha in surface. Nevertheless, it is striking that the mean slope of the surveyed stands with manual site preparation is smaller than the ones that preparation is achieved mechanically. None of the surveyed practices were achieved bearing in mind possible erosion hazards and the ones with steepest slopes had harvest residues removed. In none of them these residues were chopped (a very rare practice in the Basque country). Some years ago, piling and burning harvest residues were a regular practice. Nowadays it seems that burning is not so usual and this practice was just recorded in one stand.

The unplanted area ranges from 1.6% to 22.4% of the surface of the whole stand. But in absolute figures the maximum surface occupied by unplanted structures was around 1 ha. Road density in this stand is so high that future production is lessened by improper technical prescription.

The use of machinery during harvesting, logging and/or site preparation causes high impacts on the planted area. Validation of this visual characterisation is reported elsewhere. The smallest percentage of soil disturbance was found in "Egia" stand, but 80% of them had more than 50% of the surface disturbed, and just one of the stands where mechanical site preparation was done had less than 50% of its surface disturbed. The practices involved in forest operations also reduce the organic matter content during the inter rotation period. This fact may have a great impact in future forest nutrition and in the maintenance of a proper soil structure for plant production. When ripping is used as site preparation technique a significant number of the furrows are done on slopes considered as to high for this operation. It is striking the case of "Santa Lucia 2" That has a mean slope of 46% and ripping was used for site preparation.

When the disturbance categories are kept in mind, future production could be threatened in these stands, and it seems that practices must be corrected to improve forest management in The Basque Country. The soil disturbance survey tool developed in this study has been shown as very useful one. It is easy to perform and once disturbance categories are redefined for each particular forest management system ad when the electronic records are developed it is a very quick evaluation procedure that could be implemented as a feedback tool towards Sustainable Forest Management.

References

B.C. Ministry of Forests. 2001. Soil Conservation Surveys Guidebook. 2nd ed. Forest Practices Code of British Columbia Guidebook. Victoria. Canada. 63 pp.

Constantini, A. Grimmet, J.L. 1997. Towards sustainable management of forest plantations in South-east Queensland: I. logging and understorey residue management between rotations in steep country *Araucaria cunninghamii* plantations. Australian Forestry. 60: 213-225.

Horswell, M & Quinn, N. 2003. Minimising sediment delivery to rivers: A spatial modelling approach developed for commercial forestry. Diffuse pollution Conference. Dublin. 5A: 1-6

Merino, A; Edeso, JM; 1999. Soil Fertility rehabilitation in young *Pinus radiata* D. Don plantation form Northern Spain after intensive site preparation. Forest Ecology and Management 116: 83-91

Merino, A; Edeso, JM; Gonzalez, MJ and Marauri, P. 1998 Soil properties in a hilly area following different management practices Forest Ecology and Management 103: 235-246

Olarieta, JR, Rodriguez, R; Besga, G. Rodriguez, M and Virgel, S. 1997 Evolución de la cubierta del suelo con diferentes sistemas de preparación del terreno tras la matarrasa de plantaciones de pino radiata. II. Congreso Forestal Español. Pamplona 23-27, de Junio de 1997.

Olarieta, JR; Besga, G; Rodriguez, R; Uson, A. Pinto, M. and Virgel, S. 1999 Sediment enrichment ratios after mechanical site preparation for *Pinus radiata* plantation in the Basque Country. Geoderma. 255-267.

Effects of land use change on the production of sediments at the subcatchment scale in a Mediterranean landscape

Boix Fayos, C.[1] – González Barberá, G. – Martínez Mena, M. – Castillo, V. – Albaladejo, J.

Mediterranean mountainous landscapes have experienced a considerable change of land uses in the last fifty years, which is expected to be reflected in the dynamics of geomorphological processes, and the degree of soil loss within the landscape. The objective of this study is to assess the actual effect of land use changes on geomorphological processes and on sediment production at the sub-catchment scale. Therefore, sediment volumes trapped behind check-dams in a study area in the region of Murcia (SE Spain), were used as an indicator of sediment movement within a catchment during a certain period. The check-dams were built in the seventies as a part of a program for sediment and flood control together with afforestation works.

The land use changes within the catchment over a period of 40 years are investigated. In addition, basic geomorphological characteristics of the drainage area of the check-dams including factors such as slope steepness, slope morphology, lithology, and morphometrical parameters are analyzed. The relations between land use change in combination with the geomorphological parameters analyzed and the level of siltation of the check-dams were explored. This analysis provided insight in the most important factors related to sediment production and sediment transport at the sub-catchment scale.

[1] Soil and Water Conservation Department, CEBAS, Spanish Research Council (CSIC); Tel.: 00 34 968 396264; Fax: 00 34 968396213; E-mail: rn002@cebas.csic.es

A method for the evaluation of soils for olive cultivation using a G.I.S.

Sierra, C.[1] – Martínez, F.J. – Roca, A. – Sierra, M.

Abstract

We designed a specific method for soil fertility evaluation adapted to olive cultivation in Andalucia (Spain), and which could be adapted to other olive-producing areas, in order to plan the correct use and management of the medium..This is especially important since these are soils with a high risk of hydric erosion (Mamani et al. 2000) and the olive is of great socioeconomic importance, regulated by the E.E.C. The method is based on the philosophical principles of the F.C.C. systems Sánchez et al. (1982), Aguilar et al.(1995a y b), Martínez (1990), Sys et al. (1985),adapted using specific trials. It may be defined as an expert method of soil fertility evaluation assisted by IDRISI (SIG).

Materials and methods

Sampling followed the random stratified method of Bridges et al. (1982). Samples were taken from between the rows of olive trees every four trees at depths of between 30 and 60cm. Laboratory analysis was carried out according to Ministerio de Agricultura (1982). The GIS employed was IDRISI for Windows.

Experimental part

The structure of the proposed method was as follows:

1. **Matrices and elementary maps:** These group the selected characteristics according to the limiting factor for the olive in three levels: **LEVEL 1.** Major limiting factor which can only be improved at great cost: slope. **LEVEL 2.** Major limiting factors which can only be improved at great cost: soil depth, $EC_{2.5}$, CO_3^{2-}, texture, CEC, OC. **LEVEL 3.** Minor limiting factors which can be improved at low cost: pH, macronutrients (N, P_2O_5 and K_2O), micronutrients (Fe, Cu, Zn, Mn, and B).
2. **Matrices and multiple maps: Map I:** Texture + CEC + O.C.; **Map II:** map I + slope; **Map III:** map II + CO_3^{2-}; **Map IV:** N + P_2O_5 + K_2O; **Map V:** map III + map IV.

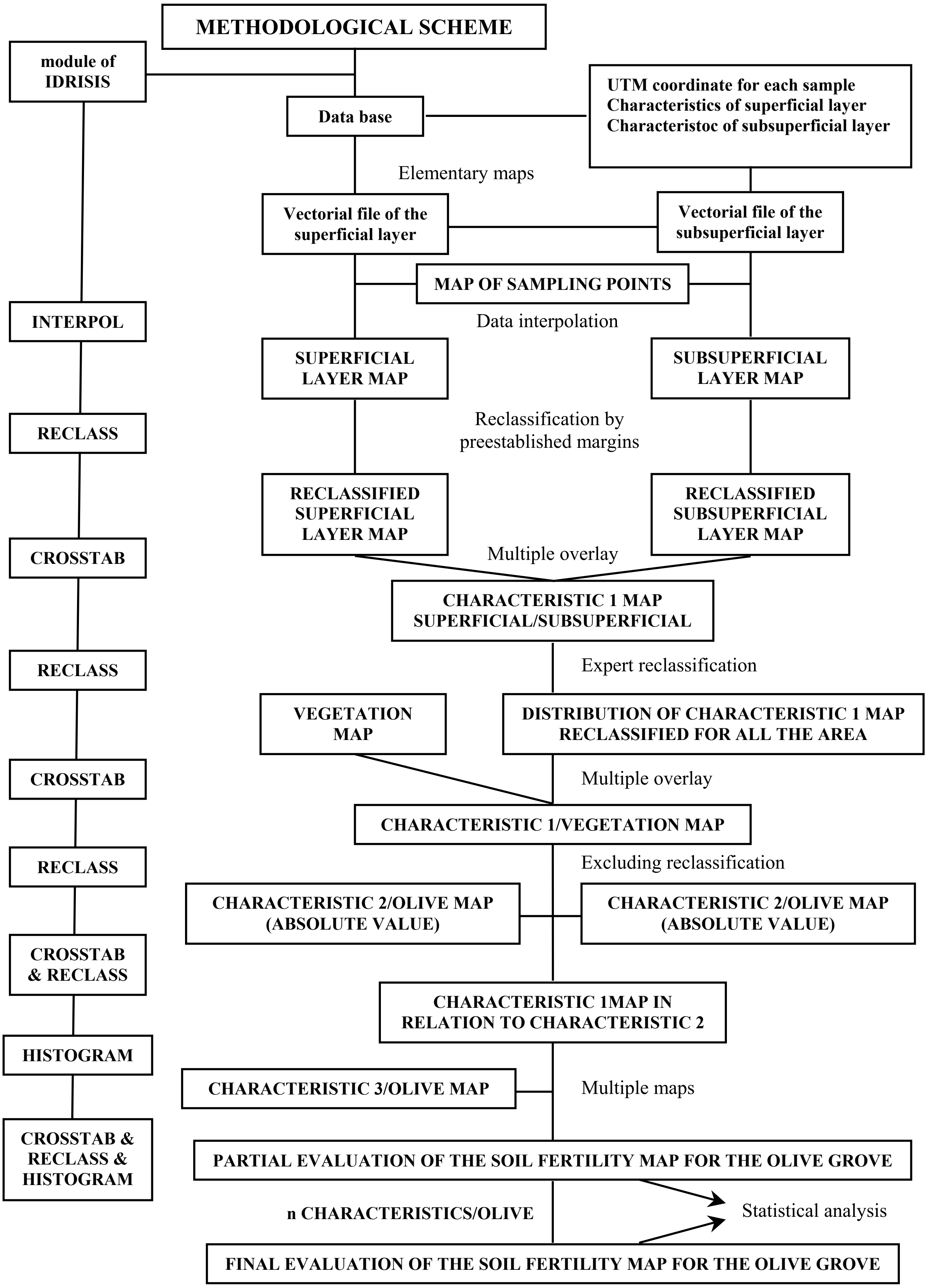
The evaluation of the fertility of soils under olive cultivation is explained in the following methodological scheme: the process begins with the creation of a database based on the analytical results which define the characteristics of the superficial and subsuperficial samples and their UTM coordinates. According to FAO (1999), the term “characteristic” designates properties of the soil which can be measured or estimated and delimits soil units.

To obtain the elementary maps we created two vectorial files of each characteristic for both the levels sampled, thus generating maps of points which identify the samples and can be overlayed on the digital land model or on any of the partial maps generated. The vectorial files are treated with the INTERPOL module, giving rise to a superficial image through interpolation of specific data, following the criteria of Del Moral (2000), with a weighting index of 2, that is, the square of the inverse of the distance, limiting the process to a search radius of 6 points around each point to be intercalated. This method tends to generate “bullseyes” around the sampling points when they are irregularly distributed. This defect can be corrected by increasing sampling in these areas.

The raster maps obtained (superficial and subsuperficial) are reclassified using the RECLASS module, creating new categories according to margins preestablished by the evaluator. In our case we used limits already proposed by other authors for each characteristic and other new limits defined following interviews with farmers and experts in olives. These images are then overlayed using the CROSSTAB module, which permits multiple overlaying. This shows, in a new raster image, all the combinations of the original categories. Next, an expert reclassification of these combinations is carried out. This consists of jointly evaluating each characteristic within the 60cm of the solum.

In a complete study all current land uses would be included, and, in this case, olive cultivation would be separated from the others. To achieve this, a vegetation map is drawn, followed by multiple overlaying of each characteristic of the solum. This results in a series of maps (characteristic/vegetation) which is reclassified by excluding the areas without olive trees, giving rise to a new map with black zones representing the “no olive tree” areas. This map is then treated statistically and histograms are drawn. These allow us to calculate the percentages of the categories established for each characteristic in the area occupied by olive trees. This is the elementary map, in which the numerical intervals are expressed as absolute values, and may be definitive in the evaluation process. In other cases relative maps may be useful. Maps of each characteristic are related according to other characteristics, for example, macro or micronutrients with texture, pH. Finally, partial maps of soil

[1] Dpto. Edafología y Química Agrícola. Universidad de Granada. Campus Cartuja, 28071 Granada, Spain. Tel.: 34 958243836; Fax: +34958243832; E-mail: csierra@ugr.es

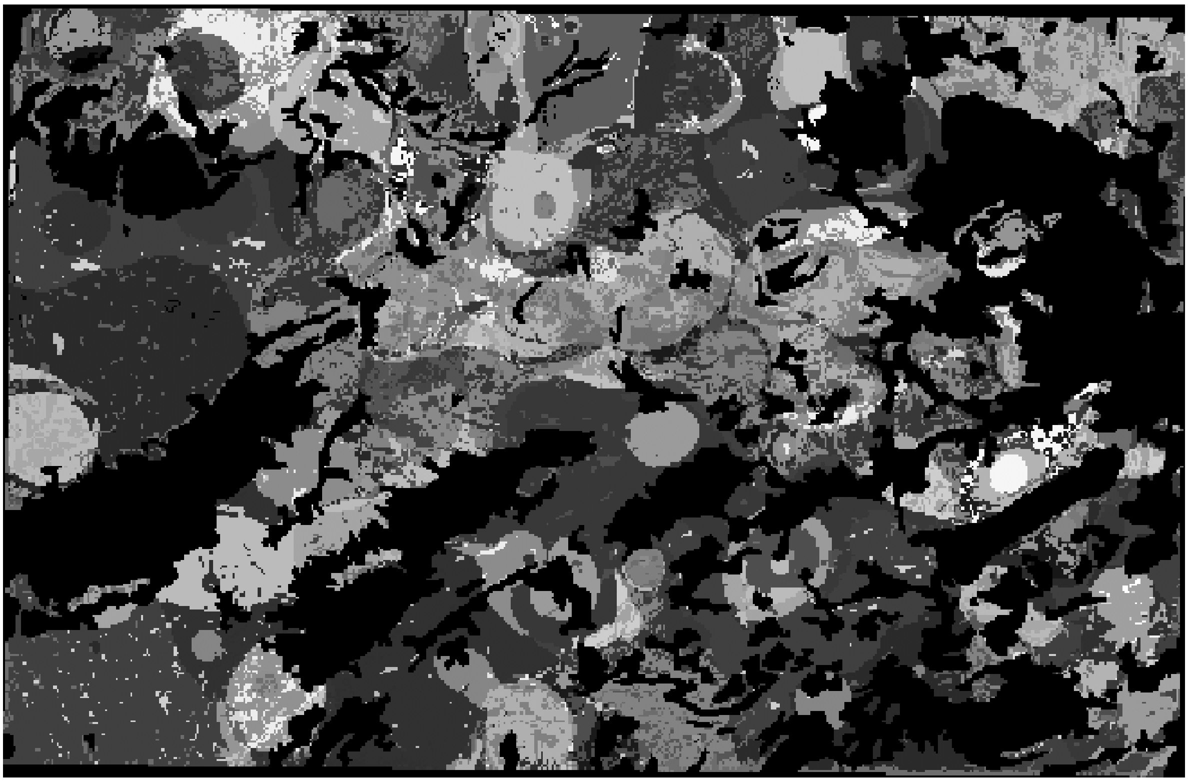


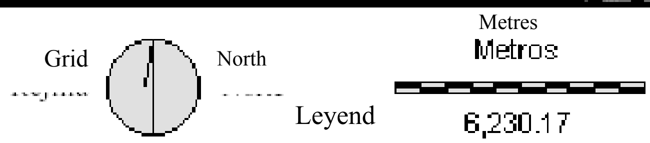
fertility evaluation can be drawn by the successive overlaying of maps of properties (multiple maps). In the IDRISI we alternate multiple overlaying (CROSSTAB) with reclassifications (RECLASS) to create the final fertility map for the soils under olive cultivation and the histogram.

This method was applied to the topographical map 1:50,000 of Alcalá la Real and the final fertility map for the olive grove is obtained. This has 75 units (map1) which can be interpreted automatically by “clicking” on the required point of the map generated by IDRISI. For example, if we "click" on a point theoretically belonging to class 4 (the largest) we obtain the following information, in agreement with the matrices given by Mamani et al. (2000): soil unit of 2593.47 ha, clayey texture, sloping, no risk of puddle formation and surface drainage favoured by the slope, low in organic material but with high cationic exchange capacity and carbonate levels from 25-50%. It has a low nitrogen content, optimum phosphorus and low potassium, and thus, we recommend organic fertilizer and vegetation cover to minimize the risk of erosion.

Conclusion

The method proposed is for the specific evaluation of soil fertility adapted to olive cultivation and can be defined as expert, aided by IDRISIS (SIG). It is structured in three levels grouping physical and chemical characteristics of the soil which indicate its potential fertility, the direct or indirect effect on the nutritional state of the olive tree and its development. The system of interpolation of the data is according to the square of the inverse of the distance and requires the correcting of sampling near the areas known as "bullseyes". The system can be improved when the program increases the possibility of combinations and reclassifications and its total automatism is achieved.





Map 1. Soil fertility map for the olive grove

Leyenda

Classes	Major limitants/NPK						
1	4/1	20	11/2	39	11/5	58	17/6
2	6/1	21	12/2	40	12/5	59	4/7
3	7/1	22	13/2	41	14/5	60	9/7
4	9/1	23	14/2	42	15/5	61	12/7
5	10/1	24	15/2	43	16/5	62	16/7
6	12/1	25	16/2	44	17/5	63	5/8
7	14/1	26	17/2	45	1/6	64	8/8
8	15/1	27	4/3	46	3/6	65	9/8
9	16/1	28	7/3	47	4/6	66	11/8
10	17/1	29	9/3	48	5/6	67	14/8
11	1/2	30	12/3	49	6/6	68	16/8
12	3/2	31	17/3	50	7/6	69	16/9
13	4/2	32	9/4	51	8/6	70	5/10
14	5/2	33	4/5	52	9/6	71	8/10
15	6/2	34	5/5	53	10/6	72	9/10
16	7/2	35	6/5	54	11/6	73	5/12
17	8/2	36	8/5	55	12/6	74	8/12
18	9/2	37	9/5	56	14/6		Other (*)
19	10/2	38	10/5	57	16/6		No olives

(*)Unit whose extension is lower than 2%

References

Aguilar, J.; Fernández, J.; Fernández, E.; De Haro Lozano, S.; Marañés, A. y Rodríguez, T. (1995a). "El olivar Jiennense". Servicio de Publicaciones e Intercambio Científico. Universidad de Jaén. 114 p.

Aguilar, J.; Fernández, J.; Fernández, E. y Rodríguez, T. (1995b). "Jerarquización de parámetros edáficos en la evaluación de la productividad del olivo". Edafología, Rev. de la SECS. pp. 101-110.

Bridges, E. M. y Davidson, D. A. (1982). "Principles and applications of soil geography". Lougnan Group. Ltd. New York.

Mamani, F.; C. Sierra; FJ Martínez;. Roca, A. (2002). "Cartografía, Génesis y evaluación de los suelos de la Hoja de Alcalá la Real". Serv. Publ. Univ. Granada. ISBN: 84-338-2891-6.

Martínez, F. J. (1990). "Estudio edáfico de la hoja de Guadix (1011). Evaluación y uso de los suelos". Tesis Doctoral. Universidad de Granada. 694 p.

Ministerio de Agricultura (1982). "Métodos Oficiales de Análisis de Suelos del Ministerio de Agricultura". Madrid.

Sánchez, P.A.; Couto, W. & Buol, S.W. (1982). "The Fertility Capability Classification System: interpretation, applicability and modification". *Geoderma*, 27: 283-309.

Sys et al. (1985). "Land evaluation". International Training Center, State University of Ghent. Ghent, Belgium.

Influence of age of abandonment on soil fertility in a bioclimatic sequence of abandoned fields on Tenerife Island (Canary Is., Spain)

Rodríguez Rodríguez, A. – Arbelo, C.D. – Guerra, J.A. – Mora, J.L. – Fuentes, F. – Armas, C.M.[1]

Abandonment of agricultural land is one of the main causes of desertification owing to important negative repercussions both social and on the landscape and environment. These latter influences include intensification of soil degradation processes especially: erosion, compaction, salinization, acidification, etc.

Changes in fertility and in soil quality of abandoned fields has been subject to controversy and the direction of the changes occurring depend on climatic conditions, soil type and other factors.

The main aim of this work is, therefore, to establish the type of change in soil fertility occurring in soils in an altitudinal bioclimatic sequence of crop-lands abandoned at different times, in the semiarid region of Tenerife Island (Canary Is.).

The soils from a total of 68 plots representative of the main abandoned cultivated areas in the southeastern province of Tenerife Island were studied. This area is characterized by a climate that varies with altitude from arid with mean annual rainfall of 130 mm (0-400 m a.s.l.), to semiarid (400-800 m a.s.l.) (350 mm of mean interannual rainfall) and finally to dry subhumid climate (800-2000 m a.s.l.) with an interannual average rainfall of 500 mm. Dominant soils in these regions are Calcisols, Cambisols and Luvisols (Calcids, Cambids and Argids) in the lowest regions, Regosols and Leptosols (Arents and Orthents) in the intermediate region and Cambisols and Leptosols (Ustepts and Orthents) in the wetter higher regions.

For each plot, the morphological, surface and soil profile characteristics and the physical and chemical properties of the soil were studied, analyzing the evolution of these parameters with time of abandonment, according to their position in the bioclimatic sequence. To integrate the heterogeneity into a value that enabled us to quantify the state of fertility of the plots, a numerical index of soil fertility was outlined on the basis of scoring functions and weighting factors. We use to this index to assess the chemical fertility of soils and their spatial and temporal variability.

According to these indices, lowest levels of fertility appear in the most arid coastal region, with problems of alkalinization, salinization and sodification, especially in the lands abandoned the longest time ago.

In semiarid areas of intermediate altitude, chemical soil fertility was more favorable than in the coastal region, with a lower incidence of salinization and sodification processes and a larger contents of organic matter and nutrients, especially in the most recently abandoned fields. In the fields abandoned longest ago, processes of laminar erosion and soil skeletization are beginning to appear.

The highest indices of chemical fertility are obtained in soils from plots in the highest zone of the sequence (subhumid) with intermediate ages of abandonment that present optimum pH, loam texture and an appropriate proportion of nutrients and organic matter.

In general, the chemical fertility indices show no differences with age of abandonment of plots, although there is some tendency for fertility levels to decrease with time in each altitudinal zone. It can also be observed that higher zones, with larger chemical fertility indices present worse conditions of accessibility and conservation of field-structures, while the opposite occurs in lower soils abandoned more recently.

The middle zones, therefore, appear to be the ones with the best physical and chemical conditions, accessibility and conservation and the most suited to the implementation of management measures in these abandoned lands, both from a productive perspective and also regarding the establishment of vegetation and other agroenvironmental measures for conservation of the soils and landscape.

[1] Soil Science Department, University of La Laguna, La Laguna, Tenerife, Canary Islands, Spain. Tel.: 34 922 318371; Fax: 34 922 318311; E-mail: antororo@ull.es

Non arable soils in the highlands of Central Greece: nature, properties and vegetation

Mitsimponas, Th.[1] – Karyotis, Th. – Noulas, Ch. – Tziouvalekas, M.

Abstract

Soil samples were collected from the highlands of Central Greece in the prefecture of Trikala (district Pertouli) to assess certain factors, which affect the degree of land degradation. Attempts were made in order to assess soil fertility and the ability of the native vegetation to uptake nutrients. Thirteen sites (S1-S13) were selected from various landscape positions originated from different parent material. It was found that soil texture varied from sandy loam (SL) to clay loam (CL). The pH ranged between 5.5 to 7.2, $CaCO_3$ was detected in two sites, and base saturation ranged from 66.7 to 100.0 % depending on the presence of exchangeable cations, especially calcium (Ca^{++}) and magnesium (Mg^{++}). Cation exchange capacity ranged between 12.0 and 40.5 cmol/kg, whilst the decreasing order of exchangeable cations was as follows: Ca^{++}>Mg^{++}>K^{+}>Na^{+}. Organic carbon greatly varied and ranged from 11.9 to 52.9 g/kg and soil available phosphorus (P) was very low (except S1) indicating conditions of low soil fertility. Total content of soil nitrogen (N) was 0.9 to 4.0 g/kg. Crop species like turf grasses and shrubs self-sown or cultivated for animal feed were generally deficient in P, K, and Cu indicating the impact of leaching within soil horizons. Nitrogen content in plants ranged between 10.0 and 36.0 g/kg, while other nutrients were found in the order: K>Ca>Mg>P. Moreover run off that occurs in slopes during the winter period or the binding of micronutrients with organic matter may affect the level of the available form. Erosion may also have affected on soil physical and chemical properties. However, some of the selected plant species should be capable of growing under the local ecological conditions, be suitable for the soil type and climate and therefore, have a successful history of local propagation and growth.

Materials and methods

Thirteen surface soil samples (S1 - S3) were collected from representative sites and most of them formed through the weathering of gneiss, schists, hard limestones or ophiolites. The examined samples were air–dried, ground and sieved (<2 mm). Particle size distribution was determined by the Bouyoucos hydrometer method (Gee and Bauder, 1986). The pH values were measured in a 1:1 soil–H_2O suspension (McLean, 1982) and the ammonium acetate (1 N at pH=7) method was used for the exchangeable cations (Thomas, 1982). The exchangeable K^{+} and Na^{+} were determined with a flame photometer. Both Ca^{++} and Mg^{++} were measured with an atomic absorption spectrophotometer. Soil carbonates were determined by the volumetric calcimeter method (Allison, 1965). Available phosphorous was extracted from acid soils by a Bray method (Kuo, 1996) and Olsen method was used in the slightly alkaline samples (Sommers, 1982). Total soil carbon was determined in the fine ground (<80 mesh) soil samples by a LECO Elemental Analyzer. Organic carbon content was estimated as the difference between the total and inorganic form. LECO CNS–2000 analyzer was used for total soil nitrogen determination. The available Fe, Cu, Zn and Mn in the soil samples were extracted in soil samples with 0.005 M DTPA (Lindsay and Norvell, 1978), whilst the azomethine-hydrogen method (Keren, 1996) was used for determination of the plant available boron. Plant materials were collected, air-dried for at least 48 h at 65 ºC, and prepared for micro-nutrients determination (Isaak and Kerber 1971) by atomic absorption.

Results and Discussion

The studied soils are located on the highlands of Pertouli (1.000 –1.300 m.a.s.l.) in the district of Trikala, Central Greece (Fig. 1) and are used for grazing, recreation purposes or as forest land. Fir trees, fern, turf, broad-leafed grasses, wild chicory, camomile, vetch, red clover, white clover and rush are among the main plant species in the studied area. Plant analyses have shown that total nitrogen varied between 10.0 and 36.0 mg/g dry matter. Vetch and clovers were the richest in N content, while the lowest values were observed in rush and turf.

The surface horizon commonly has been undisturbed for many decades. The organic matter varied greatly amongst the examined samples (Table 2) depending on biomass production, its degree of decomposition and erosion risk, as well. In practice, the decomposition of organic matter in these highlands is restricted due to reduced temperatures. In the prairie, soil organic matter is more deeply distributed because grasses produce finer and deeper roots and the soil fauna is more abundant. Parent material, slope, overgrazing and erosion are among the main activities, which have influenced soil properties (Table 1, Table 2). The following close

[1] National Agricultural Research Foundation, Institute for Soil Mapping and Classification, 1, Theophrastou Str., 41335, Larissa, Greece, Tel. + 30 2410 671297, Fax +30 2410 660 571, E-mail: karyotis@nagref.gr

Table 1. Chemical properties of the studied soils

Sites	Sand	Clay	Silt	pH	Exchangeable cations cmol/kg				CEC cmol/kg	P mg/kg
		%		(1:1)	K^+	Na^+	Ca^{++}	Mg^{++}		
S1	56	14	30	5.7	0.3	0.1	13.8	8.8	24.8	39
S2	54	10	36	5.5	0.9	0.2	17.4	5.6	33.5	4
S3	66	10	24	5.8	0.6	0.1	16.2	6.6	25.7	5
S4	50	16	34	5.6	0.8	0.1	13.3	6.4	26.9	4
S5	70	8	22	6.9	0.2	0.1	26.4	3.3	40.5	4
S6	58	14	28	5.9	0.7	0.2	9.4	3.9	20.0	3
S7	58	10	32	5.9	2.1	0.1	15.8	5.6	35.4	4
S8	64	8	28	6.0	0.8	0.1	9.7	4.9	18.1	2
S9	42	18	40	6.1	0.4	0.3	24.0	8.4	36.6	4
S10	74	6	20	7.2	0.3	0.1	11.3	1.2	12.0	7
S11	56	16	28	6.2	0.5	0.1	21.5	6.8	31.7	10
S12	42	30	28	6.3	0.6	0.1	29.5	4.1	39.9	5
S13	70	18	12	7.1	0.2	0.1	19.8	1.9	21.8	3

Table 2. Micronutrients, organic matter and total nitrogen of the studied soils

	DTPA (mg/kg)						
Sites	Fe	Cu	Mn	Zn	B	O.C.	N
						g/kg	g/kg
S1	78.9	2.4	12.8	4.0	0.4	24.8	1.9
S2	122.0	0.6	52.9	4.1	0.7	50.3	3.3
S3	74.9	1.2	13.6	10.2	0.8	23.6	1.8
S4	131.8	1.2	35.8	3.4	1.0	32.8	2.8
S5	40.1	2.0	34.1	1.8	0.8	22.1	1.7
S6	59.6	0.6	7.9	2.7	0.5	27.1	1.9
S7	88.1	0.3	18.4	2.8	1.6	52.9	4.0
S8	52.7	0.5	14.3	8.8	0.8	26.1	1.8
S9	185.7	2.8	71.3	3.5	1.2	38.0	3.3
S10	18.4	0.4	18.0	7.2	0.6	11.9	0.9
S11	63.8	0.9	21.3	2.1	1.0	27.7	1.7
S12	40.0	3.6	183.4	2.8	0.9	45.8	3.7
S13	56.3	2.1	29.5	2.1	1.0	21.1	1.9

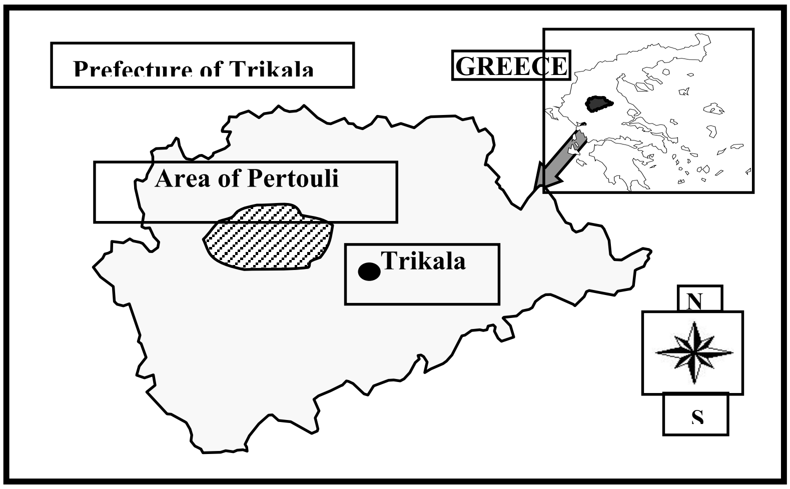


Figure 1. Simplified map of Greece illustrating the studied area of Pertouli

relation was found between total soil N and soil organic carbon: $Y_{Ntot} = 0.15 + 0.072X_{org.carb}$ (n=13, R^2 = 91.1***). The exchangeable cations were found to the following decreasing order (Table 1): Ca>Mg>K>Na. In most cases, potassium exhibits deficiency levels (Table 1) due to the kind of parent material. The application of K fertilizers is rare and K losses can be enhanced by run-off during the winter. The pH values ranged between 5.5 and 7.2.The samples collected from the sites S10 and S13 have a pH higher than 7 and contain $CaCO_3$ from secondary enrichment by the adjacent calcareous deposits. Clay content ranged between 6 and 18 % and indicates restricted chemical weathering. High sand and silt percentage can be attributed to freeze-thaw weathering. Cation Exchange Capacity varied greatly and ranged from 12.0 to 40.5. It can be stressed that certain rather high values may be due to soil organic matter, type of inorganic material and kind of clay minerals. The distribution of trace elements greatly varied and a wide range of the elements extracted by DTPA was observed (Table 2). In general, Fe, Mn, Zn and B were found at sufficient levels, whilst the content of Cu in certain of the studied soils was rather low. The available phosphorus content was very low, and only sample S1 was at normal levels (Table 1). It can be underlined that these soils are vulnerable to degradation and the application of protective management and/or proper measures should be taken, such as: banning of overgrazing, limitation of the number of grazing animals within the carrying capacity of the degraded pasturelands, incentives for artificial reforestation, erosion control measures in sloping lands, restoration of the terraces, wherever this is economically feasible and conservation of wild life.

References

Allison, L.E.; C.D. Moodie. (1965). Carbonate. In: *Methods of soil analysis. Part 2*; Black et al. (ed.) American Society of Agronomy, Madison, Wisconsin, Monogr. 9, 1379–1400.

Gee, G.W. and J.W. Bauder. (1986). Particle size analysis. In: Klute, A. (Ed.), Methods of soil analyses, Part 2, 2nd edn. Agronomy monograph 9. ASA and SSSA, Madison, WI, USA, pp. 383–411.

Isaak, R., and J. Kerber, 1971: Atomic absorption and flame photometry: techniques and uses in soil, plant and water analysis. In: Instrumental methods for analysis of soil and plant tissue, Walsh (eds.), pp. 17–37. Madison Wisc.: Soil Science Society of America.

Keren, R. Boron. In *Methods of Soil Analysis*, Part 3. Chemical methods–Soil Science Society of America, Madison, WI, 1996; Book Series 5, 1996; pp. 617–618.

Kuo, S. (1996). Phosphorus. In: *Methods of soil analysis. Part 3. Chemical methods– Soil Science Society of America, Book Series 5*, Madison, Wisc., USA, pp. 869–960 .

Lindsay, W. and W. Norvell. (1978). Development of a DTPA Soil Test Zinc, Iron, Manganese and Copper. Soil Sci. Am. J., *42,* 421–428.

McLean, F. (1982). Soil pH and lime requirement. In: Page, A. L. eds.. *Methods of soil analysis, Part 2. Chemical and Microbiological Properties*. American Society of Agronomy., Agr. Series Monograph No 9, Madison, Wisconsin, pp. 199–223

Olsen, S.R.; L.E. Sommers. (1982). Phosphorus. In: *Methods of soil analysis.* Part 2, 2nd ed.; A.L. Page et al. (ed). Agron. Monogr. 9; ASA and SSSA, Madison, Wisc., USA, 403-430.

Thomas, G. Exchangeable cations. (1982). In A. L. Page eds. *Methods of soil analysis Part 2. Chemical and Microbiological Properties*. Agronomy 9, pp.159–164.

Land transformation, land use changes and soil erosion in vineyard areas of NE Spain

Jiménez-Delgado, M. – Martínez-Casasnovas, J.A.[1] – Ramos, M.C.

Abstract

In the NE Spain, one of the agricultural systems that have been suffering more substantial transformation in the last decades is vineyards. Some research works conducted in the Penedès vineyard area (Catalonia, Spain) have shown evidences which presuppose that intensification of agriculture from the 1950's has led to changes on land topography and land use and conservation practices that produced an increase of soil loss. The present research addresses the assessment at detailed scale (1:1000) of typical changes produced in those areas (land levelling, land use and conservation practices) and their repercussion on soil erosion. A representative sample catchment of 0.63 km^2 was selected as case study area. This is part of the Penedès Tertiary Depression, where calcilutites (marls) outcrop. The annual average rainfall erosivity factor (R) ranges between 1049 – 1200 MJ mm ha^{-1} h^{-1} yr^{-1}. Two time periods were considered in the present research: one (1975) that represents the situation before the large transformations and land use changes were carried out and another (2002), which represents the situation afterwards. Stereoscopic pairs of detailed aerial photos, acquired in August 1975 and January 2002 (approximate scale 1:5000) were used to characterize those situations. Land use and conservation practices maps were produced by means of aerial photo-interpretation, as well as 1 m resolution digital elevation models (DEMs). Soil loss was estimated by means of RUSLE. The results show that agricultural land was heavily transformed, not only on the field structure, from 68 fields in 1975 to 26 in 2001, but on the slope degree: from an average degree of 11.9% in 1975 to 11.4% in 2002. The main land use changes were the substitution of traditional vineyards and winter cereals by mechanized vineyard plantations. Those changes, and the removing of traditional conservation practices, have a negative influence on soil erosion, increasing the annual soil loss by 26.5%, as average. This indicates that, in general, field's slope lowering did not conduce to decrease soil loss and that conservation practices should be maintained.

Introduction

From around the middle of the 20th century, and in particular from the 1980's, a new agriculture characterized by heavy mechanization of land transformation (levelling and field's concentration) and intensive land cropping has emerged as consequence of the intensification of the agriculture in the Mediterranean Europe, as well as in other parts of the world. One of the main objectives of this new agriculture is to make a profit in the short term, being the conservation of natural resources and/or the environmental impacts involved in land transformations and/or land use changes involved no so important. For this new agriculture, terracing and/or land levelling have been subsidized adducing improvements on soil and water conservation. However, these operations affect the upper part of the field, that is excavated and the depressions filled in. They determine the loss of the pedological structure, produce changes in the physical and chemical properties of the material exposed and influence the increase of soil erosion in intense rainfall events (Borselli et al., 2002; Borselli et al., 2003a; Lundekvam et al., 2003).

In the Mediterranean region, one of the agricultural systems that have been suffering more substantial transformation in the last decades and that incur the highest soil losses is vineyards (Martínez-Casasnovas and Sánchez-Bosch, 2000; Borselli et al., 2002; Martínez-Casasnovas et al., 2002). In the Tuscany region (Italy), where vineyard plantations increased by 90000 ha in the period 1968 – 1975, soil movement due to land levelling was estimated at a rate of 300 Mg ha^{-1} $year^{-1}$ (Borselli et al., 2002). In the Penedès vineyard region (NE Spain), some research works have also shown evidences in the same way, which presuppose that intensification of agriculture from the 1950's has led to changes on land topography, with fields' re-design and removing of soil conservation practices, which has negatively affected the soil erosion balance (Martínez-Casasnovas, 1998; Martínez-Casasnovas and Sánchez-Bosch, 2000). In this respect, landscape changes produced by terracing and levelling, expressed in terms of denudation rate, has been estimated in two or three times the one produced by water erosion (Borselli et al., 2002). Those operations also influence the increase of soil losses in extreme rainfall events, as the measured in vineyard fields of the Penedès vineyard region: 207 Mg ha^{-1} (ephemeral gully erosion included) Martínez-Casasnovas et al. (2002).

Despite land transformation (mainly land levelling and fields' re-design for fields'concentration) is an extended practice in Europe favoured by European Union subsidies (Lundekvam et al., 2003), few research works have been addressed to study its impacts on soil erosion (Borselli et al., 2003b). In this research line, the aim of the present work is to make progress in the knowledge of the impacts of land transformation on soils at

[1] University of Lleida, Department of Environment and Soil Science, Rovira Roure 191, E25198 Lleida (Spain), Tel.: +34 973702615; Fax: +34 973702613; E-mail: j.martinez@macs.udl.es

detailed scale (1:1000). The research is carried out in a representative sample catchment of 0.63 km^2 located in the Penedès vineyard region (NE Spain), for which to time periods were considered: 1975, before main land transformations took place, and 2002.

Study area

The study area is located in the municipality of Masquefa (Barcelona, Spain). It is a catchment area of 64 ha, 14.5% of which is covered by large gullies. The rest is mainly dedicated to agricultural uses. The average slope of the agricultural fields ranges between 5 – 9%. This area is part of the Penedès Tertiary Depression, where calcilutites (calcareous marls), sandstones and conglomerates are the main lithological materials (Martínez-Casasnovas, 1998). The climate is Mediterranean, with an average annual rainfall of about 550 mm (Ramos and Porta, 1994). The rainfall erosivity factor R ranges between 1049 – 1200 MJ mm ha^{-1} h^{-1} $year^{-1}$. High intensity rainfalls are frequent. On 10th June 2000, an extreme event was registered: 215 mm in total, of which 205 mm fell in 2 h 15 min. The R factor reached 11756 MJ mm ha^{-1} h^{-1}, 10 times greater than the average annual value for the area (Martínez-Casasnovas et al., 2002).

Material and methods

The assessment of the impacts of land transformation and land use change on soil erosion was based on the multitemporal analysis of detailed aerial photos from 1975 (1:7000) and 2002 (1:5000) and the estimation of soil losses by means of the Revised Universal Soil Loss Equation (RUSLE) (Renard et al., 1991). Aerial photographs were used to derive the necessary topographic information to construct digital elevation models (DEM) of both dates. These data consisted of 1-m interval contours, spot heights and breaklines, from which 1-m resolution in XY and 0.01-m in Z were derived. The DEM and the scanned aerial photographs were used to produce both orthophotos, by means of the software MiraMon v.4.0 (CREAF). The orthophotos were used to georeference field boundaries, land uses and the existence of conservation practices for both dates (1975 and 2002).

The land use classes mapped were: traditional vineyard plantations, mechanized vineyard plantations, cereals, fruit trees, unproductive, forest, shurbland, urban areas, gully area, buffer of the gully (buffer area around the gully boundary mainly occupied by shrubs) and roads. The conservation practices types that were identified are: terraces, vine rows perpendicular to the maximum slope degree, vine rows oblique to the maximum slope degree. There are also vineyard fields with rows oriented to the maximum slope degree and fields without terraces. Terraces are mainly of the type hillside ditch or broadbase, which main objective is intercept surface runoff and convey it out of the field.

The RUSLE was applied to estimate soil losses at field level. For the R factor, the average value for the study area was considered for both dates: 1120 MJ mm ha^{-1} h^{-1} $year^{-1}$ (Martínez-Casasnovas et al., 2002). The K value (soil factor) for 1975 was computed from soil data collected by Boixadera (1983) in fields of the study area. Those values range between 0.06 and 0.07. For the year 2002, after main land transformation had taken place, K values were computed from soil samples collected in transformed fields of the study area. Those values range between 0.075 (low levelled fields) to 0.077 (high levelled fields). The topographic factor (LS) was derived for each date from the DEMs by using the software USLE2d (KU Leuven) (Van Oost and Govers, 2000). This program allows multiple flow routing, which provides a more realistic result of flow movement on the fields. The cropping factor (C), was determined for each land use having into account their different vegetative stages: traditional vineyard plantation 0.697, mechanized vineyard plantation 0.743, cereals 0.580, fruit trees 0.736, unproductive 0.310, forest 0.117 and shurbland 0.117. Finally, the conservation practices factor (P) was assigned according to the criteria proposed by Wischmeier and Smith (1978).

Results and discussion

The results of the land use change analysis indicate that, although the surface dedicated to agricultural did not change in the considered period (61,8% of the total area in 1975 and 61,6% in 2002), there were significant land use changes that affected 70% of the area and that would determine changes in the soil loss balance. For example, traditional vineyard plantations, which supposed 29% of the total area in 1975, disappear as land use class in 2002. In the same way, cereals, that occupied 26.6% of the area in 1975, only represented 4% of the area in 2002. Along this period, a new land use class appeared: mechanized vineyard plantations, which in 2002 occupied 31.8% of the total area. This class mainly substitutes cereals and traditional vineyard plantations, the last in the fields with higher degrees of levelling.

Regarding the impact of land transformation and land use change in soil losses in the period 1975 - 2002, Table 1 summarizes the change analysis based on the estimated soil losses in representative fields of the study area. From these data, it can be deduced that soil loss is about 26.5% higher in 2002 with respect 1975. This indicates that the soil movements involved in the land transformation carried out in the area to enlarge the fields and to reduce the slope degree did not serve to reduce soil loss. Then, the increase of soil loss has to be attributed to changes on land uses and conservation practices. We can stand out some examples. In the field with

ID 5 in 2002, although the slope degree did not substantially change, the soil loss increased from 11.5 to 38.4 Mg ha^{-1} year^{-1} due to the removing of terraces. In the case of fields with ID 6 and 33 in 2002, where the slope degree either was maintained or reduced from the 1975 situation, the increase of soil loss has to be attributed to the change on land use, from cereals in 1975 to mechanized vineyard in 2002. The change of traditional vineyard to mechanized vineyard also produced increase of soil loss due to the removing of conservation practices. This is the case of field 38 in 2002, which comes from the transformation of fields 10 and 11 in 1975. In this case, soil loss increased from 55.4 – 67.2 to 124.6 Mg ha^{-1} year^{-1}, although the slope degree is reduced from 6.3 – 7.0% to 6.1%, on average. In the fields that suffer higher degrees of transformation (levelling), fields 5, 7 and 9 in 1975, a decrease of the soil loss rates can be observed (Table 1). This is due to the decrease of the average slope degree after the levelling, from 6.6 – 7.7% to 6.6%. In this case, the decrease of the average slope degree and the change of conservation practices to a better protection compensate the increase of soil loss that would be produced by the change in the land use to mechanized vineyards.

Table 1. Change analysis of the estimated soil loss in representative transformed fields of the Penedès region.

Field characteristics – year 2002					Field characteristics – year 1975				
ID Field	Land use	Slope (º)	Conservation practices	Soil loss (Mg ha^{-1} year^{-1})	ID Field	Land use	Slope (º)	Conservation practices	Soil loss (Mg ha^{-1} year^{-1})
5	C	4.7	Contour ⊥max S	38.4	74	TV	4.9	Terraces ⊥max S	11.5
6 33	MV MV	6.6 5.6	Contour ⊥max S Contour /max S	109.5 108.0	21	C	6.5	Contour ⊥max S	61.0
27	U	8.4	-	44.6	30	U	6.4	-	46.3
29	MV	4.4	Contour ⊥max S	45.9	4	TV	3.3	Contour =max S	38.6
30	U	9.6	Contour ⊥max S	91.6	1	C	9.5	Contour ⊥max S	100.7
38	MV	6.1	Contour =max S	124.6	10	TV	6.3	Contour ⊥max S	55.4
					11	TV	7.0	Contour ⊥max S	67.2
40	MV	6.1	Contour ⊥max S	87.0	3	C	6.0	Contour /max S	67.9
97	MV	6.6	Contour ⊥max S	81.4	5	C	7.5	Contour /max S	85.1
					7	TV	7.3	Contour /max S	116.3
					9	TV	6.6	Contour ⊥max S	117.2
87	U	6.9	-	75.9	41	C	5.2	Contour /max S	48.8
					18	F	5.1	Contour =max S	91.1
					56	U	6.5	-	25.4
					69	TV	6.2	Contour ⊥max S	24.9

Legend: C (cereal), MV (mechanized vineyard), TV (traditional vineyard), F (fruit trees), U (unproductive); max S (maximum slope degree), ⊥ (perpendicular), / (oblique), = (parallel)

Conclusions

Land transformation and land use changes in fields of the Penedès vineyard region, carried out in the last three decades to favour the establishment of new mechanized vineyards, had negative repercussions on the soil loss balance. Soil loss increased by 26.5% on average from 1975 to 2002. This indicates that the soil movements involved in the land transformations carried out in the area to enlarge the fields and to reduce the slope degree did not serve to reduce soil loss. Then, the increase of soil loss has to be attributed to the changes on land uses and conservation practices.

References

Borselli, L., Pellegrini, S., Torri, D., Bazzoffi, P., 2002. Tillage erosion and land levelling: Evidences in Tuscany (Italy). In: Rubio, J.L., Morgan, R.P.C., Asins, S., Andreu, V. (eds), Proceedings of the Third International Congress Man and Soil at the Third Millenium, Geoforma Ediciones, Logroño (Spain), pp 1341 – 1350.

Borselli, L., Bazzoffi, P., Torri, D., Pellegrini, S., 2003a. Modelling DTM modification by land levelling: simulation using Bullrun model. In: Book of Abstracts & Field Guide of the COST Action 623 "Soil Erosion and Global Change", Budapest, 5 – 8 July 2003, pp 32.

Borselli, L., Torri, D., Torri, Øygarden, L., De Alba, S., 2003b. Land levelling and erosion. In: COST Action 623 "Soil Erosion and Global Change", Budapest, 5 – 8 July 2003.

Lundekvam, H., Romstad, E., Øygarden, L., 2003. Agricultural policies in Norway and effects on soil erosion. Environmental Science and Policy 6, 57 - 67.

Martínez-Casasnovas, J.A., 1998. Soil – landscape – erosion. Gully erosion in the Alt Penedès – Anoia (Catalonia, Spain). A spatial information technology approach: spatial databases, GIS and remote sensing. Ph.D. Thesis, University of Lleida, Lleida, Spain.

Martínez-Casasnovas, J.A., Sánchez-Bosch, I., 2000. Impact assessment of changes in land use / conservation practices on soil erosion in the Penedès – Anoia vineyard region (NE Spain). Soil & Tillage Research, 57 (1-2), 101 - 106.

Martínez-Casasnovas, J.A., Ramos, M.C., Ribes-Dasi, M., 2002. Soil erosion caused by extreme rainfall events: Mapping and quantification in agricultural plots from very detailed digital elevation models. Geoderma 105 (1-2), 125 -140.

Ramos, M.C., Porta, J., 1994. Rainfall intensity and erosive potentiality in NE Spain Mediterranean area. First results on sustainability of vineyards. II Nuovo Cimento 17, 291-299.

Renard, K. G., Foster, G. R., Weesies, G. A. i Porter, J. P., 1991. RUSLE: Revised Universal Soil Loss Equation. *Journal of soil and water conservation,* 46(1): 30-33.

Van Oost, K., Govers, G., Desmet, P.J.J., 2000. Evaluating the effects of changes in landscape structure on soil erosion by water and tillage. Landscape Ecology 15, 577-589.

Wischmeier, W.H., Smith, D.D., 1978. Predicting rainfall erosion losses - A guide to conservation planning. USDA Agriculture Handbook num. 537. US Government Printing Office, Washington, DC.

Impacts of land transformations on soil physical properties in the Priorat vineyard region (NE Spain)

Cots-Folch, R.[1] – Laporta, L. – Martínez-Casasnovas, J.A. – Ramos, M.C.

Abstract

The Priorat region, where the main land use had been vineyard for several centuries, reached its maximum extension during the 19th century. Due to the phyloxera and the crisis of wine-producers at the beginning of the 20th century this land use was near completely abandoned. However, during the last two decades, the region has suffered important changes, transforming the abandoned areas, covered by natural vegetation, into new vineyards, with the construction of terraces in hillslopes. In most of cases, those terraces have walls more than 2-m high and with the soil surface structure completely changed.

The objective of this work is to analyse the impacts of these land transformation on soil physical properties, such as texture and water infiltration capacity in Porrera (Priorat region, NE Spain). Soils are classified as Lithic Xerorthents and are locally called "licorell". For this study two different situations were selected in a hillslope 100-m long: the first one in an undisturbed position, with natural vegetation; the second one and in a new vineyard, planted in terraces after important transformations two years ago. Soil surface samples, 0-20 cm, were collected at several points along the slope for analysis of texture, organic matter, and aggregate stability against different desaggregation forces. At the same sampling locations, hydraulic conductivity (saturated and unsaturated) was measured using a disk permeametre.

This preliminary study shows that in these soils with high percentage of coarse elements (> 60%), works carried out during land transformations produced changes in particle size distribution of the fine fraction, increasing the fine sand fraction. In addition, levelling eliminate or incorporated most of the organic matter exisiting on natural vegetation or in the older tradicional vineyard plots. These facts affect hydraulic conductivity and water retention capacity, decreasing by 45%. The differences observed with the landscape position in the undisturbed plots disappear in the transformed plot. No clear differences are observe on aggregate stability.

Introduction

The intensification of the agriculture in the Mediterranean Europe, as well as in other parts of the world, has emerged as consequence of social and economical constrains being necessary the adaptation of fields to new situations. Social and economical impacts often determine the types of land use within a region and they affect environmental aspects (Mander and Palang, 1994). In that sense, areas previously abandoned has been recuperated and changes in the management practices have been implemented. This is the case of the Priorat region located in Tarragona province, NE Spain. The main crop for centuries in that area has been vineyard, which reached its maximum extension during the 19th century. But, due to the phyloxera and the crisis of wine-producers at the beginning of the 20th century this land use was near completely abandoned. However, from the 1990's this area has suffered an important economical revalorization, increasing by more than 100% the vineyard cultivated surface. This expansion involve important land transformations, transforming abandoned areas, covered by natural vegetation, into new vineyards with the construction of terraces in levelled fields and heavy mechanization of land transformation. Those levelling works modify the soil surface characteristics, which influence the infiltration properties at the soil surface (Poesen et al., 1990; Leonard and Andrieux, 1998; Malet et al., 2003). In addition the spatial variability lead to heterogeneous infiltration and runoff responses on hillslopes affects soil hydrological properties.

The objective of this work is to analyse the impacts of these land transformations on soil physical properties, such water infiltration and water retention capacity in Porrera (Priorat region, NE Spain). Soils are classified as Lithic Xerorthents and are locally called "licorell".

Study area

The study is carried out in the Priorat region (Tarragona, Spain), located in the central part of Tarragona province, in a depression formed in the split of the southern part of Montsant mountain chain. Soils are classified as Lithic Xerorthents, developed on schist, locally called "licorell". The average slope of the agricultural fields is higher than 25%. Climate is classified as Mediterranean temperate with trend to continental, characterised by dry winds mainly from the NE, and an average annual temperature of 15ºC (ranging from 6ºC to 23ºC). Average rainfall ranges from 450 to 650mm, mainly distributed in spring and autumn.

At present, the vineyard surface is about 1600 ha and wine production has increased during the last years from 13000 HL in 2000 to 19000 HL in 2003.

[1] University of Lleida, Department of Environment and Soil Science, Rovira Roure 191 E-25198 Lleida (Spain), Tel.: 34 973702837; Fax: 34 973702613; E-mail: roser.cots@macs.udl.es

Materials and methods

The assessment of the impacts of land transformation on soil hydrological properties was carried out in three plots with convex-concave slope, in the municipality of Porrera (41º 11' N, 0º51' W), one of them transformed with the construction of terraces. The other two plots were undisturbed with the original level. The average slope of each plot is about 45%. The undisturbed plots are planted with old hazel nut trees and vine and the disturbed plot consisted of a new vineyard, planted after land transformation with the construction of terraces. In each of them, several points were considered along the slope (6 points in the plots with terraces-plot DP; 4 points in the plot with hazel-nut trees plot-plot UHN, and 3 points in the old vineyard- plot UV respectively in the old plots-plots). The location of points at each plot is shown in Table 1.

At each position, surface soil samples were taken for laboratory analysis. All samples were air dry and crushed using a 2-mm mesh. Texture (USDA) and coarse elements and organic matter were analysed following the methods described in Porta et al. (1986). Aggregate stability against different desaggregation forces (Kemper and Rosenau, 1986; Amezketa et al., 1996) were evaluated at each sample. In addition, water retention capacity at 33 and 1500 kPa were evaluated using Richard plates. In the field, bulk density and saturated hydraulic conductivity was evaluated. Bulk density was measured making a hole in the soil and by measuring soil mass and volume (Blake and Hartge, 1986). Hydraulic conductivity was evaluated with a CSIRO disc tension infiltrometer 25cm-diameter base, controlling tension at the soil surface (Perroux and White, 1998). Measurements were carried out at the end of 2003.

Results and discussion

The most remarkable characteristic of the analysed soils is its high percentage of coarse elements, ranging from 46 to 77%, in both disturbed and non disturbed plots. No significant differences were observed on average (65%- 67%, respectively), but in the terraced plot the percentage of coarse elements is higher at the bottom of the plot (Table 1). However, the facts show differences in the distribution size of coarse elements between two managements studied: in the non disturbed plots there is an homogeneous distribution of the size elements whereas in disturbed soils exits a high percentage of the > 8mm coarse elements. Only in the non disturbed plot we observed changes from top to bottom, decreasing the percent of higher coarse elements at the bottom and increasing the fine fraction at the top. No differences were observed in the disturbed plots.

The fine fraction (fine silt + clay) is similar in disturbed and nondisturebd, but while clay content is higher in the non-disturbed plot, the fine silt fraction is higher in the disturbed plot. In the old plantation we can observe differences with the landscape position in the fine silt fraction but not in the clay fraction. This result has been point out by other authors, attributed to soil erosion processes (Ampontuah et at., 2003). No significant differences were found in the sand fraction among plots, but fine sand fraction is higher in the upper slope while the coarse fraction in lower in those positions. The most significant change is the organic matter content, which in the new plantation is 0.64%, while in the non disturbed is about twice (1.2% on average).

Other soil properties evaluated in both situations are presented in Table 2. Bulk density was 1690 kg m^{-3} on average, although with slightly higher values in the old planted plot that in the new plantation by effect of works levelling. The mechanical alterations of soil surface produced with the terraces construction affect some hydrological properties. In that sense, we can observe a significant reduction on hydraulic conductivity (Ko) in the land levelled plot in relation to the old plantation systems (175mm in the plot with terraces vs. 230 and 246mm in the old plantations). Water retention capacity (WRC) is also significantly reduced (17.9mm in terraced pot vs. 29.3 and 37 mm in the old plots). These values are very low (< 64mm) according to the critical values established for soils with xeric regime (Porta et al., 1999). An analysis of ANOVA performed with these data confirmed the significant differences at 5% level. The observed changes in hydraulic conductivity and water retention capacity can not be only explained by the observed changes in texture and organic matter. Although the increase in the fine silt fraction could contribute to seal the soils, the interpretation should include additional information about the changes in the pore redistribution and the break of the natural water circulation channels in the soil profile.

The applied tests for aggregate stability showed slightly higher values in the non-disturbed plots but the differences were no significant. The higher differences were observed when the standard method (Kemper and Rosenau, 1986), was applied. In addition, there were not differences between aggregate stability against the different desaggregation forces, represented by the different treatments applied with method proposed by Amezqueta et al. (1996).

Table 1. Soil characteristics at each position along the slope in transformed and non transformed plots.

Samp. point	Location (UTM31N)			o.m	Texture (USDA)					Elem.> 2mm (%)		
	X	Y	Z	(%)	clay (%)	silt (%)		sand (%)		2-8 mm	>8 mm	> 2mm
						F	C	F	C			
DP1	318933	4563086	338	0.4	6.1	9.5	3.8	35.2	44.6	26.6	59.0	85.7
DP2	318999	4563143	313	0.8	9.2	12.6	5.9	34.6	36.4	20.2	57.1	77.3
DP3	318773	4563343	385	0.4	7.1	13.5	8.2	36.4	34.8	25.3	47.9	73.2
DP4	318709	4563258	417	1.0	7.2	15.1	5.6	28.6	43.4	29.7	47.9	77.6
DP5	318678	4563384	439	0.6	5.3	13.2	7.3	46.2	28.0	20.8	31.8	52.6
DP6	318628	4563403	463	0.5	5.2	10.3	5.5	48.1	30.9	20.9	33.8	54.6
UV1	318984	4563254	289	1.2	7.2	8.1	7.0	36.8	39.7	28.9	39.2	68.1
UV2	318982	4563517	301	1.6	6.1	11.8	7.0	34.9	40.2	32.6	31.7	64.3
UV3	318860	4563547	358	0.7	7.5	10.6	9.4	45.6	27.0	30.4	30.8	61.2
UHN1	323129	4563169	407	2.0	7.8	14.5	4.2	23.4	50.1	29.3	43.6	72.9
UHN2	323027	4563564	441	0.7	5.7	16.7	8.1	36.3	33.2	33.2	28.7	61.9
UHN3	322994	4563435	461	1.4	6.1	17.1	6.9	31.0	38.9	36.7	30.8	67.5
UHN4	322981	4563098	484	0.6	7.4	7.7	5.0	27.0	52.9	35.4	30.0	65.4

Table 2. Soil physical and hydrological properties on the disturbed and non disturbed plot: bulk density, hydraulic conductivity (Ko), CRAD, aggregate stability (against different desaggregation forces)

Sampling poing	Bulk density kg m^{-3}	Ko (mmh^{-1})	CRAD (mm)	Aggregate stability			
				Standard (%)	WMDStw (m)	WMDslw (m)	WMDfw (m)
Transformed plot							
DP1	1462	261.4	18.3	82.8	1.23	1.30	1.20
DP2	1436	105.8	13.0	63.4	1.20	1.23	1.22
DP3	1656	172.1	20.3	64.5	1.27	1.32	1.25
DP4	1653	148.7	24.3	83.2	1.10	1.21	1.10
DP5	1530	191.4	17.3	69.4	0.94	0.95	0.96
DP6	1282	169.8	16.6	83.7	1.16	1.12	1.10
Untransformed plots							
UV1	1668	171.9	16.6	75.5	1.21	1.30	1.20
UV2	1659	257.3	30.7	89.9	1.27	1.27	1.30
UV3	1703	262.2	39.0	87.2	1.27	1.27	1.25
UHN1	2129	380.9	49.3	68.0	1.16	1.02	1.06
UHN2	1889	319.3	48.0	73.0	1.20	1.17	1.14
UHN3	1948	430.9	52.3	58.2	1.14	1.11	1.11
UHN4	1233	548.5	27.9	65.8	1.19	1.14	1.11

Conclusions

Land transformations carried out in the Priorat area during the last decades, with land transformations of abandoned areas are modifying not only the landscape but soil physical and hydrological properties having negative repercussion on water available for plants and increasing water losses by runoff. An significant reduction on the hydraulic conductivity and water retention capacity is produced, being up to 45% lesser in the transformed plots.

References

Amezketa, E., Singer, M., Le Bissonnais, Y., 1996. Testing a new procedure for measuring water-stable aggregation. Soil Sci. Soc. Amer. J., 60: 888-894.

Ampontuah, E.O., Robinson, J.S., and Nortcliff, S., Assesment od soil particle redistirbution on two contrasting cultivated hillslopes. In Book of Abstracts of "Soil erosion adn sediment redistribution in river catchments: Measurements, modelling and management in the 21st century. Silsoe, UK. pp 1.

Kemper, W.D., Rosenau, R.C., 1986. Aggregate stability and size distribution. In: Methods of Soil Analysis. Part I, Physical and Mineralogical Methods. 2nd edition A. Klute (ed.). Agronomy 9: 425-442.

Léonard, J., Andrieux, P. 1998. Ilfiltration characteristics of soils in Mediterranean vineyards in southern France. Catena, 32, 209-223.

Malet, J.P., Auzet, A.V., Olivier Maquaire, Ambroise, B., Descroix, L., Esteves, M., Vandervaere, J.P., Truchet, E.,2003. Earth Surface Processes and Landforms, 28, 547-564

Mander, Ü., Palang, H. 1994. Changes of landscape structure in Estonia during Soviet period. Geojournal 33, 45-54

Perroux, K.M., White, I. 1998. Designs for disc permeameters. Soil Sci. Soc. Am. J., 52: 1205-1215.

Poesen, J.W.,Ilgelmo-Sánchez, F., Mücher H., 1990. The hydrological response of soil surfaces to rainfall as affected by cover, position and rock fragments in the top layer. Earth, Surfaces, Processes and Landforms, 16, 653-671.

Porta, J., López-Acevedo, M., Rodríguez, R. 1986. Técnicas y experimentos en edafología. Colegio Oficial de Ingenieros Agrónomos de Cataluña. Barcelona. 283 pp.

Porta, J., López-Acevedo, M., Roquero, C. 1999. Edafología para la agricultura y el medio ambiente. Mundi-Prensa, Madrid, 849pp.

Historical land-use changes of wine growing areas developed on volcanic soils in Hungary

Fehér, O.[1] – Madarász, B.[2]

The most famous Hungarian wine-growing districts are in volcanic areas. The present paper tries to answer the following questions: (1) How has land-use been evolving in these areas in the 19th and 20th centuries? How have the social and economical changes affected the distribution of the different land use types?
For the better understanding of these processes several historical map "generations" and written records were analysed (BÉL 1942, 1984, ÁGOSTON 1820, FÉNYES 1842).

There were two main Neogene volcanic phases in the Carpathian Basin. The first phase was the calc-alcaline volcanism during the early and middle Miocene. The volcanic activity started with silicic volcanism, with a huge amounts of pumiceous pyrclastic flow deposits (ignimbrites). In the middle Miocene andesitic-dacitic intermediate volcanism started. During this phase large stratovolcanoes developed in the northern part of the country as part of the Inner Carpathian Volcanic Chain.

The second phase was the alcaline basalt volcanism. The main peroid of this activity was the Pliocene, however it started at the end of the Miocene, and lasted at some places until the second half of the Pleistocene. In this phase basalt plateaus, tuff rings and maars were formed.

The first step of our investigation was the selection of study areas representative for the land-use of volcanic territories. Six sample areas, alltogether with an area of 100 km^2, were chosen in different Hungarian volcanic areas *(Figure 1.)*. Our study focused on the so called wine-hills. These are volcanic hills of ~3-400 m asl. elevation with special topographic, pedologic and climatic properies.

Figure 1. Sample areas

For the areal comparison of the described land use changes, military maps of the Habsburg Empire were used. The so called 1st and 2nd surveys (*1764-1785*, *1819-1866)* were performed at a scale of 1:28000. The 3rd military survey (*1869-1880)* and the maps from the 1950's used already 1:25000 scale. The maps from the 1950's were updated in the 1990's by the Hungarian Military Mapping Institute. For the detection of the latest changes in land use the 1:50000 CORINE Land Cover (FÖMI, 2003) database from the 1998-99 survey was used. These maps were derived from the interpretetion of space images. Transformation of the maps and interpretation of the different types of land-use (LUT) were carried out by the MicroStation and ArcView softwares.

Wine production in the Carpathian Basin was already important at the time of the Roman Empire. All of our study areas were significant wine-producing areas at least since the Middle Ages. Generally we can say that vine production started on the wine-hills in the 14th century (LICHTNECKERT, 1990, FEHÉR, 1999).

The golden-age of the vine–hills dates back to 17th-19th century, as it is clearly visible on the maps of the 1st and 2nd military surveys. In this period the percentage of vineyards is the highest. There is an interesting correlation between woodlands and vine growing areas on the upper slopes of the vine-hills. During the early 19th century, parallel with the relative expansion of vineyards there is a considerable decrease of forested areas.

On the foothills there is a striking correlation between the territorial extent of meadow and pasture versus arable lands. In the Tapolca Basin, as often mentioned in the documents of the 18th century, wetlands

[1] Szent István University, Department of Soil Science and Agrochemistry, Gödöllő, Hungary. H-2100 Gödöllő, Páter Károly utca 1. E-mail: olenyka@spike.fa.gau.hu
[2] Department for Physical Geography, Geographical Research Institute, Hungarian Academy of Sciences.

were drained and used as meadows. Later, at the end of the 19th century, there was a significant increase of arable lands on the territories of former meadows. This happened at the time of the liberation of serfs.

Certain declines of the wine production in these territories are related to wars, loss of foreign markets, damage from frost or drought. However, after the periods of decadence these regions were always able to renew. There was only one wine-desease, the vine-pest (phylloxera) which transformed dramatically not only the land-use structure of the slopes, but also tradition and culture of the production of high quality wine. This had a major afect on land use at the end of the 19th century. The analyses of the cartopgrapic data brought surprising results: there was no dramatic damage caused by the vine-pest. Two possibilities can account for this observation: (1) The studied territories are the most valuable wine-growing areas in Hungary, thus their protection and reclamation was among the first tasks during and after the disease. (2) The time elapsed between the two military surveys is too long to register the changes caused by the wine-pest. (3) Since our base maps were military surveys, the detailed registration of vineyards, like old, dead or new plantations, was of no interest for the cartographers.

Between the two World Wars wine producers were hit by the economic crisis and by the collapse of the Austro-Hungarian Monarchy, therefore additional reduction of wine growing areas was took place.

In the early 1960's large-scale wine-growing played a major role in the organization of collective farms. At this time there was a tendency of forest expansion, which was related to the afforestation program of steep slopes. This caused a relative decrease of vineyards on steep-slopes like e.g. in Kopaszhegy, one of our study areas. In certain cases fruit tree plantations were established on the steep slopes of the former vineyards (Andornaktálya, Erdőbénye). At the same time there was an increase of vineyards on the foothill areas characterised by gentle slopes. The reason for his process was the mechanization of the vine cultivation, which requires large parcels and gentle slopes *(Figure 2.)*.

According to our investigations the present day land-use structure is the result of an evolution of several centuries. Detailed examination of topographic maps and historical records allowed us to follow the changes in the land cover, and connect them to the social and economic processes. The fertile soil developed on volcanic material and the favourable microclimate made the area attractive for agriculture. The unique conditions of the wine-hills made the vini growing wide-spread in the area. Land-use structure always had to be adjusted to soil and microclimate conditions and it also depended on the state of development of agriculture and society. The recognition of processes in the past helps to understand present landscape and land-use pattern better.

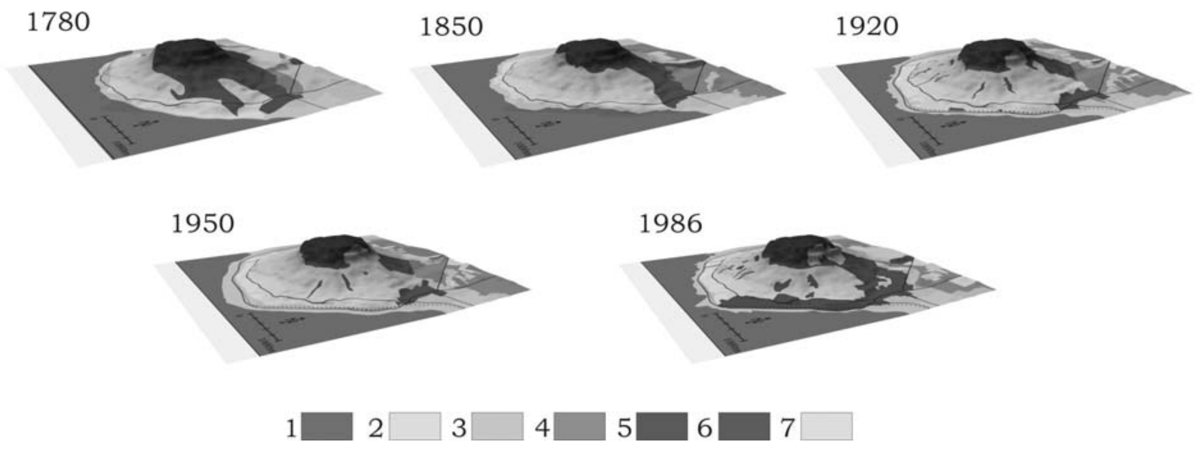


Figure 2. Changes of land-use on the wine-hill of Badacsony between 1860 and 1998.
(1. Lake Balaton, 2. vineyard, 3. pasture, meadow, 4. arable land, 5. settlement, 6. forest, 7. mine

References

LICHTNECKERT ANDRÁS: The history of Balatonfüred-Csopak wine-region. (in Hungarian) Veszprém, 1990.

FEHÉR, O., FÜLEKY, G.: Landscape of the Balaton Lake in the 19th century. In: Branis, M. eds.: Acta Universitas Carolinae Environmentalica Vol.13 .(1999) Nos 1-2 pp.51-57.

ÁGOSTON JÓZSEF: A' szõlõmívelésrõl. (Viticulture). Tudományos Gyûjtemény 1820.XII. (in Hungarian)

BÉL MÁTYÁS: "Notitia cominatum Veszpremiensis, Simighiensis et Szaladiensis" c. kéziratának ismertetése. Dr. Lukács Károly, A.M. Biológ. Kutató Int. Munkái XIV. kötet. Tihany, 1942. (in Hungarian)

BÉL MÁTYÁS: Magyarország népének élete 1730 táján. (The life of Hungary around 1730) Gondolat, Budapest,1984. (in Hungarian)

FÉNYES ELEK: Magyarország statisztikája (Statistics of Hungary)Pest, 1842. (in Hungarian)
CORINE Land Cover: Institute of Geodesy, Cartography and Remote Sensing, Hungary 2003.

SoilCap.html
Soil capability programme using Land-capability-classification system of the USDA

Dorronsoro, B.[1] – García, I. – Dorronsoro-Diaz, C. – Diez, M. – Santos, F. – Dorronsoro-Fdez, C.

Introduction

As it is well known, soil is a component of the natural medium that acquires its morphology and properties after a long and slow evolution and after reaching equilibrium with environmental conditions. It is, then, a natural entity, which does not anticipate human use in its evolution. Nevertheless, ever since humans during the Neolithic shifted from hunting and gathering to farming and herding, the soil has undergone intensive exploitation. Some 10,000 years of irrational soil use by humans has transpired, with no objective beyond seeking maximum yield from every kind of soil use. As a result, the soil has reached the present day intensely degraded to the point that a great part of arable land, especially in arid and semiarid regions, is in a situation of irreversible deterioration. To stop this dramatic trend, the only solution is to institute rational soil use—that is, to use each soil in a way that best suits its characteristics and to programme its management for minimal degradation. This is precisely the final aim of land evaluation.

Land evaluation is an applied classification system that assesses the capacity of the soil for its optimal use—that is, to derive maximum benefits with minimum degradation. This can be defined, according to van Diepen et al. (1991), as "any method to explain or predict the use potential of land".

Different types of soils present widely different properties, and therefore the response to each use differs. Land evolution is based on the idea that this response is a function of these properties, and, hence, knowing these, we can predict the behaviour of the soil under a given use. From the study of such properties, different degrees of suitability of the soil can be inferred for each end proposed.

As land evaluation is intended to offer practical results that can be plotted on territorial maps, such endeavours cannot be limited to the analysis of the physical medium of the earth, but rather must be complemented by the corresponding socio-economic studies that enable cost-benefit analyses of the profitability of the land used. Thus, land evaluation enables predictions on the biophysical and economic behaviour of land for current and potential uses.

The application

This computer program shows how to evaluate soils for Land Capability according to the Land-capability-classification system of the USDA (Montgomery and Kieberg, 1965), but as politico-socio-economic criteria are not employed, the Soil Evaluation term proposed by Dorronsoro (2002) instead of Land Evaluation have been used. Soil evaluation represents the first step for land evaluation; soil evaluation would be similar to land evaluation, but excluding all social, economic and political characteristics.

It is a application with educational purposes to introduce the students in the soil evaluation techniques.

Each area to evaluate is represented in a diagram block. The program is organized in three stages. In the first stage three questions about the soils are established, their location and forming factors. In this previous stage bonus can be obtained to compensate for the possible mistakes in the final stage of the soil evaluation. In the second stage, for each soil, data are provided in relation to the general characteristics of the zone where the soil is located (climate and morphological as well as physico-chemical data) together with a photograph of the profile and landscape in question.

[1] Dpto. Lenguas y Ciencias de la Computacion, E.T.S.I. Informatica, Campus Teatinos, Universidad de. Malaga. 29071 Malaga, Spain. Tel.: 34 952133303; Fax: 34 952131397, E-mail: dorronsoro@uma.es

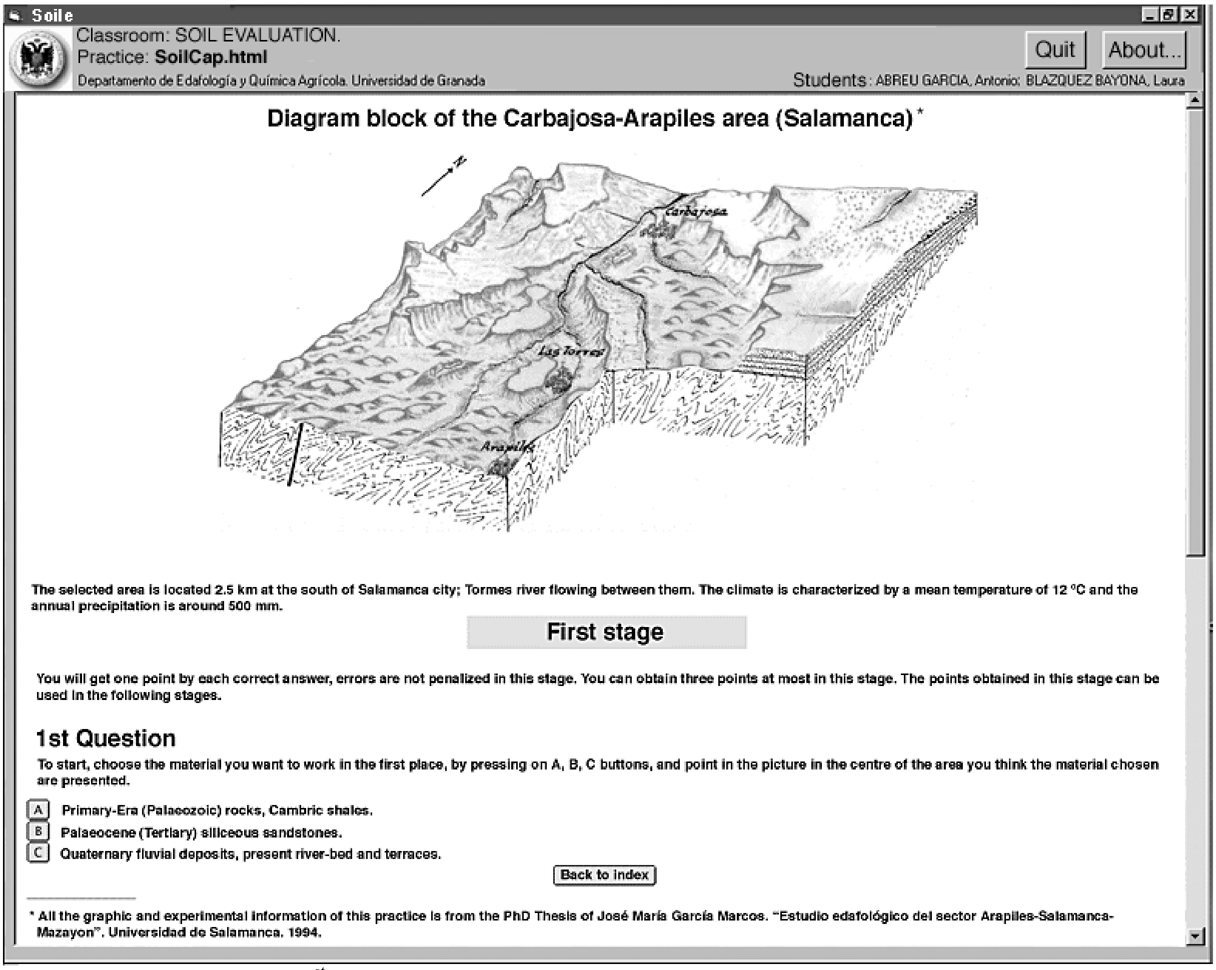


Figure 1. Show page of the 1st question.

For the soil evaluation, a series of questions are posed concerning: 1) slope of the terrain; 2) soil depth; 3) rock content; 4) rock and gravel content; 5) drainage; 6) flood risk; 7) texture; 8) pH; 9) degree of base saturation; 10) carbonate content; 11) salt content; 12) climatic aridity; 13) frost risk; 14) degree of erosion (Figure 2).

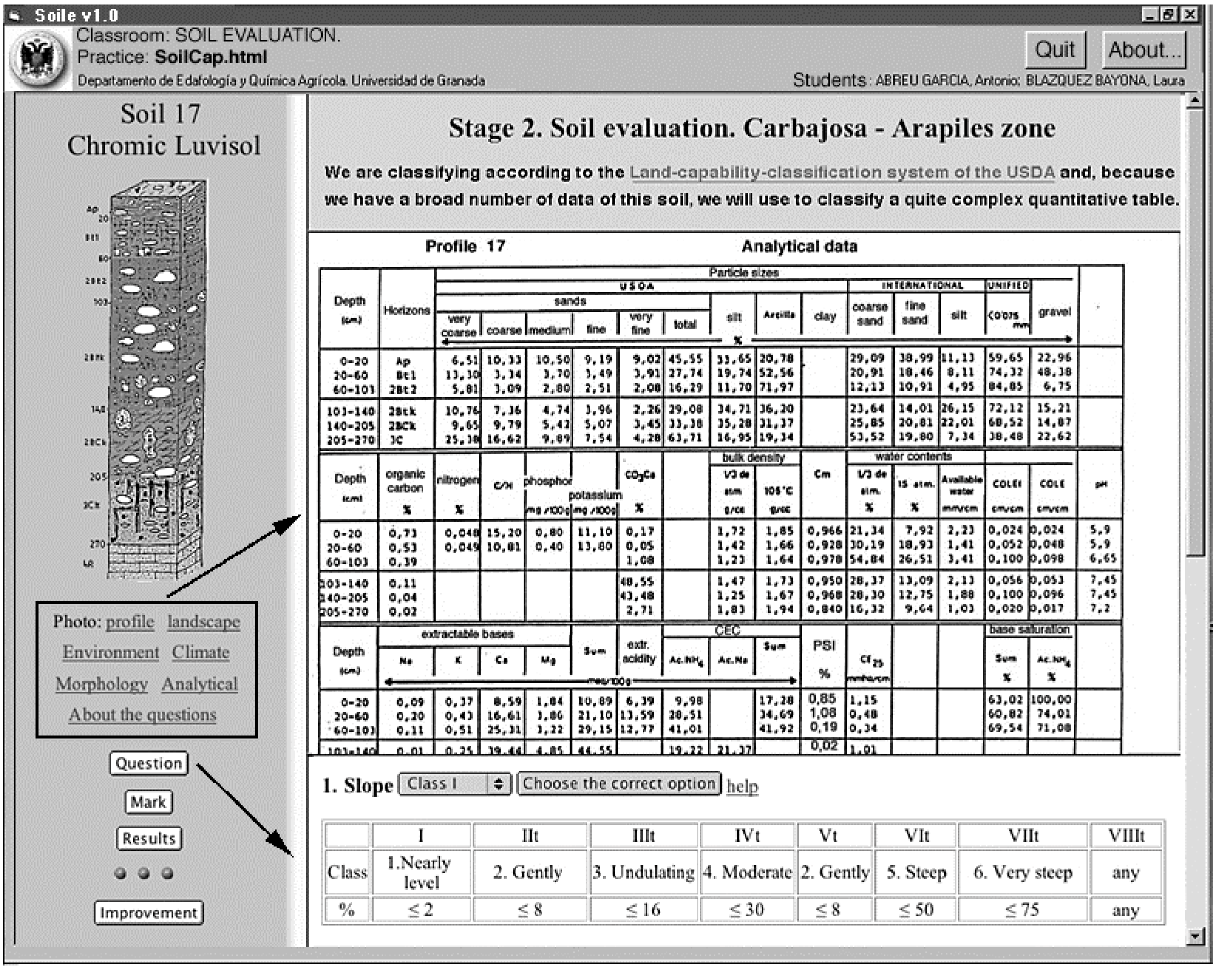


Figure 2. Show page of the stage 2. Soil evaluation.

To define the use capacity degrees for the several evaluator parameters data of Dorronsoro (2002) have been used. In the third stage prescription-of-use map of the evaluated soils is made.

The program allows both the self-learning of the students as their self-evaluation. The highest score is 10 points, each wrong answer being penalized two points (Table 1).

RESULTS					
FACTORS		Yours answers	Correct answers	Where to look for	Mark
FACTOR 1	Slope	IIt	IIt	Analytical: slope 6%	10
FACTOR 2	Depth	I	I	Morphology: rocks to 270 cm	10
FACTOR 3	Rocks	I	I	Environment: rocks 0%	10
FACTOR 4	Stones	I	I	Environment: stones 3%	10
FACTOR 5	Drainage	IIId	IId	Environment: drainage moderate	8
FACTOR 6	Texture	I	I	Morphology: loam	8
FACTOR 7	pH	I	IIa	Analytical: pH 5,9	6
FACTOR 8	Base saturation	I	I	Analytical: V 100%	6
FACTOR 9	Carbonates	I	I	Analytical: CaCO3 0.2%	6
FACTOR 10	Salts	I	I	Analytical: C.F. 1.15	6
FACTOR 11	Sodium	I	I	Analytical: PSI 0,9%	6
FACTOR 12	Aridity	IIIc	IIIc	Climate dry months 4	6
FACTOR 13	Frost	I	I	Climate frost months 2	6
FACTOR 14	Erosion	I	I	Erosion table	6
	CLASS	IItdac	IItdac		6

Table 1. Example of "results alert" for one exercise.

The structure of this program is multi-platform (PC, Mac, Linus, etc.); it is written in html/JavaScript. A specific high-security navigator (Soile) has been developed to examine students (Figure 3), by cancelling some non-desired options of the usual navigators (navigator menu, refresh of the page, access to the source, access of the historical, etc) and providing automatic recording of the results.

The application is available at: http:/edafologia.ugr.es/index.htm

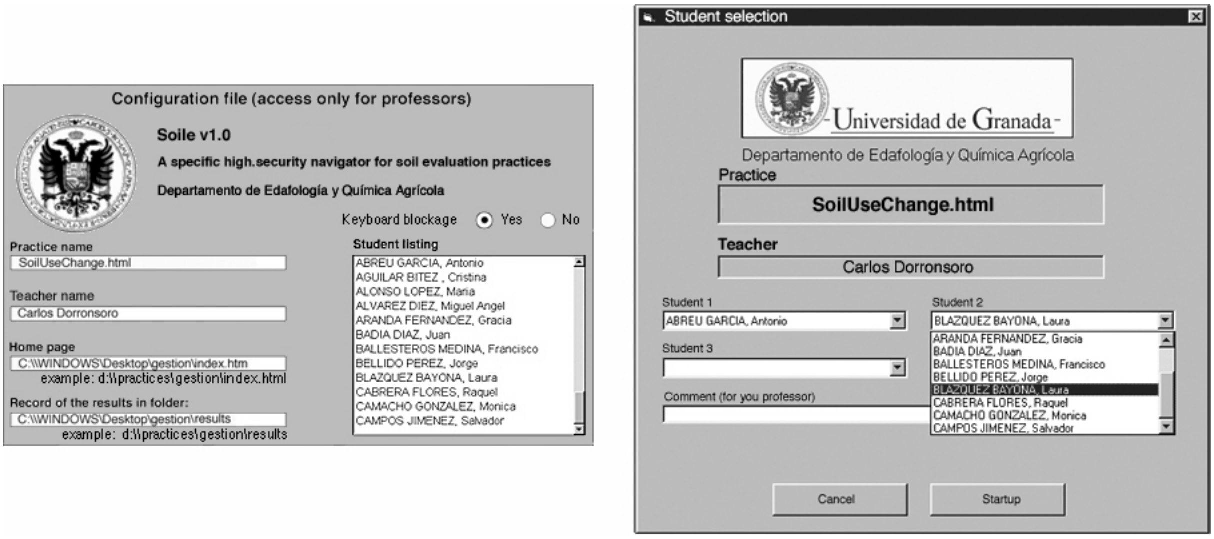


Figure 3. Configuration options for teachers (left side) and students (right side).

References

Dorronsoro, C. 2002. Soil evaluation. The role of the Soil Science in the Land Evaluation. Sustainble use and management of soils in arid and semiarid regions. SUMASS 2002.Cartagena (Murcia-Spain). Volume I. Edts.: A. Faz, R. Ortiz, A.R. Mermut. 106-128. Quaderna Editorial. Murcia. Klingebiel, A.A. & Montgomery, P.H. 1961. Land capability classification. USDA Agricultural Handbook 210. US Government Printing Office, Washington, DC.

van Diepen, C.A., Van Keulen, H., Wolf, J. & Berkhout, J.A.A. 1991. Land evaluation: from intuition to quantification. In: Advances In Soil Science (ed. B.A. Stewart). Springer, New York, pp. 139-204.

SoilUseChange.html

Dorronsoro-Diaz, C. [1] – Martinez, F.J. – Martin, F. – Dorronsoro, B. – Simon, M. – Fernandez, E. – Dorronsoro-Fernandez, C.

Introduction

The globalization of the world makes the demands of the society modify quickly and the agricultural productions were involved in few predictable changes. Very cost-effective crops today will give up in short-term. The changes in soil use produces uncertainty in the farmer because he knows the behaviour of his soils to the crops used, but ignore their capacity for new crops. In these cases, land evaluation represent an efficient help, advising and avoiding serious losses by the selection of mistaken uses.

Different types of soils present widely different properties, and therefore the response to each use differs. Land evolution is based on the idea that this response is a function of these properties, and, hence, knowing these, we can predict the behaviour of the soil under a given use. From the study of such properties, different degrees of suitability of the soil can be inferred for each end proposed.

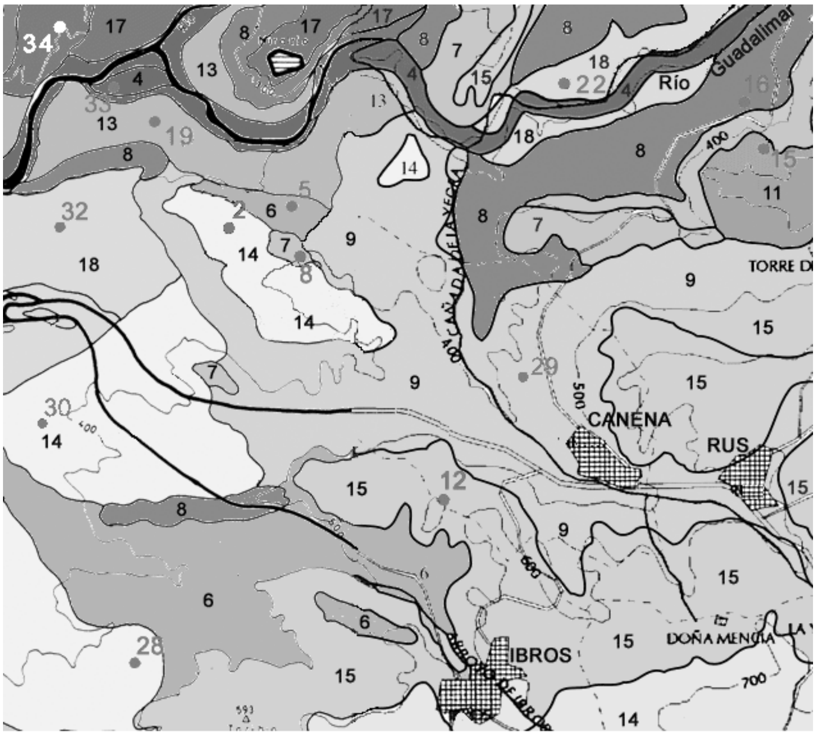
As land evaluation is intended to offer practical results that can be plotted on territorial maps, such endeavours cannot be limited to the analysis of the physical medium of the earth, but rather must be complemented by the corresponding socio-economic studies that enable cost-benefit analyses of the profitability of the land used. Thus, land evaluation enables predictions on the biophysical and economic behaviour of land for current and potential uses.

Study area

As is well known, the olive orchard is an erosive crop in which the economic profitability depends on subsidies from the EU. The soil of a large part of Andalusia (southern Spain) are completely eroded due to the extensive cultivation of the olive. Therefore, it would be desirable to change some this land to another type of use that would be less erosive and more profitable.

The study area is the region of La Loma (Jaén); particularly the sector between Linares and Baeza, in the southern side of the Guadalimar river. It is located in the Guadalquivir river basin, inside the Betic Chain. The litology is dominated by carbonate materials, mainly marls, marly limestones, calcaric sandstones and limestones. The relief is hilly with smooth and moderate slopes. Guadalimar river has a sequence in bad preserved steppy terraces (Delgado, 1983; Marañés, 1997; Simón, 1997).

[1] Instituto de Optica "Daza Valdes", CSIC. Serrano 121, 28006 Madrid, Spain. Tel.: 34 915616800; Fax: 34 915645557; E-mail: cdorronsoro@oc.mde.es



LEGEND

SOIL MAP UNITS

	Major soils	Inclusions	Geology
4	Calcaric fluvisol		Fluvial sediments. Holocene
6	Calcaric Regosol	Calcic Vertisol Haplic Calcisol	Marls and marlstones. Miocene
7	Calcaric Regosol	Calcaric Phaeozem Calcaric Cambisol	Clays and sandstones. Trias
8	Calcaric Regosol	Calcaric Cambisol	Argillites and sandstones.Trias
9	Calcaric Regosol Haplic Calcisol	Calcaric Cambisol	Sands and marls. Miocene
11	Petric Calcisol Haplic Calcisol	Eutric Leptosol Calcaric Regosol Chromic cambisol	Limestones and dolomites. Lias
13	Haplic Calcisol		Guadiamar Middle Terraces
14	Petric Calcisol Haplic Calcisol	Eutric Leptosol	Glacis
15	Haplic Calcisol	Calcic Vertisol Calcaric Regosol Calcaric Arenosol	Conglomerates, sandstones and marls. Miocene
17	Calcic Luvisol	Luvic Calcisol	Old glacis
18	Calcaric Cambisol	Calcaric Regosol Petric Calcisol	Guadiamar Lower Terraces

Figure 1. Cartographic map of the zone.

The application

This communication concerns the trails of use change in an olive-growing zone to other crops by means of the system "A framework for land evaluation (FAO, 1976)". The tested crops are: almond tree, pistachio, cherry tree, vineyard, chickpea, sunflower, wheat, potato and aromatic plants (Satureja cuneifolia, Acinus alpinus, Lavandula latifolia, Lavandula lanata, Sideritis funkiana, Sideritis hirsuta, Thymus zygis y Salvia lavandulifolia).

Soil evaluation is presented in an interactive way by a computer program in such a way that it can be used as a learning tool by students in classes on Land Evaluation.

For each soil, data are provided in relation to the general characteristics of the zone where the soil is located (climate and morphological as well as physico-chemical data) together with a photograph of the profile and landscape in question, represented on a map of the corresponding cartographic unit.

The soil evaluation is made after answering a total of 20 questions on soil characteristics: 1) slope of the terrain; 2) soil depth; 3) rock content; 4) rock content; 5) gravel content; 6) drainage; 7) Organic carbon; 8) texture of the surface horizon; 9) texture of the subsurface horizon; 10) pH of the surface horizon ; 11) pH of the subsurface horizon; 12) degree of base saturation of the subsurface horizon; 13) base saturation degree of the subsurface horizon; 14) carbonate content of the surface horizon; 15) carbonate content of the subsurface horizon; 16) salt content of the surface horizon; 17) salt content of the subsurface horizon; 18) sodium content of the surface horizon; 19) sodium content of the subsurface horizon; 20) degree of erosion.
The correlation matrix necessary to calculate the aptitude degrees of the several crops have been defined using data of Martínez (1990), Sys et al. (1993) y Marañes (1997).

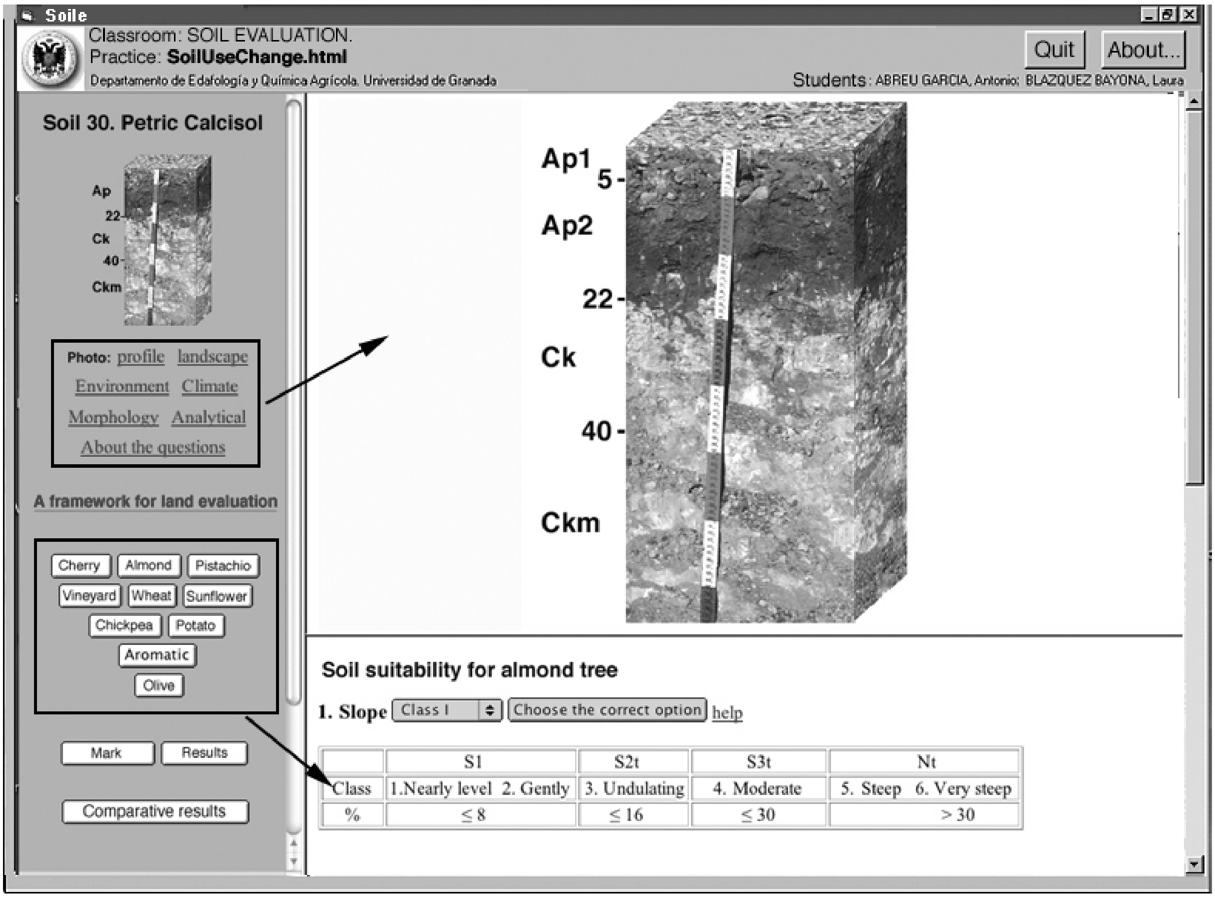


Figure 2. Show page of soil evaluation.

As politico-socio-economic criteria are not employed, the Soil Evaluation term proposed by Dorronsoro (2002) instead of Land Evaluation have been used. Soil evaluation represents the first step for land evaluation, soil evaluation would be similar to land evaluation, but excluding all social, economic and political characteristics.

The application allows both the self-learning of the students as their self-evaluation. The highest score is 10 points, each wrong answer being penalized two points.

The structure of this application is multi-platform (PC, Mac, Linus, etc.); it is written in html/JavaScript. A specific high-security navigator (GsuelosExplorer) has been developed to examine students, by cancelling some non-desired options of the usual navigators (navigator menu, refresh of the page, access to the source, access of the historical, etc) and providing automatic recording of the results.
The application is available at: http:/edafologia.ugr.es/index.htm

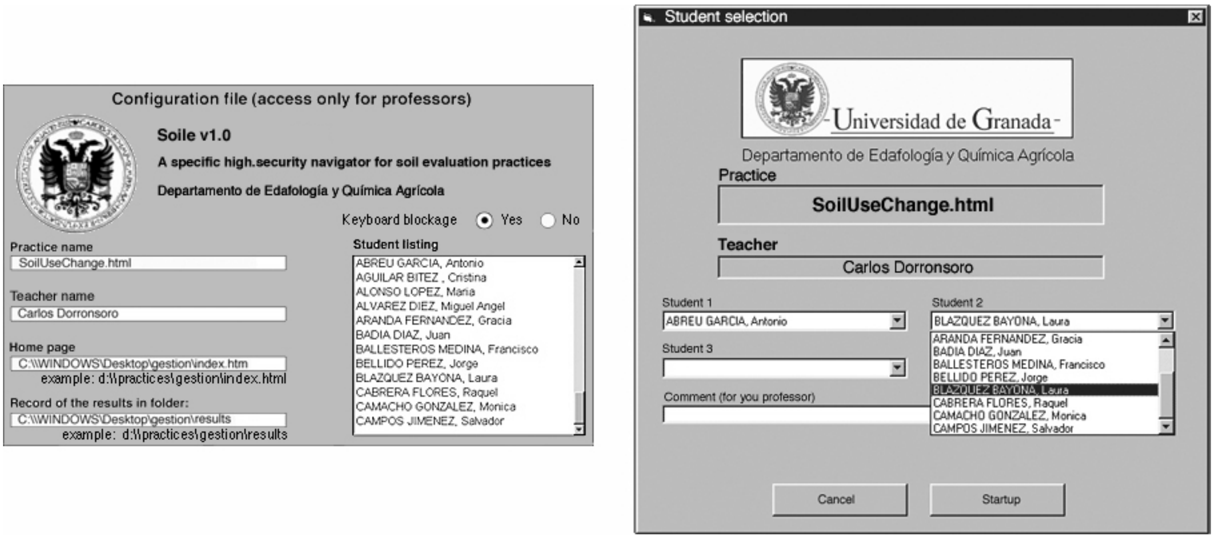


Figure 3. Configuration options for teachers (left side) and students (right side).

References

Delgado G. 1983. Estudio edáfico de la zona de Linares. Capacidad de uso de los suelos. Tesis Doctoral. Universidad de Granada.

Dorronsoro C. 2002. Soil evaluation. The role of the Soil Science in the Land Evaluation. Sustainble use and management of soils in arid and semiarid regions. SUMASS 2002.Cartagena (Murcia-Spain). Volume I. Edts.: A. Faz, R. Ortiz, A.R. Mermut. 106-128. Quaderna Editorial. Murcia.

FAO. 1976. A framework for land evaluation. Soils Bulletin 32. Rome. Italy.

Marañés A. 1997. Suelos de olivar de La Loma (Jaén). Tesis Doctoral. Universidad de Granada.

Martinez F.J. 1990. Estudio edáfico de la hoja de Guadix (1.001). Evaluación y uso de los suelos. Tesis Doctoral: Universidad de Granada.

Simón M., Marañés A., García I., Asensio C., Iriarte A. 1997. Mapa de suelos 1:100.000. Úbeda-906. Proyecto LUCDEME. Ministerio de Medio Ambiente y Universidad de Granada.

Sys, C., Van Ranst, E., Debaveye, J. & Beernaert, F. 1993. Land evaluation. Part 3: Crop requirements. Agricultural Publications 7. General Admin. Develop. Coop., Brussels.

Erosion control throught the establishment of a shrub with economical use in the Mediterranean conditions

Martínez-Raya, A[1].- Francia, J.R.- Cárceles, B.- Ruiz-Gutiérrez, S. - Martínez Vilela, A.

Abstract

The behaviour of one shrub specie in southern Spain has been studied with respect to soil protection against erosion. The specie selected were Thymus baeticus Boiss. ex Lacaita, adapted to the soil and climate of the area. This plant is used in the region for seasoning as well as for its aromatic and medicinal properties.

The research plots are placed in the Protected Natural Area of Sierra Nevada, in the province of Granada, Southeast of Spain. Sustainable alternatives are sought to replace traditional systems for harvesting the plants, which are frequently uprooted, implying a loss of soil protection and consequently serious erosion. The use capacity of different soils of the study area has been analysed with the aim of regenerating these soils (Martínez-Raya & cols., 1993).

The methodology was based on the use of closed plots of 100 m2, with allows a permanent evaluation of the runoff and the transport of solids and their relationship with the rainfall intensity of each single event.

The protection of the soil is also studied for different harvesting intensities of the plant. These results are very important, from the socioeconomic point of view, for the elaboration of use plans in natural protected areas. Different rainfall episodes have been studied for three years, with results showing that a harvesting of 50% of the biomass presents the best results and can be considered the most appropriate both for sustainable vegetation as well as for effective soil protection against erosion.

Keywords: Soil erosion; Runoff; Mediterranean shrubland; Sustainable use.

Introduction

The objective of this work is to study the soil protection provided by a shrub species with habitat in the southeast of Spain. The selected plant has been Thymus baeticus L. The fact that it is a plant already present in the region guarantees its accommodation to the climatological and soil conditions of the area, limiting the possible failure in its development to the management system used, once discarded the natural conditions. Another reason to select this species has been its economic interest, since it is known its use to get different essences (Muñoz, F., 1987), its medicinal employment (traditionally it has been used to combat colds), melliferous (Socorro, O. & cols., 1987) and for seasoning (it is used to season hunt meat), (Valle, F. & cols 2001).

The soils of our region are subjected to serious erosive problems (ICONA, 1982), due fundamentally to the combination of two factors: the characteristics of the Mediterranean climate, with torrential precipitations and the scarce vegetable cover of the soils.

The products from essential oils have been used traditionally in the region, normally representing this use the harvesting of a small percentage of the plants. However, in the last years, the pressure on wild populations is getting bigger (Estategia Forestal Española, 2000) due to the increase in the demand of the products obtained from these plants for its use in different sectors (cosmetic, liquor store, perfumery, aromatherapy, etc.). This growth, together with the inadequate of the traditional systems of harvesting that in many cases imply that the plant is completely pulled up, make their cultivation a necessary option for the protection of the environment, as well as a development possibility for these marginal rural areas.

In our region the most serious problems of erosion appear frequently in abandoned lands by the establishment of crops in soils with null or scarce agricultural aptitude. In these soils subjected to serious degradation processes, the failures in the regeneration plans that are normally used these days could be solved in many cases through the establishment, in a first phase, of a vegetable cover with this kind of shrub that protects the soil against erosion and help to its regeneration for the establishment, in successive stages, of more demanding plants.

This way, the introduction of improved varieties and the crop growing of these species together with the use of soil management techniques that allow a more effective use of the rain water and the protection against erosion; can constitute a real alternative for the improvement of the agrarian profitability of these areas, as well as to contribute to population fixation and the conservation of the environment.

[1] Centro de Investigación y Formación Agraria, Apartado 2027-18080 Granada (España). Tel.: +34 958267311; Fax: +34 958258510; E-mail: armarra@arrakis.es

Materials and methods

Description of the study site

The research parcels are placed in Sierra Nevada Natural Park (36º56'38"N, 03º29'42"E, 1350m), in the municipal term of Lanjarón (Spain).

The average annual rainfall is 698.7 mm and the average annual temperature is 12.4 ºC. The main bio climatic feature of the area is the important water deficit in summer, constituting doubtlessly a limitation when determining the specie that can be grown.

The soils of the study area have been classified by Sánchez Gómez (1990) as Typic Xerorthens (USDA, 1998).

For this study we have used closed parcels (Hayward, 1969; Kinnel, 1982; Riley, 1982) made of galvanized foil, with collectors and sedimentation tanks that allow us to exactly quantify the soil sediments as well as the runoff volumes, facilitating the study of the movements of nutrients and chemical compounds.

We have settled 4 parcels, with a surface of 96 m2 each one, placed in a slope of 17.5%. To obtain the vegetable material micropropagation techniques through cultivation in vitro have been used and once obtained the plants in nursery, they have been transplanted to the parcels for the study.

We have studied the protection of the soil provided by the species with two different harvesting intensities: 50 and 100%. For this, different rain events have been evaluated along the 4 years of study, measuring for each erosive event the runoff and the transportation of solids. For the control of the rain events a monthly rainfall recorder Hellman-type has been installed at the edge of the parcel.

The sampling of the runoff water, as well as of the transported solids was carried out at the end of each erosive event. The sediments are calculated adding those that are picked up in the final collector to those that are in suspension in the water accumulated in the sedimentation tanks. The soil losses, expressed in kg*ha-1, refer to dry weight to 105 ºC.

The biomass produced has been measured in each parcel. The vegetable material was harvested at the end of Julio or beginnings of August.

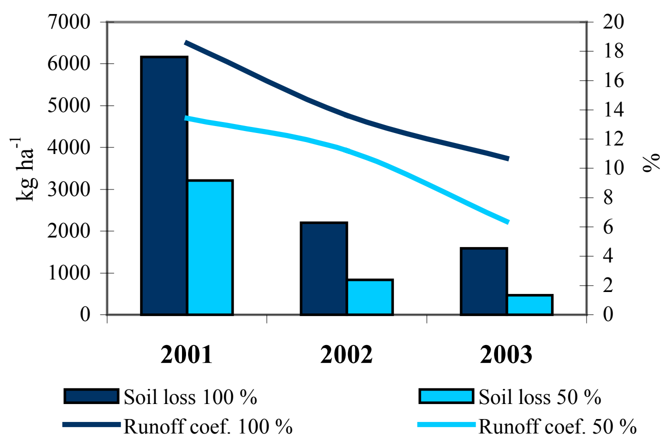
We have carried out measures of the content of humidity of the soil, between 0 and 50 cm of depth, with the equipment Diviner 2000 available in Sentek Pty Ltd, 77 Magill Road, Stepney, South Australia 5069.

The infiltration rate has been determined in the study parcels by means of an infiltrometer of simple ring.

Results and Discussion

The results obtained refer to the period 2000-2003. We have controlled a total of 28 erosive events, calculating for each one the rainfall, the energy, and maximum intensity of rain in 30 minutes (I30) and the EI30 factor of the USLE (Wischmeier, W.H., 1978).

Figure 1. Soil loss / Runoff coeficient



We have analyzed statistically (Statgraphics Plus 4.1) the precipitation data obtained for each erosive event together with the runoff coefficient and the soil loss caused by them, finding that the factor EI30 gives the biggest correlation (approximately 0.93 for the two treatments) between the soil loss and the characteristics of the precipitation, being the lineal model the one that better adjusts this correlation by means of a simple analysis. As for the runoff volume, the factor EI30 also presents the biggest correlation, although it is not very significant.

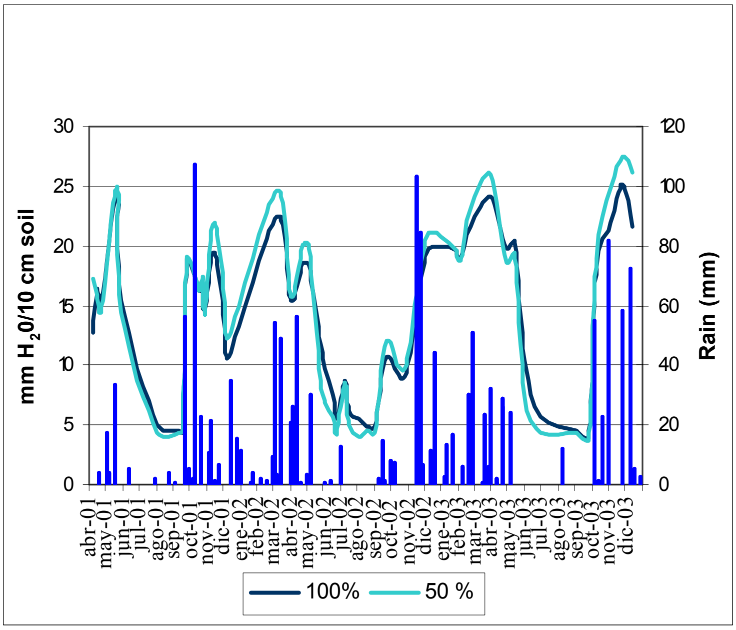
The distribution of the erosive events as function of the precipitation was the following:

Rainfall intervals (mm)	Nº of events
$R \leq 25$	5
$25 < R \leq 50$	10
$50 < R \leq 80$	10
$R > 80$	3

Figure 1 shows the average annual evolution of soil loss and the average runoff coefficient for the two different harvesting intensities. Data for the year 2000 have not been included since they are not representative since establishment of the plants in the parcels is very recent

As we can see in the graph, with the establishment of the vegetable cover we get a progressive decrease of the soil loss as well as the runoff coefficient. We can also appreciate that 50% harvesting provides a better protective effect of the soil, since the covering grade by vegetation is biggest.

The humidity content of the soil was measured from the year 2001 up to the 2003 with the equipment Diviner 2000 (Sentek®), with a distribution in time of the measures so that they reflect the seasonal variations.

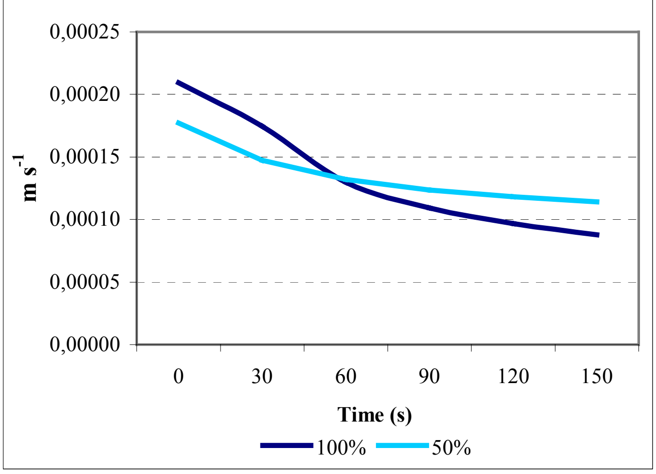


The graph (Fig. 2) represents the variation of the humidity content of the soil in its first 10 cm of depth (this depth has been chosen since it is the one affected by the erosive phenomena, and since it is quite significant of the depth roots of the plant) as function of the precipitation along the time for the two studied harvesting intensities. It can be observed that the maximum humidity content in the soil is reached after the spring rains and that there is an important decrease on the humidity content during the summer. We can also appreciate that during this period the consumption of soil water is bigger for the 50% harvesting intensity due to the biggest demand of the vegetation. It can also be observed that there is a bigger increment of the humidity after the rain for the 50 % harvesting intensity due to the increment of useful water that this treatment produces.

The infiltration was measured with a simple infiltrometer, taking in each parcel 3 measures distributed at random to try to reflect the possible zone variations and doing an average estimation.

The results present a good adjustment to the curve of Kostiakov (Zapata A. & cols, 2000) As we can observe in the graph (Fig. 3) even when the infiltration rate is bigger in a first moment for the soil with a 100% harvesting intensity, the equilibrium speed is bigger for a 50% intensity, as we can expect from a soil with smaller erosion.

Figure 3. Infiltration



The biomass production has been measured for the two treatments. The results are shown in table 1. We can see that the 50% harvesting intensity treatment presents better results as for a sustainable production in time, staying this practically constant along the years of the study. On the other hand, the production of vegetable material for the 100% harvesting intensity diminishes vastly along the time. This decrease can be attributed to a reduced soil conservation with this treatment, as well as to the sprout difficulties that the *Thymus baeticus* experiences when it is harvested at the soil level.

Table 1. Biomass production

	Dry weight (kg ha^{-1})	
	100%	**50%**
Year 1	615	417
Year 2	262	420
Year 3	82	406

Conclusions

The results of this study show that the use of a vegetable cover constituted by a shrub is an effective tool to fight against soil erosion in areas subjected to serious degradation processes. The main benefit obtained is the increase in the effective precipitation, factor of considerable importance under the Mediterranean conditions. The use of a species with possible economic use allows besides protecting the floor, to increase the agrarian profitability of marginal lands.

The study reflects the importance of the sustainable use of these vegetable resources in order to guarantee a production sustained in time, as it is confirmed with the best results obtained with the 50% harvesting intensity treatment in front of the 100% harvesting treatment that implies an exhaustion of the resource in the medium to long term.

Acknowledgements

This work has been financed under project INIA SC 0016. We are grateful for the facilities provided by the personnel of the Parque Natural de Sierra Nevada.

References

ESTRATEGIA FORESTAL ESPAÑOLA, (2000). Ministerio de Medio Ambiente. Secretaría General de Medio Ambiente. Dirección General de Conservación de la Naturaleza.

HAYWARD, J. A. (1969). The use of fractional acre plots to predict soil loss from a mountain catchment. Lincoln Paper in Water Resources. Jun. 94 pp.

ICONA (1982). Paisajes erosivos en el sureste español. Monografía 26.

KINNEL, P.I.A. (1982). Initial results from runoff and soil loss plots at Ginninderra, A.T.C. CSIRO. Disivion of soils 61: 1-12.

MARTÍNEZ RAYA, A. & cols. (1993). Plantas aromáticas, melíferas y medicinales: Caracterización y selección enfocada a la lucha contra la erosión. Congreso Forestal Español: 103-107.

MUÑOZ, F. (1987). Plantas medicinales y aromáticas. Estudio, cultivo y procesado. Mundi-Prensa.

RILEY, S. J. & cols. (1982). An inexpensive and easily installed runoff plot. J. Soil Cons. NSW 37: 144-147.

SANCHEZ GÓMEZ, S.T. (1990): Aplicación del estudio de suelos a la dinámica de la cuenca del río Lanjarón. Relación: suelos-geomorfología. Tesis Doctoral de la Universidad de Granada, 147 pp.

SOCORRO, O. & cols. (1988). Vegetación y flora apícola de la Alpujarra Granadina. IV Congreso Nacional de Apicultura. Zaragoza.

UNITED STATES DEPARTMENT OF AGRICULTURE. (1998): Keys to Soil Taxonomy. Eighth Edition

VALLE, F & cols. (2001) El medio natural del Poniente Granadino. Editorial Rueda. Madrid

WISCHMEIER, W. H. y SMITH, D. D. (1978). Predicting rainfall erosion losses. A guide to conservation planning. U. S. Department of Agriculture. Agriculture Handbook nı 537. 58 pp.

ZAPATA, A, & cols. (2000).Variación de algunas propiedades hidráulicas de los suelos en una cuenca pequeña de Sierra Nevada. XVIII Congreso AERYD. Huelva.

Response of soil with endemic shrubs from Canary Islands to simulated rainfall

Chinea, E. – Rodríguez Rodríguez, A. – Mora, J.L.[1]

Water erosion is one of the main degradation processes that affect the soils of the Canary Islands.

Establishment of plant cover on the soils is one of the most effective ways to prevent and control this process, and also to recover degraded soils.

In arid and semiarid environments such as the Canary Islands, with soils affected by intensive erosive processes it is difficult to establish plant cover owing to the poor quality of the soils and the shortage of water. For this reason, the possibility of using plant covers with high rusticity leguminous shrubs is studied which have important advantages compared to P-N-nutrition and also have an important forage value for cattle.

In order to establish the hydrological-erosive response of soils under plant cover of different leguminous shrub species endemic to the Canary Islands, several experiments were carried out with a portable rain simulator.

Soil used for the experiment was Haplic luvisol (Haplustalf), with 430 g kg^{-1} of clay in the first 50 cm, 52 g kg^{-1} of organic matter and a coarse crumble structure. The studied species are 24 month-old plants of *Chamaecytisus palmensis, Teline canariensis*, *Teline osyrioides sericea* and *Teline osyrioides osyrioides* and the water used in the simulation was sodium- bicarbonated (EC = 0.43 dS m^{-1}, pH = 8.39).

Four experiments were carried out (rain intensity 64 mm h^{-1} for 30 minutes) for each of the four shrub species, cut and uncut, and the time taken for surface ponding to occur and runoff, and the depth of infiltration of the rainwater were recorded.

First, the basic infiltration rate and the initial infiltration rate were determined by a double-ring infiltrometer in the soils with different cover and agricultural treatment (cut and uncut).

The initial infiltration rate and the basic infiltration rate are significantly higher in uncut than in cut plant covers (i.r: 200 mmh^{-1} vs. 60 mmh^{-1}; b.i.r.: 24 mmh^{-1} vs. 15 mmh^{-1}). Moreover, the mean depth of the water front was 30 cm in uncut plants and 20 cm in cut plants.

Regarding the response to simulated rainfall, all cut shrubs presented a similar behaviour reaching surface ponding and runoff in short time periods (8.8 and 15.5 minutes, respectively), although the start of runoff is later in soils with *Chamaecytisus palmensis*.

In uncut shrubs, the start of surface ponding and runoff occurs in double the time as in cut shrubs (17.0 and 24.2 minutes, respectively) and the cover of *Chamaecytisus palmensis* presented significantly longer times than the other plant cover.

Hence, uncut shrubs of *Chamaecytisus palmensis* present the best hydrological-erosive response and the best efficiency at improving infiltration and reducing runoff, while shrubs of the genus *Teline*, owing to their scopary biotype are the least effective, especially when cut.

[1] Soil Science Department, University of La Laguna; La Laguna, Tenerife, Canary Islands, Spain. Tel: 34 922 318371; Fax: 34 922 318311, E-mail: antororo@ull.es

Mineralogical transformations in carbonate soils affected by a spill of pyrite tailings

García, I.[1] – Martín, F. – Dorronsoro, C. – Simón, M. – Diez, M. – Bouza, P. – Aguilar, J.

Introduction

When the tailings from a pyrite mine are exposed to oxygen and water, sulphides oxidise to sulphates, the pH falls markedly due to the formation of sulphuric acid, and the pollutants solubilize (Förstner & Wittmann, 1983). In the case of pyrite, the most abundant sulphide in these tailings, the oxidation can be represented by the following reactions:

$2FeS_2(s) + 7O_2(g) + 2H_2O \longleftrightarrow 2Fe^{2}+(aq) + 4SO_4^{2-}(aq) + 4H^+(aq)$ (1)

$4Fe^{2}+(aq) + O_2(g) + 4H^+(aq) \longleftrightarrow Fe^{3+}(aq) + 2H_2O$ (2)

The Fe^{3+} released in Reaction (2) may hydrolyze to form ferric hydroxide:

$Fe^{3+}(aq) + 3H_2O \longleftrightarrow Fe(OH)_3 + 3H^+(aq)$ (3)

or may oxidize additional pyrite by the reaction:

$FeS_2(s) + 14Fe^{3+}(aq) + 8H_2O \longleftrightarrow 15Fe^{2+}(aq) + 2SO_4^{2-}(aq) + 16H^+(aq)$ (4)

Reaction (2) is very slow at pH<4.0 and has been described as the rate-determining step in pyrite oxidation; nevertheless, Fe-oxidizing bacteria (e.g. Thiobacillus ferrooxidans, Thiobacillus thiooxidans) increased the oxidation rate of Fe^{2+} by 10^5 (Singer & Stumn, 1970) and thus, oxidation rates for pyrite are 10- to 20-fold higher than those resulting from purely chemical oxidation (Battaglia et al., 1998; Boon & Heijnen, 1998).

When $CaCO_3$ is present in the soils, the acidity is neutralised, the oxidation of Fe^{2+} to Fe^{3+} proceeds rapidly (Singer & Stumm, 1968), iron precipitates and the calcium and sulphate ions form gypsum (Ritsema & Groenenberg, 1993; Kashir & Yanful, 2000):

$Fe^{3+}(aq) + 2SO_4^{2-}(aq) + H^+(aq) + 2CaCO_3(s) + 5H_2O\ Fe(OH)_3(s) + 2CaSO_4.2H_2O(s) + 2CO\,(g)$ (5)

On 25 April 1998 the retention walls in a pond containing the residues from the pyrite mine of Aznalcóllar (southern Spain) broke open, and approximately 4x106 m^3 of polluted water (solution phase) and 2x106 m^3 of toxic tailings (solid phase) were spilled into the Agrio and Guadiamar River Basin, affecting some 55 km^2 (Grimalt et al., 1999). The solid phase consisted of different sulphides such as pyrite (75-80%), sphalerite and galene (5%), chalcopyrite (1.5%), arsenopyrite (1%), as well as minor amounts of bournonite, boulangerite, nuffieldite jaskolkiite and numerous trace metals (Almodóvar et al., 1998; López-Pamo et al., 1999). The principal pollutants were: Zn, Pb, Cu, As, Sb, Bi, Cd and Tl (Cabrera et al.., 1999; Vidal et al., 1999; Simón et al., 1999).

From the spill, the soils were covered by a layer of tailings of variable thickness averaging 7 cm (López-Pamo et al., 1999). When the tailings from a pyrite mine are exposed to oxygen and water, sulphides oxidise to sulphates, the pH falls markedly due to the formation of sulphuric acid, and the pollutants solubilize (Nordstrom, 1982; Förstner & Wittmann, 1983, Nordstrom et Alpers, 1999; Alastuey et al., 1999).

The aim of this work is to analyze the effect of the pyrite tailing oxidation, over time, on soil mineralogy.

Material and Methods

In some places in these soils, two months after the spill, a thin layer of reddish-yellow soil (7.5YR 6/8) a 4 mm thick developed immediately underneath the tailings. This layer appeared a few weeks after the spill, the colour being owed to abundance of Fe in the tailings (Simón et al., 1999). At 15 months the layer became 15 mm thick and at 4 years, 60 mm, with the uppermost 5 mm clearly discoloured (2.5Y 7/4). In each date, the layers were sampled each millimetre and, below the reddish-layer, each 5 cm up to reach the unaffected soil. All samples were sieved to 2 mm.

In each sample, the particle-size distribution was determined by the pipette method after elimination of organic matter with H_2O_2 and dispersion with sodium hexametaphosphate (Loveland and Whalley, 1991). The pH was measured potentiometrically in a 1:2.5 soil-water suspension. The $CaCO_3$ equivalent was determined by a manometric method (Williams, 1948). The cation-exchange capacity (CEC) was determined with 1N Na-acetate at pH 8.2. Pills of soil and lithium tetraborate (0.6:5.5) were prepared and the total content in Fe was measured by X-ray fluorescence using a Philips PW-1404 instrument. A Zeiss-950 scanning electron microscope with a Tracor Northern 523 X-ray energy-scattering microanalyser (SEM-EDS) was used to examine the morphology and analyse the composition of certain minerals present in the first 6 mm of the soil. For X-ray diffraction, a Philips PW-1710 instrument with CuKa radiation was used. The climate of the study area is typically Mediterranean (hot, dry summers; cold, wet winters; temperate autumns; and springs with variable

[1] Departamento de Edafología y Química Agrícola. Universidad de Almería. Tel.: 34 950 015117; Fax: 950 215319; E-mail: inesgar@ual.es

rainfall). The average annual rainfall is 630 mm, the average temperature 17.9 °C and the potential evapotranspiration 975 mm.

Results and discussion

The soils in which the reddish-yellow layers (RYL) develop are carbonated (8%) and sandy (46%) soils, with low organic matter content (1.7%), alkaline pH (8.0) and slightly developed profile (Xerorthent and Xerofluvent (Soil Survey Staff, 1999)).

Over time, the pH decrease with the progress of the contamination (table 1), reaching the value of 2.5 at five years from the staying of the tailings in soil, causing the decrease and even the dissolution of the carbonates; in this sense, two month after the spill carbonate content is reduced up to 58%, the samples from 15 months and 5 years are completely decarbonated, having a strong fall in the cation exchange capacity values. The iron within this layer strongly increased, indicating a high degree of pollution. Also, from this Fe distribution, we deduce that this metal was responsible for the reddish-yellow coloration.

Table 1. Mean values of some characteristics of uncontaminated soils (UCS) and mean values of the central samples in the RYL taken at two months, fifteen months and five years from the spill.

	UCS	*at 2 months*	*at 15 months*	*at 5 years*
pH	7.9	5.6	3.5	2.5
$CaCO_3$ (%)	7.8	3.3	0.0	0.0
CEC($cmol_c kg^{-1}$)	15.3	nd	nd	9.2
Fe (%)	2.50	4.67	5.46	9.80

Mineralogy of uncontaminated soil was dominated by quartz, feldspars, calcite and dolomite (figure 1), and the infiltration of the acidic solution produced and intense weathering of the calcite, totally disappearing in soil at 15 months from the pollution. The other constituents have less substantial variations. In this sense, feldspars and phyllosilicates are reduced approximately to half at five years from the spill. On the other hand, the peaks in the X-ray diffractograms of the resistant-to-hydrolysis minerals, like quartz, increase its intensity.

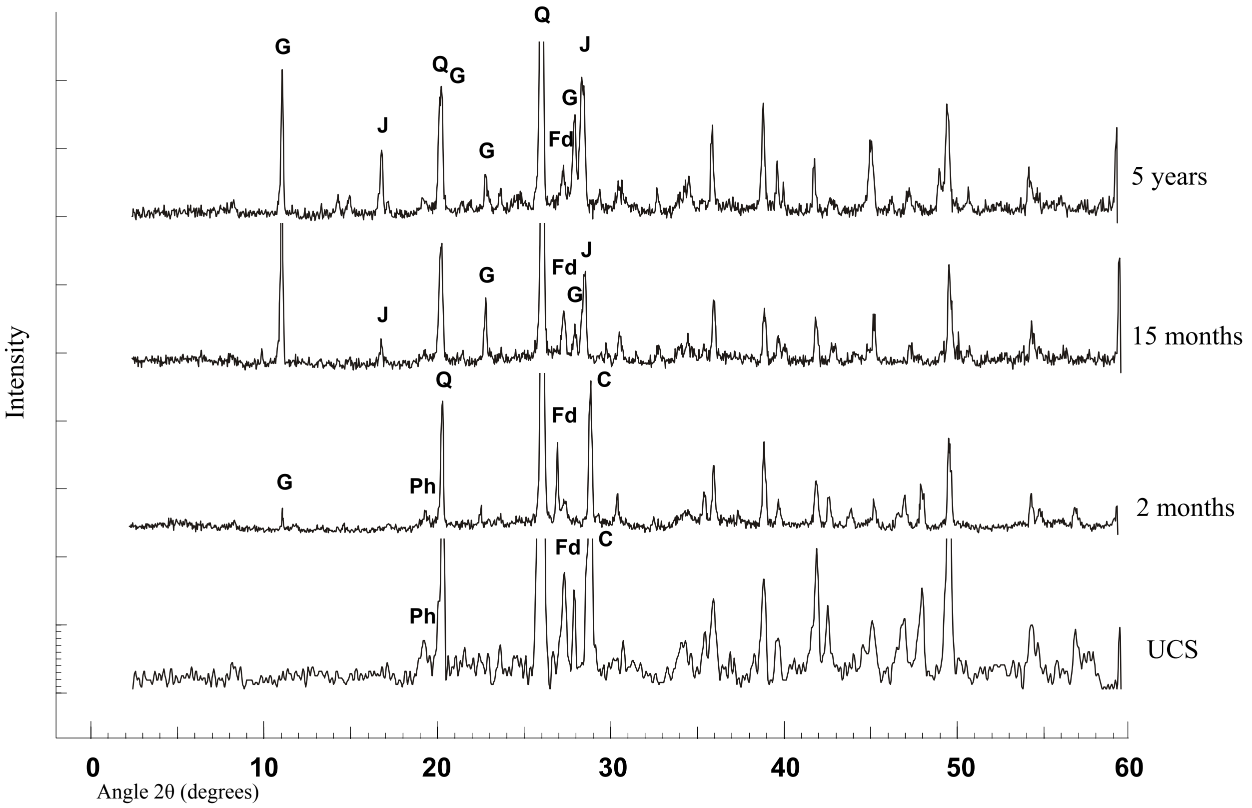


Figure 1. X-Ray diffractograms before (UCS), 2 months, 15 months and 5 years after the spill. (C: calcite, Q: quartz, Fd: feldspars, Ph: phylosilicates, G: gypsum, J: jarosite)

Table 2. Mean values of the soil mineralogy (%) before (UCS) and at two months, fifteen months and five years from the spill

	UCS	*at 2 months*	*at 15 months*	*at 5 years*
Quartz	45	45	45	50
Feldspars	20	20	15	10
Phyllosilicates	20	20	20	10
Carbonates	15	5	0	0
Gypsum	0	5	15	15
Jarosite/Plumbojarosite	0	0	5	15

Very important are the neoformations produced by the high quantity of iron and sulphates dissolved in the contaminant solution (table 2). In this way, the calcium released in the weathering of the calcite reacts with the sulphates to form gypsum (Ritsema and Groenenberg, 1993) which increases gradually until reach the 15% of the total soil; meanwhile the sulphate, iron and potassium form jarosite which, as the contamination progressing, trend to change to plumbojarosite. So the plumbojarosite is relatively abundant in the decoloured zone of the layer formed at 5 years. The electron microscopy (SEM_EDS) reveals, both crystals of gypsum and jarosite, as other neoformations like the needled crystals of S and Fe (melanterite ¿?) or the plated-habit crystals of S and Al (alunite ¿?) figure 2.

According to the clay mineralogy, the oriented aggregates of the clay fraction in the samples from the soil underlying the reddish-yellow layer gave diffractograms showing illite, kaolinite, smectite, interstratified complexes of chlorite/smectite, calcite and feldspars. In the samples of the reddish-yellow layer, the peaks become broader and lower, indicating a generalized breakdown of minerals, both phyllosilicates as well as feldspars. The presence and alteration of the components in the soil (mainly, feldspars, micas and clays) boosted the capacity of acid neutralization and retention of released metals. Identification of such mineral alteration is not easy, the phyllosilicates and particularly smectites apparently being the most active in neutralizing the acidity (Pons et al, 1982; van Breemen, 1980).

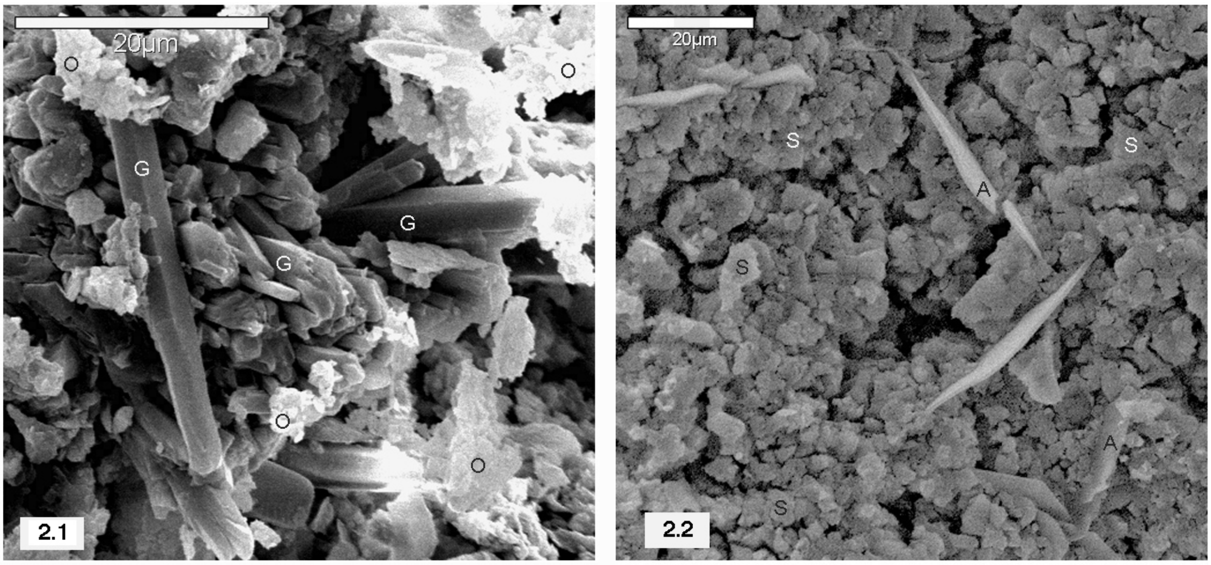


Figure 2. Microphotography by SEM of soils in the interior of the reddish-yellow layer. Photo 2.1, tabular crystals of gypsum (G) in a mass of Fe oxyhydroxides (O). Photo 2.2, acicular crystals of Al sulphate (A) in a mass of sulphates of Fe, Al, Zn and Ca (S).

Conclusions

The infiltration in soil of the solution coming from the pyrite tailing oxidation hydrolyze the silicates, weather the carbonates, acidify the soil and neoform minerals, mainly gypsum and other minerals of the jarosite group, melanterite and alunite.

Acknowledgements

This work has been realized by the financial support of the project REN2003-03615 Ministerio Educacion y Ciencia.

References

Alastuey, A., García-Sánchez, A., López, F. & Querol, X. 1999. Evolution of pyrite mud weathering and mobility of heavy-metals in the Guadiamar valley after the Aznalcóllar spill, south-west Spain. The Science of the Total Environment, 242, 41-55.

Almodóvar, G.R., Sáez, R., Pons, J.M., Maestre, A. Toscano, M. & Pascual, E. 1998. Geology and genesis of the Aznalcóllar massive sulphide deposits, Iberian Pyrite Belt, Spain. Mineralium Deposita, 33, 111-136.

Battaglia-Brunet, F., d´Hugues, P., Cabral, T., Cezac, P., García, J.L. & Morin, D. 1998. The mutual effect of mixed Thiobacilli and Leptospirilli populations on pyrite bioleaching. Mineral Engineering, 11, 195-205.

Boon, M. & Heijnen, J.J. 1998. Chemical oxidation kinetics of pyrite in bioleaching processes. Hydrometallurgy, 48, 27-41.

Cabrera, F., Clemente, L., Díaz Barrientos, E, López, R. & Mutillo, J.M. 1999. Heavy metal pollution of soil affected by the Guadiamar toxic flood. The Science of the Total Environment, 242, 117-129.

Förstner, U. & Wittmann, G.T.W. 1983. Metal pollution in the aquatic environment. Springer-Verlag, Berlin.

Kashir, M. & Yanful, E.K. 2000. Compatibility of slurry wall backfill soils with acid mine drainage. Advances in Environmental Research, 4, 252-268.

López-Pamo, E., Barettino, D., Antón-Pacheco, C., Ortiz, G., Arránz, J.C., Gumiel, J.C., Martinez-Pledel, B., Aparicio, M. & Montouto, O. 1999. The extent of the Aznalcóllar pyritic sludge spill and its effects on soils. The Science of the Total Environment, 242, 57-88.

Loveland, P.J. & Whalley, W.R. 1991. Particle size Analysis. In: Soil Analysis: Physical Methods (eds K.A. Smith & C.E. Mullis), pp. 271-328.

Marcel Dekker, New York.Nordstrom, D.K. 1982. Aqueous pyrite oxidation and the consequent formation of secondary iron minerals. In: Acid Sulfate Weathering (eds J.A. Kittrick, D.S. Fanning & L.R. Hossner), pp. 37-56. Soil Science Society of America, Madison, WI.

Ritsema, C.J. & Groenenberg, J.E. 1993. Pyrite oxidation, carbonate weathering, and gypsum formation in a drained potential acid sulfate soil. Soil Science Society of America Journal, 57, 968-976.

Simón, M., Ortiz, I., García, I., Fernández, E., Fernández, J., Dorronsoro, C. & Aguilar, J. 1999. Pollution of soils by the toxic spill of a pyrite mine (Aznalcóllar, Spain). The Science of the Total Environment, 242, 105-115.

Singer, P.C. & Stumn, W. 1968. Kinetics of the oxidation of ferrous iron. Second Symposium on Coal Mine Research, pp. 12-34. Mellon Institute, Pittsgurgh, PA.

Singer, P.C. & Stumn, W. 1970. Acidic mine drainage: the rate-determining step. Science, 167, 1121-1123.

Vidal, M., López-Sánchez, J.F., Sastre, J., Jiménez, G., Dagnac, T., Rubio, R. & Rauret, G. 1999. Prediction of the impact of the Aznalcóllar toxic spill on the trace element contamination of agricultural soils. The Science of the Total Environment, 242, 131-148

Williams, D.E. 1948. A rapid manometric method for the determination of carbonate in soils. Soil Science Society of America Proceedings, 13, 127-129.

The temporal and spatial changes of the soil's macro- and micro element content as an indicator of soil erosion

Farsang, A.[1] – Rácz, P. – Barta, K.

Introduction

The hypothesis according to which the "fate of a lacustrine system is in the hands of its catchment area" is especially true for Lake Velence. Agricultural production on the catchment area along with the intensity of fertilization as well as the implementation of water and soil friendly approaches in the agricultural production and fertilization play a crucial role in the deceleration of eutrophization and the improvement of water qualities within a lake system used mainly for recreation as Lake Velence. The catchment area of the lake covering approximately 602.4 km^2 is about 23 times of the water surface. The lack of any natural obstacles on the catchment area enables the practically undisturbed transportation of the sprinkled nutrients onto the base of erosion via the flows carrying water and sediment into the creeks, as the wet meadows lying adjacently to the creeks were put under agricultural production in the 1970s. These 50-70 m wide wet habitats served as some sort of physical and chemical traps for the eroded nutrients. In order to create larger plots, suitable for production via the application of high-capacity machines (Bódis K., Dormány G. 2000), shelter belts were eradicated. These also must have served as an erosion trap for the eroded soil particles in case of sloping plots, thus enabling the preservation of water quality in Lake Velence besides soil protection.

The present study involved the analysis and discussion of several aspects in relation to the catchment area of the Cibulka creek (Fig. 1.), covering an area of approximately 14 km^2. This is a subregion of the catchment of the Vereb-Pázmánd waterflow, which is largely responsible for the contamination of Lake Velence. The following aspects were considered:

- to shed light onto the spatial and temporal variations of the nutrition cycle of soils in the area
- to investigate how the morphology, the organic content as well as the cohesion of the soils influence the spatial variance
- to decide which micro- or macroelements can be considered as indicators of soil erosion
- to determine those slope segments, which are most exposed to soil erosion, nutrition leaching, and accumulation in the pilot area, running parallel with the slopes and utilized for vine growing and acting as a major source of nutrition contamination to the lake
- to correlate the erosion and accumulation slope segments, received as an output from the modeling software Erosion 2D, with the variations of the metal content along the slope

The study site

The whole watershed is highly diversified petrographically, pedologically and in terms of land use. On the loess-covered surfaces mid-eroded chernozem brown forest soils and chernozems can be found. The topsoil reaction is neutral with pH 7.21–8.50.The granite and andesite bedrock areas are covered by shelter forests with *Quercus cerris*, *Quercus pubescens* and *Carpinus betulus*, and sporadically by *Robinia pseudoacacia* and *Pinus nigra*. Poor grazing lands are also present. The chernozem soils are cultivated as arable lands with wheat, corn and sunflower and as vineyards or orchards; meadow chernozems and slope sediment soils exist only in small patches. The *climate* of the study site is moderately cool and dry, the annual average temperature is 9.5–9.8 ^{o}C, the amount of precipitation is 550–600 mm with half of it in summer (in: Marosi, Somogyi 1990) often in wild tempests.

Among the changes of landscape utilization on the catchment of Cibulka creek during the past 20 years the transformation of the arables into wine-growing areas was of primary importance. The Hungarovin viniculture (Pázmánd) purchased arable lands in several steps from the Agromark Producer's Cooperative at the end of the 1980s, beginning of the 1990s planting vine-stocks into the newly gained areas and introducing large-scale intensive production.

A *150 x 300 m plot was chosen as the site of a detailed, high resolution analysis* on the catchment of Cibulka creek. The aspect of the plot was north-eastern, with an average angle of 4^{o}, 1^{o} and 6^{o}. The average annual precipitation at the site is between 550-600 mm, 50-55 % of which comes during the summer (Marosi, Somogyi, 1990), very often as heavy showers.

[1] Univerity of Szeged, Faculty of Science, Department of Physical Geography and Geoinformatics, Hungary, 6721 Szeged, Egyetem str. 2-6.; Tel.: 00-36-62-544-397; Fax: 00-36-62-544-158; E-mail: andi@earth.geo.u-szeged.hu

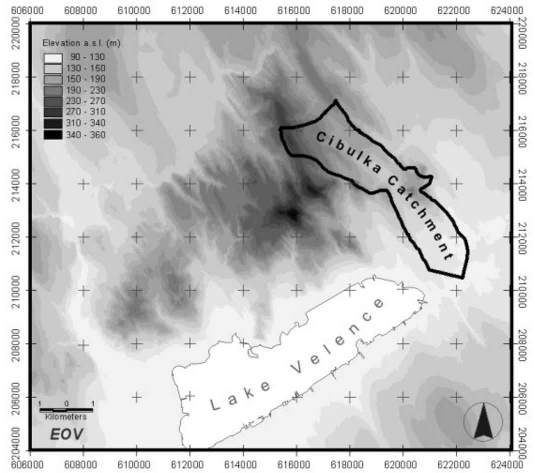


Figure 1. The location and relief conditions of the analyzed catchment area and the Velence Mts.

The *thickness of the productive topsoil* exceeds 150 cms. The pH of the topsoil is slightly alkaline with values ranging between 7.21–8.5. One of the key factors influencing soil erosion in the area; namely the vegetation cover was around 35% at an average during the period of the analysis. The pilot plot was carefully selected in order to represent an area where landscape utilization is similar to that of the slopes of the catchment area; namely where large-scale wine-growing is present.

Sampling and analysis material and methods

Detailed sampling and the laboratory analysis of the collected samples for the selected pilot plot was carried out in three steps: samples were collected at two times in 2001 (May and June) and once in 2003 (May) for the individual slope segments. Sampling was carried out with the help of a quadrate of 25x25m. The exact location of the sampling sites was recorded with the help of a theodolite in order to help re-sampling. Average samples were taken for the uppermost 10 cm of the topsoil. The following soil parameters and nutrients have been examined in details: pH(KCl), K_A (Arany-type cohesivity index), $CaCO_3$, humus content (%), available micro- and macroelements (NO_2-NO_3-N, P_2O_5, K_2O, Na, Mg, Ca, Mn, Zn, Cu, Fe, Mo, B, Al, As, Cd, Co, Cr, Hg, Ni, Pb). The analysis of the nutrients was restricted to the available nutrients alone. After extraction with the acetic acid solution of ammonium-lactate for the macroelements, and Lakanen Erviö extraction for the microelements, measurements were carried out with an ICP Thermo Jarell Ash ICAP 61E (Búzás, 1988).

In order to determine the variations in the rate of soil erosion, and the accumulation segments along the slope, the soil erosion modeling software Erosion 2D was utilized (Schmidt, 1996). The model was run for a single rainfall event, which occurred in the area under investigation in May 2001 (length: 1 hour, intensity: 19.3 mm/h). Data for this have been gained from pluviometer measurements of a local meteorological station.

Results

The spatial and temporal variations of the available nutrition content of the topsoil

Based on its physical properties the soil of the pilot plot can be classified as sandy loam with an Arany-type cohesivity index of 32-41 (Fig. 2). Regardless of the regional differences, the plot under investigation as a whole is medium or poor quality considering the nutrition content. The amount of organic matter, used as an indicator of the available N content, ranged between 0.8% and 2.8%. The P and K content in certain areas (e.g. the NW margin) is extremely high in all samples taken at different times (P_2O_5: 350-400 ppm, K_2O: 250-300 ppm) despite the collection of average samples. The average macroelement content for P was 70-100 ppm, while for K it was between 100-150 ppm (Fig. 4-5.).

Macro- and microelements as indicators of erosion

Before the plantation of vine-stocks to the area (1990), the nutrition supply was even for the whole of the pilot plot, but there has been a major rearrangement in the nutrition content for the past 10 years. The *rearrangement patterns and tendencies are different* for the individual elements analyzed, mainly depending on their chemical properties. Those elements which are adhered to the grain surfaces or to the organic particles of the soil (e.g. P, K, Pb, Cd, Ni), follow a spatial distribution pattern corresponding to the variations of the cohesivity, and humus content of the topsoil. As the microrelief pattern fundamentally determined the

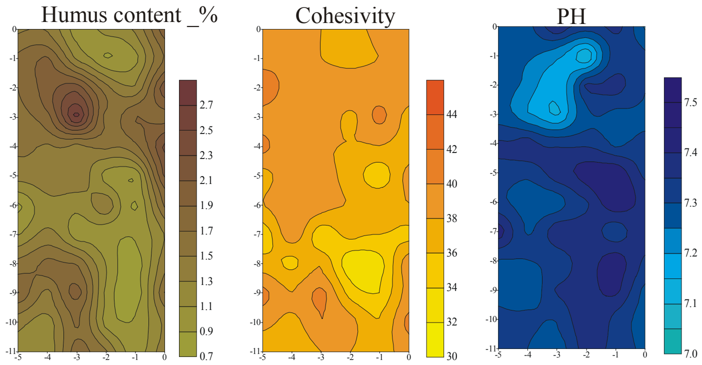


Figure 2. The spatial distribution of the humus content, cohesivity and pH of the soils of the pilot plot

transportation and movement of the soil grains, and the topsoil, richest in organic matter, the spatial distribution pattern of the latter elements is very similar to that of the relief. These correlations are depicted in Table 1. It can be clearly observed that the concentrations of the above mentioned elements are positively correlated with the organic content of the soil (r^2: 0,626-0,808), and the cohesivity. The other major group of elements is leached from the topsoil following the fertilization of the area and transported downward in the soil in a soluble form (e.g. N, and Ca). The concentrations of all elements are negatively correlated with the alkalinity o the soil, because the decrease of the pH results in an increase of the available elements.

Table 1. The correlation matrix of the soil properties and the available macro- and microelement contents

	pH	**Clay content**	**Corg**	**P**	**K**	**Cd**	**Ni**	**Pb**	**Co**	**Al**	**Cu**	**Zn**	**N**
pH	1,00	-,396	-,491	-,263	-,334	-,396	-,477	-,431	-,441	-,502	-,120	-,299	-,201
Clay content	-	1,000	,533	,280	,382	,371	,326	,353	,071	,148	-,055	,279	,254
Corg	-	-	1,000	,631	,808	,739	,803	,626	,489	,426	-,061	,571	,377
P	-	-	-	1,00	,742	,649	,570	,733	,237	,066	-,279	,537	,375
K	-	-	-	-	1,00	,614	,703	,582	,415	,344	-,005	,635	,585
Cd	-	-	-	-	-	1,00	,667	,701	,356	,303	-,160	,516	,262
Ni	-	-	-	-	-	-	1,00	,550	,667	,580	-,175	,410	,273
Pb	-	-	-	-	-	-	-	1,00	,339	,188	-,253	,508	,310
Co	-	-	-	-	-	-	-	-	1,00	,800	,184	,274	,192
Al	-	-	-	-	-	-	-	-	-	1,00	,334	,149	,137
Cu	-	-	-	-	-	-	-	-	-	-	1,00	,247	,224
Zn	-	-	-	-	-	-	-	-	-	-	-	1,00	,656
N	-	-	-	-	-	-	-	-	-	-	-	-	1,000

The rearrangement and the local increases and decreases of the nutrition content can be linked to the *microrelief* of the pilot plot, indicating the initiation of a valley formation. The certain steeper, areas highly exposed to erosion, where even soil profiles eroded to the loessy bedrock can be observed, and the flattening accumulation areas, discriminated by field (profile erosion) (Fig.3.) and topographical observations, can be clearly separated with the help of the spatial distribution maps of individual elements (Fig. 4.). This is characteristic for both the macro- (P, K), and the microelements (Zn, Cd, Ni, Pb). Besides the development of the microrelief, the intensive ploughing in the direction of the slope also influences the spatial variations and distribution pattern of the physical properties, humus content as well as the macro- and microelement content of the soil.

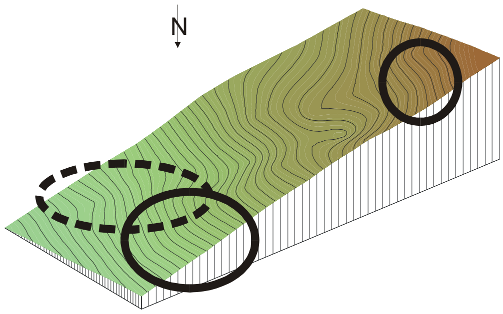


Figure 3. The relief conditions of the pilot plot (150-300) with the areas exposed to erosion (continuous line) and accumulation (dotted line) marked (based on field observations, isohypse lag: 0.5 m)

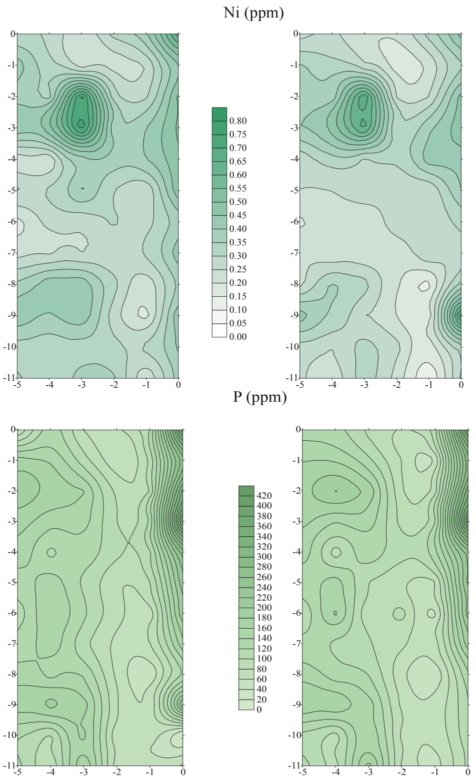


Figure 4. The spatial and temporal variations of the available P and Ni content (May and June 2001.)

The erosion modeling software Erosion 2D was run for a given slope segment of the pilot plot in order to separate the areas exposed to intensive erosion (the curve is negative, results in a transportation of soils) and characterized by possible deposition and accumulation (with positive values of the curve). According to the output results, in two areas positive material transport (at a distance of 70-80 m, and 210-220 m from the base of the slope), and in one area (at a distance of approx. 160 m from the base of the slope) intensive erosion could have been predicted (about1 t/ha). The area under investigation in the model has a 100% vegetation cover composed of woodlands, excluding the possibility of significant input regarding soil particles and nutrients as well. Finally these erosion and accumulation segments determined with the help of the model were compared to the nutrient profiles of the individual segments in order to see whether the tendencies of the elements considered as indicators of erosion correspond to the findings of the model (Figs. 5.). According to our findings, it were the elements P and K, from the macroelements, and Cu from the microelements, which are characterized by a distribution pattern along the slope similar to the one predicted by the model.

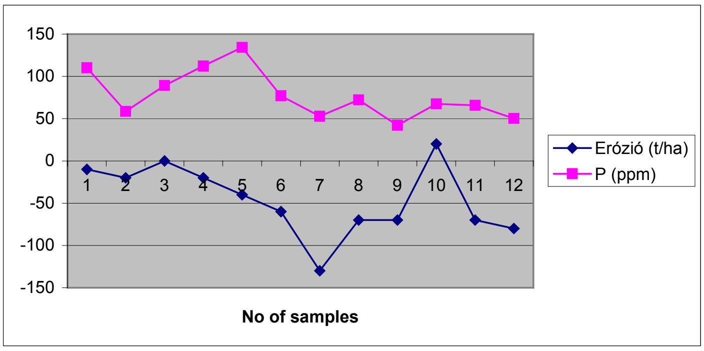


Figure 5. Variations of the P content of the topsoil and the erosion-accumulation segments along the slope (the distance between the sampling sites is 25 m) (Values indicating soil erosion are 10x exaggerated)

Via the analysis of the temporal variations of nutrient profiles for the individual segments (May 2001. – June 2003.), the following statements can be made. After a uniform nutrient supply 13 years ago (no further fertilization or nutrient supply occurred in the area afterwards) a spatial differentiation of the nutrition content of the topsoil was initiated. This resulted in an erosional transportation of non- or hardly-soluble elements (e.g. P), which are adhered to the grains, along the profile. According to the analysis of the P content for three succeeding sampling periods (Fig.6) the initial even distribution of the nutrients along the slope starts differentiating with the pass of time; namely displaying a decrease in the segments exposed to erosion and an increase in those where accumulation occurs. Following an artificial uniform upfill of the soils with nutrients, a state of equilibrium is reached as a result of the surficial processes. This varies from slope to slope and is influenced by such factors as the slope profile and other important factors influencing soil erosion.

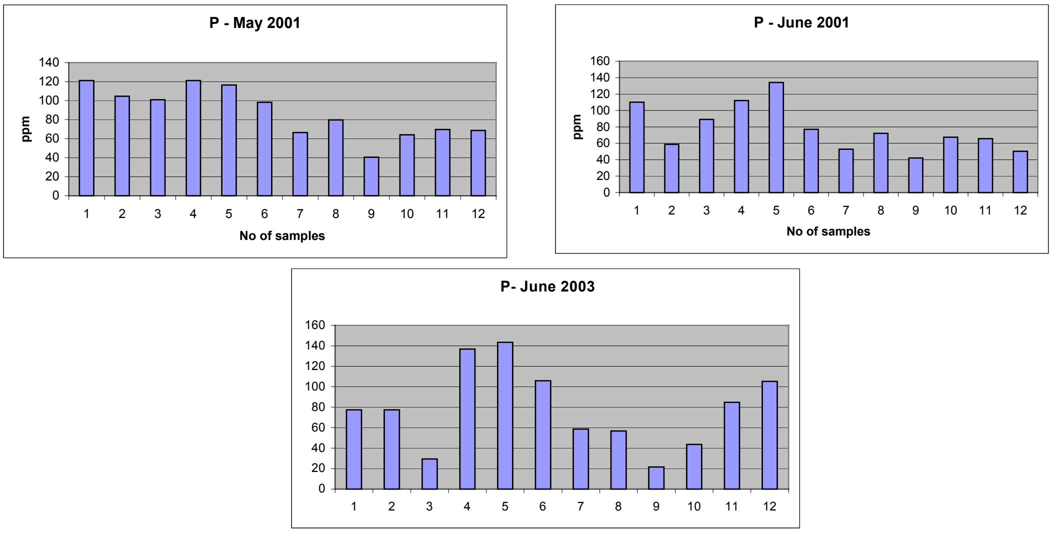


Figure 6. The temporal variations of the available P content of the topsoil along the slope between May 2001. and June 2003.

References

Bódis K., Dormány G. (2000): Land use changes of three decades in the Velence Mountains, Hungary Acta Geographica Szegediensis, Thomus XXXVII., pp.11-19.

Búzás I. (szerk.) (1988): Talaj- és agrokémiai vizsgálati módszerkönyv 2. Mezőgazdasági Kiadó, Budapest, 1988. P. 243.

Déri J. (1986): A vízgyűjtőterületi növényítakaró-változás hatásai a tápanyagok kimosódására Hidrológiai Közlöny 66. Évf. 6. Szám pp. 323-328.

Debreczeni B., Debreceni B.né (1983): A tápanyag és a vízellátás kapcsolata Mezőgazdasági Kiadó Budapest, pp. 138-159.

Duttmann R. (1999): Partikulare Stoffverlagerungen in Landschaften Geosyntesis 10 p.233.

Heathwaite L, Sharpley A., Bechmann M. (2003): The conceptual basis for a decision support framework to assess the risk of phosphorus loss at the field scale across Europe. J. Plant Nutr. Soil Sci. 2003 august., pp. 447-458.

Isringhausen S. (1997): GIS-gestützte Prognose und Bilanzirung von Feinboden und Nahrstoffaustragen in einem Teileinzugsgebiet der oberen Lamme in Südniedersachsen Diplomarbeit, Universitat Hannover, pp. 34-42.

Kádár I. (1998): Kármentesítési kézikönyv II.: A szennyezett talajok vizsgálatáról. Környezetvédelmi Minisztérium 1998. p.151.

Karászi K. (1984): A Velencei-tó rekreációja Vízügyi Műszaki Gazdasági Tájékoztató, Budapest, 1984. P.145.

Kerényi, A., Szabó, Gy. (1997): The role of morphology in enviromental pollution Zeitschrift für Geomorphologie 1997 Aug. Bd. 110. pp. 197-206.

Marosi S., Somogyi S. (szerk.) (1990): Magyarország kistájainak katasztere II. MTA FKI, Bp. pp. 684-699.

Michael, A. (2000): Anwendung des physikalisch begründeten Erosionsprognosemodells Erosion 2D/3D-empirische Ansätze zur Ableitung der Modellparameter, Ph.D. dolgozat, Universität Freiberg.

Schmidt, J. (1996): Entwicklung und Anwendung eines physikalisch begründeten Simulationsmodells für die Erosion geneigter landwirrtschaftlicher Nutzflächen, Berliner Geogr. Abhandlung.

The project was founded by the Hungarian Ministry of Education, FKFP research grant 0203/2001 and OTKA research grant F37552.

Evaluation of erosion risk at abundant heavy metal mining site

Burai, P.[1] – Tamás, J. – Kovács, E.

Abstract

The accelerated erosion resulted from heavy metal mining waste disposal, where environmental aspects are ignored, leaded to natural hazard worldwide. For the accurate spatial analysis of the erosion process at the test site near Gyöngyösoroszi a large scale digital elevation model provided the base data set. The parameters of the classical RUSLE model were evaluated in a highly detailed and integrated GIS environment. Dynamic data sources were gained from satellite, and airborne hyperspectral images. The supervised classification of the spectral features and the validation of the model calculations were carried out with GPS controlled ground and parallel laboratory measurements. At the control points, spatial heavy metal migration was also evaluated. The developed GIS of the area subjected to contamination by erosion is applicable to evaluate the risk in a quantitative way.

Introduction

Erosion is a complex, natural process that often is accelerated by such human activities as, agriculture, construction, surface mining, and urbanization. The accelerated erosion rate has both environmental and economic impacts that have resulted in extensive damage and expense. There is an increased demand for erosion control professionals to design and implement erosion control measures. Mining activities affect relatively small areas but can have a large local impact on the environment. Release of metals from mining sites occurs primarily through acid mine drainage and erosion of waste dumps and tailings deposits (Salomons, 1995; Yan and Bradshow, 1995; Szücs et al., 2000).

Recently, digital erosion modelling of contaminated media has also come into focus since several potential pollution sources, such as mine tailings, can be found in water catchment areas. In these cases, the input data include the spatial distribution of the contaminants' concentrations in addition to the basic spatial parameters, in high resolution. With the advancement of GIS technology and the widespread availability of digital data, the development of these models has become more efficient. Furthermore, the results can be exported to a GIS format and projected over the two- or three-dimensional topographic maps and terrain models for further analyses and presentation. Kertész et al. (1997) pointed out that the analysis of flood period's satellite images, and the usage of different spectral bands enhance the spatial isolation of not only water bodies, but also waterlogging areas. Dobos et al., (1997, 2000) was developped and tested an effective method to reduce te errors of hilly area's water accumulation in Hungary, by the usage of DEM, together with satellite images.

Based on a digital elevation model (DEM), the directions of potential material transport resulting from water erosion can be identified for a mine tailing and the runoff and erosion rates can be estimated by using the Smith-Wischmeier equation (Wischmeier and Smith, 1978; Morgan, 1995).

These influences are described in RUSLE with the equation:

$A = R\ K\ L\ S\ C\ P$

where: A = average annual soil loss, K = soil erodibility factor, L = slope length factor, S = slope steepness factor, C = cover-management factor, and P = supporting practices factor. A soil loss (erosion rate) in tons per acre per year is computed by substituting values for each RUSLE factor to represent conditions at a specific site.

In this study, a geographic information system (GIS) is used to integrated map field studies, remote sensing data, watershed models, and the dispersion of heavy metal mine waste.

Method

Revised Universal Soil Loss Equation (RUSLE) was applied within a raster geographic information system (GIS) to estimate erosion, sediment yield and sediment deposition from Gyöngyösoroszi. This erosion model was generated in Geo Information environment for a site in North Hungary, Gyöngyösoroszi where nearly 7 Mm^3 of heavy metal (Pb, Zn, Cd, Cu, Ni, As) rich mining waste was abandoned in 1989. The mine waste is partly under water, lakes are located on three stages of the tailing and to some extent the tailing is covered with inert coarse material and vegetation, but not the slopes. As a result, the fine mining waste can easily be eroded contaminating the surrounding areas. Geospatial landscape data were derived in situ measurments, hiperspectral remote sensing technologies.

[1] University of Debrecen, Centre of Agricultural Sciences, Department of Water and Environmental Management, H-4032 Debrecen, Böszörményi út 138. Hungary. Tel/Fax: +36 52 508 456, E-mail: pburai@gisserver1.date.hu

There were high scale maps (1:1,000) and topographic maps (1:10,000) available from the area of the mine tailing and its surroundins. In addition, high scale maps were available from the time previous to the installation of the mine tailing, thus DEM could be generated about the conditions of the year 1955 (Figure 1).

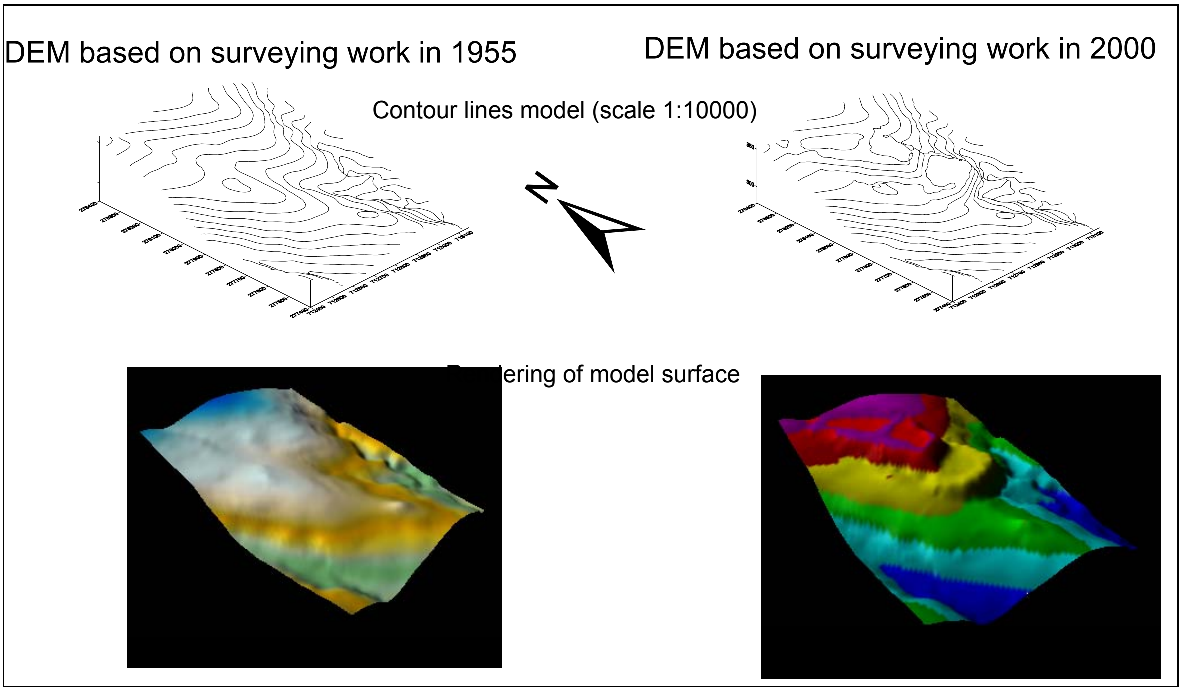


Figure 1. DEM from case study area

Vegetation map of this are was computed by remote sensing data. We compared aerial hyper and multispectral images, with the background data from the test site. Hyperspectral records were obtained using a new 80-channeled aerial spectrometer (Digital Airborne Imaging Spectrometer /DAIS 7915/. Survey on present topographic conditions was refined with conventional geodetic tools as well as DGPS measurements. Basic data of the digital model were prepared and processed with the softwares ERDAS 8.6, Surfer8, Idrsisi32, and ArcGIS. RUSLE model was calculated with the program Idrisi Kilimanjaro

Results

L (slope length factor) and S (slope steepnes factor) devalues were calculated from the DEM. For the evaluation of the total impact of the studied mine tailing on its environment resulting from water erosion the potential runoff directions should be considered (*Figure 2*).

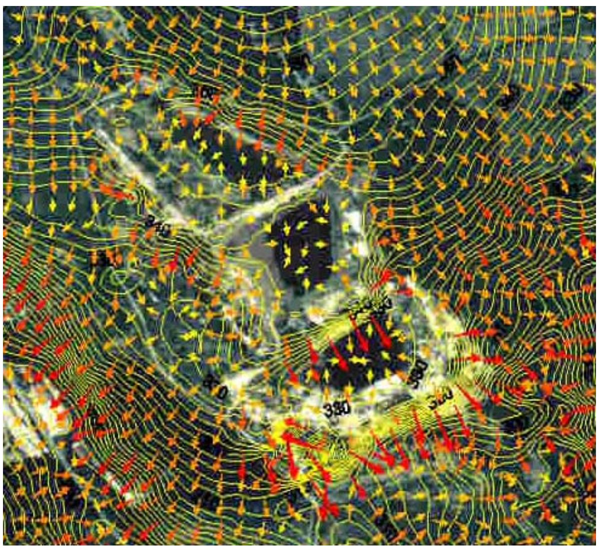


Figure 2. Studied area - runoff directions of the mine tailing

K value were calculated on the basis of soil maps and measured soil properties, while C value were calculated from remotely sensed data. For the caluclation of C, channels in red (RED) and near infra (NIR) spectral ranges of the hyperspectral data were considered, the reflectance of which is good correlation with the vegetation cover. At the sudy area, land use includes mainly deciduous forest, shrub associations, and degraded forest (Figure 3.).

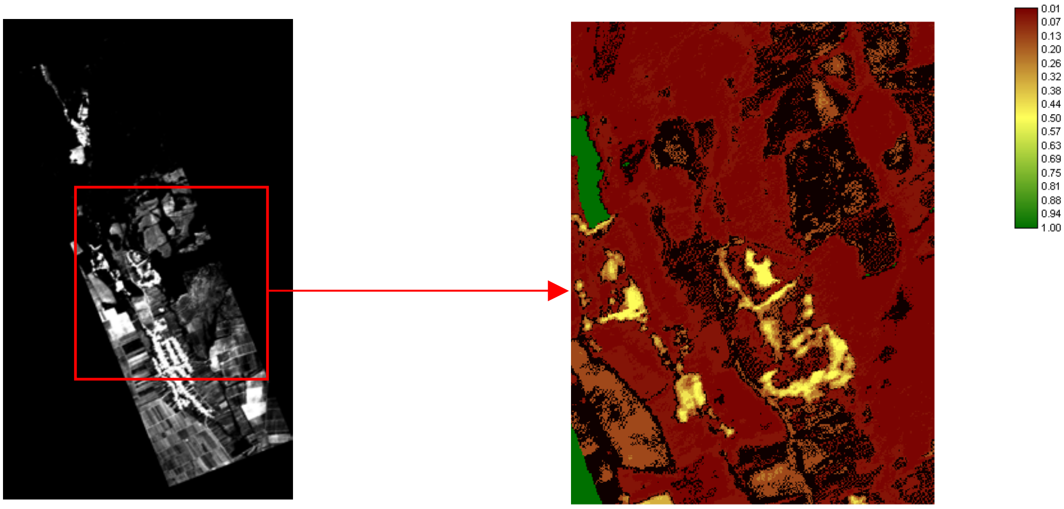


Figure 3. C factor map is calculated remote sensing data

The P factor (conservation practice factor) was not relevant to the study area and therefore calculated as value = 1, which does not influence the output of the model. Besides the above mentioned data sources, other measured parameters can also be used for the generation of the model.

Conclusions

Using a digital terrain model, areas where erosion probability is high can easily be identified. The RUSLE applied in GIS environment provides information on the extent of the erosion risk for any discrete point of the area. In case of the Szárazvölgyi mine tailing, the contamination maps created from heavy metal concentration data representative to the surface can also be incorporated to a contaminant transport model, with the consideration of the contaminant transport processes. The model results identify non-point sources and sink trace-metal bearing sediment.

References

Desment, P. and Grovers, G., (1996). A GIS procedure for automatically calculating the USLE LS factor on topographically complex landscape units. Journal of Soil and Water Conservation, 51 (5), pp. 427-433.

Dobos E., Micheli E. M. F. Baumgardner, Larry Biehl, Todd Helt, (2000). Use of combined digital elevation model and satellite radiometric data for regional soil mapping. Geoderma. 97: 367-391.

Dudka, S., Adriano, D.C., (1997). Environmental impacts of metal ore mining and processing: A review. *J. Environ. Qual.*, 26, 590-602.

Hickey, R., (2000). Slope Angle and Slope Length Solution for GIS. Cartography, v. 29, no. 1, pp. 1-8.

Kertész, Á., Márkus, B., Tózsa, I., (1997). Land Use Change Analysis by GIS. In Land Use and Soil Management, Edited by Filep, Gy., Debrecen, pp. 265-283

Morgan, R.P.C., (1995). Soil Erosion & Conservation. 2nd Ed. Longman. 63-83.

Renard, K., Foster, G.R., Weesies, G.A., Porter, J.P., (1991). RUSLE Revised universal soil loss eguation. Journal of Soil and Water Conservation, 46, 30-33.

Salomons, W., (1995). Environmental impact of metals derived from mining activities: processes, predictions, prevention. *J. Geochem. Elxpor.*, 52(1-2), 5-23.

Szücs A., Jordán Gy., Qvarfort, U., (2000). Integrated modelling of acid mine drainage impact on a wetland stream using landscape geochemistry, GIS technology and statistical methods. In: Fabbri, A. (ed.), Deposit and Geo-environmental Models for Resource Exploitation and Environmental Security. NATO ASI Series Book. Kluwer Academic Publishers.

Wischmeier, W.H., Smith D.D.: (1978). Predicting rainfall erosion losses. USDA Agricultural Research Service Handbook 537.

Yan, G., Bradshaw, A.D. (1995). The containment of toxic wastes: II. Metal movement in leachate and drainage at Parc Lead-Zinc Mine, North Wales, *Env. Pollut.*, 90(3), 379-382.

Zoom effect on soil data for soil erosion evaluation in a small mediterranean basin using GEOWEPP

Regoyos, M.[1] – Casermeiro, M.A. – Espluga. A. – Otero. I. – García. A. – Hernando, M.I. – de la Cruz, M.T. – Molina. J.A.

Introduction

Soil erosion is one of the most important environmental problems especially in soils that have developed in a Mediterranean type of climate. The calculation of sediment yield is of key importance for decision makers and land owners. In this context, the use of specific software together with the Geographic Information System could be considered a standard solution.

Soil data are among the key factors in calculating sediment yield and historically has been assessed from different points of view by different models. Thus USLE (Wischmeier and Smith, 1965) introduced the factor K which represented mainly texture. LISEM (De Roo et al., 1994) uses aggregate stability, rocky content, crust formation facility, infiltration, etc. KINEROS (Woolhiser et al., 1990) utilizes the infiltration and humidity of the soil. Finally, WEPP (Alberts et al., 1995) uses texture, organic carbon, cationic, interchange capacity, porosity, depth and others.

Geowepp is the SIG application of WEPP and allows soil erosion to be estimated in small plots and catchments. This program allows specific data files on climate, soils, topography and land management characteristics to be introduced. The soils data are the same as in WEPP.

The objective of this study is to evaluate the importance of soils data in relation with other variables and the scale of study.

Materials and methods

The case study area (1400 ha) is part of catchments of the Guadalix River in the hydrological basin of Tajo river Madrid Spain. Geologically this area is characterised by Miocene sediments sands (Tertiary detritic), known as *facies Madrid* or *arcosas.* .(IGME, 1980). The climate is Mediterranean pluviseasonal oceanic (Rivas-Martinez, 1997) with an annual average precipitation of 498 mm. The land use is natural rangeland devoted to cattle grazing. There is evidence of rill erosion.

Thirteen sub catchments were defined using a raster Digital Elevation Model of 50 m^2 of pixel . In every sub-catchment (average surface 11 ha) soil samples were collected following the recommendation of the FAO (F.A.O., 1977) Soils analysis includes: soil particle distribution, pH, electrical conductivity, organic carbon, cation exchange capacity, humidity, porosity, bulk density and mineral density (I.S.R.I.C., 1993), (Smith and Mullins, 1991) .

Two scenarios were defined. First, the soils were considered homogeneous and one soil sample was used. Second, the area was divided into 13 subareas, and one soil sample was used in every sub-catchment

Runoff, sediment loss, and sediment yield were calculated in both scenarios by two different calculation methods (Watershed and Flowpath) using GEOWEPP. The conditions for the simulation are the following: Digital Elevation Model (grid $50m^2$); critical source area, 150ha; minimum source channel length, 500 m; land condition, grass.

Results and discussion

The soil (Table 1) belonged to sand or loamy sand textural classes, with a high value for coarse sand (average 86.4) and a low value for clay (8.7). It also presented low values for organic carbon (average 0.42 %), while it showed intermediate values for cation exchange capacity. The rocky content inside the soil profile was low (average 5 %) due to the geological origin of the parent material. These soils were very homogeneous in the different sub-basins and were classified as Dystric Arenosols (FAO, 1998)

Two different methods (watershed and Flowpath) for the calculation of runoff, soil loss and sediment yield were used with GEOWEPP software (Table 2).

Differences existed between the scenarios as well as the calculation method. Runoff volume, soil loss and sediment yield decrease in scenario 2, (Table 2) (Figure 1), in which more soil data were used. This data suggest high sensitivity of the software package in areas in which the soil loss is very low (less than 12.44 tonne ha^{-1} yr^{-1} in the worst case). If we focus on the calculation method, the watershed method shows higher values than the Flowpath method. These data are explained by Flowpath showing higher sensitivity to runoff and soil loss.

[1] Projects and Rural Planning Department. Universidad Politécnica de Madrid. E.T.S.I. Agronómos. E-28040. Madrid. Spain. Tel.: +913365837; E-mail: mregoyos@ppr.etsia.upm.es

In any case the differences between scenarios are lower than expected, which could be explained by the relative weight of climate compared with other soil variables and also by the great homogeneity of the soil data in the case study area.

Nevertheless the values for soil loss and sediment yield are very low, almost nil. These data do not agree with field observation. These data suggest the importance of the type of flow chosen in this case: Hortonian overland flow or Saturation Overland Flow (KIRBBY, 1999). However, GEOWEPP uses the Green-Ampt model for the infiltration calculation, which is more appropriate for semiarid environments like the case study and mainly is related to Hortonian Flow. Future research will allow the efficiency of GEOWEPP use in Mediterranean areas to be tested.

Table 2. GEOWEPP output calculation data

WEPP simulation method	Scenario 1		Scenario 2	
	Watershed	Flowpath	Watershed	Flowpath
Runoff volume (m^3/yr)	205494.5	94526.07	156623.2	59641.16
Soil loss (tonne/ha)	322.92	518.62	252.11	381.58
Sediment yield (tonne/yr)	322.33	0	251.82	0
Area (ha)	1443	1443	1443	1443
Soil loss (tonne/ha/yr)	12.44	11.64	10.77	9.19
Sediment yield (tonne/ha/yr)	12.44	0	10.77	0

Figure 1. Sub basin of the study area, sediment yield of Scenario 1 and 2.

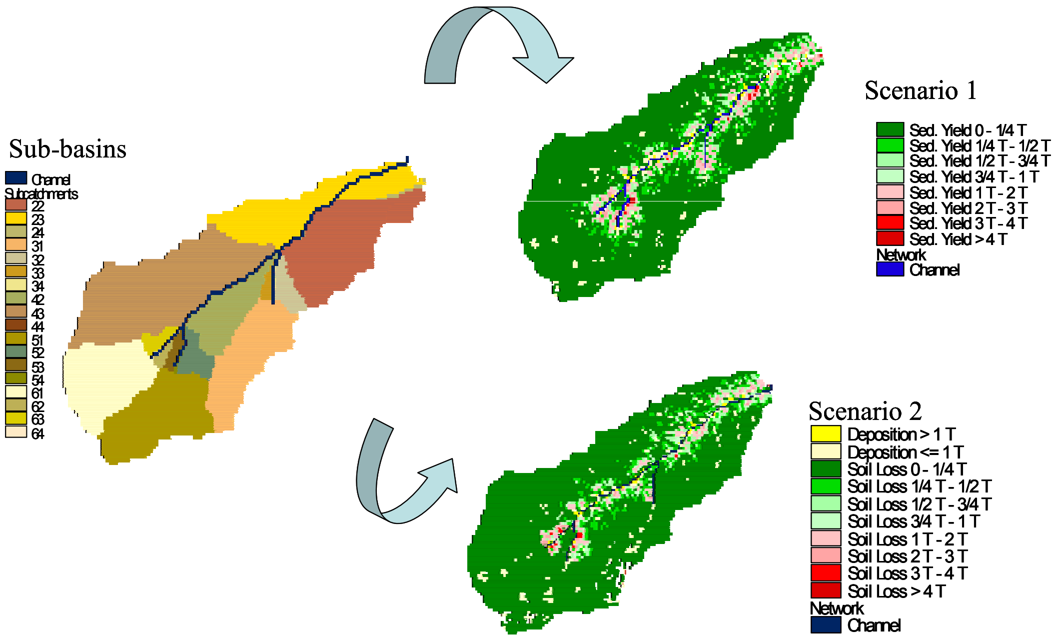


Table 1. Soil main Features

Sample	Depth cm	Textural Class	Particle Size distribution %			Organic Carbon %	Organic Matter %	CEC (meq/100 g)	Rocky content %	pH	Bulk density Mgm^{-3}
			Sand	V.Fine Sand	Clay						
1	0-4	SAND	87.4	2.59	8.6	0.72	1.24	21.40	2	6.56	1.41
	4-30	SAND	86.8	2.55	9.0	0.70	1.20	10.70	5	5.99	
	>30	LOAMY SAND	84.4	2.65	10.9	0.35	0.60	12.99	5	5.43	
2	0-2	LOAMY SAND	82.3	3.40	13.5	0.76	1.31	16.05	5	6.30	1.24
	2-30	LOAMY SAND	81.7	2.64	14.5	0.60	1.03	13.75	5	5.62	
3	0-30	LOAMY SAND	86.1	2.12	10.7	0.16	0.28	17.57	2	5.32	1.46
4	0-5	SANDY LOAM	76.4	3.03	18.8	0.49	0.84	23.69	5	5.47	1.34
	5-20	LOAMY SAND	87.8	1.33	10.2	0.78	1.34	22.92	3	5.68	
	20-30	LOAMY SAND	80.2	2.55	14.9	0.32	0.55	11.64	5	5.36	
5	0-2	LOAMY SAND	85.7	3.78	10.9	0.36	0.62	21.40	5	6.74	1.33
	2-22	LOAMY SAND	83.8	2.71	11.5	0.54	0.93	9.93	6	6.88	
	>22	SAND	88.5	5.50	6.7	0.35	0.60	9.17	5	6.18	
6	0-30	SAND	83.7	7.23	5.9	0.19	0.33	7.64	5	5.70	1.62
7	0-3	SAND	89.8	3.80	5.9	0.58	1.00	14.52	5	6.19	1.40
	3-30	SAND	89.2	2.61	8.5	0.40	0.69	12.99	5	6.28	
	>30	SAND	86.0	3.29	9.8	0.24	0.41	11.46	5	6.18	
8	0-8	SAND	88.8	1.63	4.9	0.29	0.50	10.70	5	6.25	1.24
	>8	SAND	87.2	2.70	4.0	0.34	0.58	9.17	5	6.80	
9	0-5	SAND	84.8	3.44	10.0	0.62	1.07	17.58	5	6.23	1.41
	5-30	LOAMY SAND	81.9	4.11	10.5	0.37	0.64	11.46	10	5.54	
10	0-30	SAND	90.8	2.50	6.2	0.21	0.36	6.88	2	5.08	1.59
11	0-30	LOAMY SAND	80.6	4.19	11.0	0.21	0.36	8.41	4	5.77	1.48
12	0-30	SAND	89.3	4.95	4.3	0.49	0.84	12.23	5	5.86	1.37
13	0-10	SAND	92.3	2.82	2.3	0.28	0.48	12.23	5	6.23	1.41
	>10	SAND	91.7	2.30	2.6	0.17	0.29	10.70	5	5.50	
AVERAGE			86.4	3.20	8.7	0.42	0.72	13.20	5	5.99	1.4
STD			4.073	1.18	3.857	0.20	0.34	4.31	0.1	0.45	0.1

Conclusions

1. The soils in the study area are Dystric Arenosols.
2. No significant differences were observed in the two scenarios studied, which could be due to the homogeneity of the soil in the watershed studied.
3. By raising the detail level, to include more soil data, the loss of soil diminishes, which implies a high sensitivity for the model.
4. The data obtained with GEOWEPP do not agree with significant erosion phenomena observed through field observations.

Acknowledgement

This research is sponsored by a grant (07M/0006/2002) from the III research programme of the Comunidad Autonoma de Madrid.

References

Alberts, E.E. et al., 1995. Chapter 7. Soil Component. In: USDA-ARS-MWA (Editor), USDA-Water Erosion Prediction Project (WEPP). NSERL report nº 10, West Lafayette, pp. 7.1-7.47.

De Roo, A.P.J. et al., 1994. LISEM: a new physically-based hydrological and soil erosion model in GIS-environment: Theory and implementation. IAHS publication nº 224 (Proceedings of the Canberra Conference), 439-448 pp.

F.A.O., 1977. Guía para la descripción de perfiles. FAO, Roma, 60 pp.

FAO, I.a.I., 1998. World reference base for soil resources. FAO, Roma.

I.S.R.I.C., 1993. procedures for soil analysis. ISRIC, Wageningen.

IGME, 1980. Mapa geológico de España Hoja, Madrid.

KIRBBY, M., 1999. From Plot to Continent: Reconciling Fine and Coarse Scale Erosion Models. In: D.E. Sttot, R.H. Mohtar and G.C. Steinhardt (Editors), Sustaining the Global Farm, pp. 860-870.

Rivas-Martinez, S., 1997. Syntaxonomical synopsis of the potential natural plant communities of North America, I. Itinera Geobotánica, 10: 5-148.

Smith, K. and Mullins, C.E., 1991. Soil analysis physical methods. Marcel Dekker Inc.

Wischmeier, w.H. and Smith, D.D., 1965. Predicting rainfall-Erosion Losses from Cropland East of the Rocky Mountains. USDA Agricultural Handbook nº 282, Washington.

Woolhiser, D.A., Smith, R.E. and Goodrich, D.C., 1990. KINEROS a Kinematic Runoff and Erosion Model: Documentation and User Manual. USDA_ARS, 77.

ErosPredict –a model for predicting water erosion in Denmark

Djurhuus, J.[1] – Højsgaard, S. – Heckrath, G. – Olsen, P.

In Denmark water erosion is not a general problem from the farmers' point of view. However, erosion is a potential problem for the aquatic environment, mainly due to loss of phosphorus. Thus, an expert system for predicting water erosion in Denmark was established on the basis of data collected in Denmark during the period 1994 to 1999. The data were collected from fields at local farms. A field was defined as uniformly cultivated, and about 75% of the observations were from fields below 7.5 ha. For each field rill erosion was measured in late autumn and in spring. In total there were 1041 observations, of which 213 had erosion. The figures for erosion were highly right-skewed with a 75% quantile of 1.49 m^3 ha^{-1}, and with a maximum value of 28.4 m^3 ha^{-1}. The data include the following cultivation systems: grain (winter wheat and winter rape), Christmas trees, ploughed, stubble harrowed, grass and stubble field. Erosion was never recorded for fields with grass and stubble fields. The expert system consists of three parts, one model that predicts the probability of erosion, another part that predicts the amount of erosion, given that there is erosion, and a third model that predicts the soil surface roughness, given as Mean Upslope Depression (MUD). The amount of erosion is then estimated by combining the probability of erosion with the amount of erosion, given that erosion had occurred. The probability model includes the following variables: cultivation system, aspect, water impermeable layer (yes/no), soil type (clay + fine silt), precipitation and snow melting on frozen soil, days with precipitation above>20 mm, 99% quantile of a two-dimensional LS factor, and MUD. The model for erosion given that there is erosion includes: cultivation system, water impermeable layer (yes/no), soil type (clay + fine silt), accumulated precipitation for days with precipitation above 8 mm and the mean of the two-dimensional LS factor, whereas the model for MUD includes: cultivation system, soil type (clay + fine silt) and days with precipitation above>20 mm. The expert system can be used to spot areas where erosion is a potential problem for the aquatic environment and to suggest measures for reducing erosion.

[1] Danish Institute of Agricultural Sciences, Department of Agroecology, Research Centre Foulum, P.O. Box 50, DK-8830 Tjele. Telephone: +45-89-991-900; Telefax: +45-89-991-919; E-mail: jorgen.djurhuus@agrsci.dk

The First Large Scale Digital Elevation Model of the Upper Catchment Area of Barcau-Berettyó river basin

Josan, N. – Nistor, S.[1]

Abstract

In many parts of the world the cross-border rivers rises a lot of problems, the ecological, water resources management, pollution and erosion problems being the most important of them. The romanian authors aim was to create the Digital Elevation Model of the Barcau-Berettyó river basin.

The first step of the project was the elaboration of the relief map for the upper catchments area of Barcau-Berettyó river (the Romanian side). The hydrological erosion modelling is a crucial and vital step in the DEM model elaboration. The steps which were followed during the realisation of the project started with analysing the topographical maps and using different techniques and analysing the obtained results finally lead to the maps of the relief.

The outstanding characteristic of this project is given by its oneness: it is the first GIS using project ever made having this space resolution which deal with a cross-border river. The results which were obtained and will be obtain during the further stages of the international research work will have a crucial importance not only in hydrological erosion and landscape management aspects but on other fields of cross-border cooperation such as regional development, environmental protection.

Intoduction

The aim of this project was given by the idea that rivers, in this case the Barcau-Berettyó river, has no border so that the study of the river must take into account primarily this aspect.

Geographical Information Systems are increasingly used for capturing and manipulating large volumes of data required during modelling fluvial system. In particular, using GIS as a platform for hydrological modelling has received much attention (reviwed by Maidment, 1993), especially with respect to process-based distributed models (Gao et. Al., 1993), although there continue to be frequent calls for greater integration of environmental models, including those for fluvial systems, and GIS (Fedra, 1993, Nemani et al. 1993). The integration of remotely-sensed data can provide gridded maps of many parameters such as land cover and other hydrologically important variables (Schulz, 1993, Winkler, 1993). Dobos et al., (2000) was developed DEM to test water accumulation and Kertész et al., (1997) carried out analysis with satellite images to detect land use change in Hungary. Using vector data for parameter estimation is less common, although Bhaskar et. al. (1992) have employed vector river networks to calculate drainage density.

The first stage of the GIS implementation was to translate the model requirements into a series of digital data sets which allowed the necessary parameters to be divided. Tamás et al., (1997, 2002) Tamás and Lénárt (2003) HydroGIS results in Hungary, was taken as a bases the lower watershed to develop our large scale GIS logical data model.

The data acquisition was made using both vector and raster materials. The reasons which determined the authors to deal with such a task were numerous: the existence of topographical paper maps and the current use of them is, in authors believe, a major problem in cross-border study of Barcau-Berettyó river system. Taking into account that the frequency of re-printing new topographical paper maps is, in both countries, 10-15 years, the impossibility of interactive using of data contained by paper maps were just some reasons for the starting of the project.

The benefits of the project are of short and long term. The short term benefits are represented by the possibility of interactive using of the data, the compatibility with other data sources, the refreshing of data base becomes faster and easier and, not at least, the precision of the analyse is higher than in the other case. The next step in a short term could be the improving of data base with other elements of the system such as digital form of vegetation cover, land use, climatic data, human aspects. The interactive data base which is to be establish give the possibility of a general analyse of the environment, allow the possibility of taking fast and correct decisions for the problems of the area.

Materials and Tools

The materials used for the project were the colour topographical maps with contour lines at 1: 50 000 scale, the distance between contour lines being 10 m., the altitudes being related to the Baltic Sea base level.

The project was made in several steps these being the following:

[1] University of Oradea, Romania, Str. Armatei Romane nr. 5, 410087 Oradea, Tel/fax.+40-259-408111; +40-259-408105

Step 1. For assembling the scanned maps was used the Corel Photo Paint version 8 programme, all 72 pieces of scanned maps being assembled into final form resulting 16 complete colour topographical maps which represent the whole catchment area of Barcau river (the Romanian side). One of the major problem in using the dissimilar data was the incompatibility of the Hungarian and Romanian geometrical data systems and cartography model. From the different projection of the topographical maps (EOV, UTM, Gauss Krüger) to the incompatibility of data storing systems represented major problems which must be solved. The projection of the Romanian side' s maps are Gauss-Krüger and for integrated GIS environment the maps were transformed into a UTM projection.

Step 2. The assembled topographical maps were then registered and rectificated using ArcInfo User 7.2.1 (ArcTool) version software programme. The operation was necessary for putting into correct coordinates of the maps which is vital for the precision of the following steps made during the project.

Step 3. It was the digitization operation. This operation was made using ArcView GIS version 3.1 software programme and during this operation was digitized the hydrographical network, the contour lines and the altimetric points. The digitization of the hydrographical network was made dividing it into two main categories for the spatial pattern hydrological analysis: permanent flows and periodic flows followed by Tamás (1999, 2000, 2003) scientific recommendations for data integration.. Although not all the periodic flows were represented on the topographical maps there were digitized based on the inflexions of the contour lines. The most common method of acquiring elevation data in digital raster format is digitizing contours from a topographic map and applying an interpolation method to transform the contour data into a DEM. Aumann et al. (1990) and Pilouk et al. (1992) described procedures for the automatic detection of skeleton information for digitized contour maps to improve the DEM. Makarovic et al. (1988) advocate the use of selective sampling techniques to improve the DEM.

The digitization of contour lines was made according to their altitude. Thus the digitization was made dividing the contour lines according to their altitude obtaining 14 categories of elevation (100m., 150m., 200m., 250m., 300m., 350m., 400m., 500m., 550m., 600m., 650m., 700m., 750m., 800m.,). The digitization was made just for the normal contour lines thus the altimetrical difference between two consecutive contour line was 50 meter.

The digitization of the altimetric points was made for each quadrangle of the topographical maps.

Step 4. The conversion of the digitized contour lines into vertex points. After transforming all the digitized contour lines into points a script programme was made in order to give for all the points resulted from contour lines and for the points resulted from digitizing the altimetric points the proper polar coordinates. All the points, with their elevation values and coordinates, were introduced into a table under Microsoft Excell programme.

Step 5. The next step was a Digital Elevation Model (DEM) construction from the Barcau river basin.

There are three principal methods for representation of topography using a network of elevation data, namely grid-based networks, contour-based networks, and Triangulated Irregular Networks, or TINs (Moore et al., 1991). Because there is not available earlier GIS scientific analysis on this site, Tamas (2001, 2003) method used to GIS data integration and conversion to support spatial decision. We conclude based his method that grid-based model are the most common forms of Digital Elevation Models used by many researchers for topographic modelling and analyses of a river basin, but in our case the raster are not appropriate for dynamic hydrological modelling because they cannot represent various shapes of mountain slopes such as topographic convergence, divergence, convex or concave.

The automated interpolation methods based on stereo comparison yield continuous surfaces, although in a discretized form. The other forms of data input consists of sampled data and these require either interpolation to obtain to obtain a continuous surface in the case of grid structure or a triangulation method for the TIN structure. The triangulation method generally starts with a point file, but there are also programmes which use digitized contour input is even grid input. If relief was analyzed on the basis of iso-line, DEM showed virtually flat area on under sampled locations. We used, Tamás et al. (2004) applied methods in IDRISI environment, to optimize the constrained triangulation and removing over- and underestimated (Brige /Tune) edges. Based on publication the parabola, as a second-order non-linear polynomial method,was chosen to combines a B/T edges of critical points to re-Triangulation.. The topographic surfaces, the sharp brakes of the angular TIN landscape are eliminated by draping more rounded forms using filtering techniques. After this step the TIN data structure can describe more properly the-continuous-surface consists of triangular facets. Within the converted raster structure, an irregular network of points (as derived by digitizing contours and skeleton information from a toposheet) need to be interpolated to form a semicontinous surface. The term 'semi' is used becouse the surface split up according to the raster size chosen. The center of the cell are considered to be samples of the continuos function, but in fact the raster data set constitutes a step function.

The interpolation problem has attracted much attention and several schemes are in use in the various packages. The deterministic approach attempts to fit a type of surface through a set of sampled (z) values at known x, y coordinated. If the data points are regarded as true values of the variable at the sampled location, an exact scheme is required. A smoothing scheme may be selected if it is known or believed that there is considerable measuring error.

The selected geostatistical methods approaches depend on whether or not the spatial data may be considered as having random variation. The estimation of spatial mean within a given area depends on sample size and the inclusion probability of a sample. The theory is discussed in the so-called design-based methods of the classical sampling theory.

Each interpolation, as predictive method, has its own advantages and weaknesses. The choice of interpolation method depends primarily on the nature of the variable and its associated spatial variation, although there are other influences. Among the deterministic methods worth to be mention polynomial interpolation methods (the piecewise polynomial interpolation), the linear interpolation, cubic and bi-cubic interpolation, pointwise interpolation, windows.

Tamás (1998, 2001), Tamás and Búzás (2003) demonstrated via agriculture and remediation examples that the deterministic interpolation schemes have several limitations of DEM. Authors emphasized the spatial correlation properties within the data set which are not taken into account in deterministic schemes. The distances are considered geometric distances, not in statistical sense. Also considered limitation in these study, is given by the fact that the method do not take into account the uncertainties associated with the interpolation. The kriging methods provide measures of reliability of the DEM estimates. Tamás and Lénárt (2002) demonstrated that Kriging as a spatially optimized weighted gridding method, produced visually and physically appealing risk DRASTIC maps from irregularly 3D space data to prevent groundwater pollution in Debrecen aquifer.

The kriging procedure starts with an exploratory analysis of the spatial nature of the data. The data set may be inspected by contouring using a simple linear or inverse distance interpolator to check for the presence of trends. Subtraction of a mean before contouring could assist the visual inspection. In case of isotrophy the omnidirectional experimental semi-variogram can be made of the entire data.

If the semi-variogram are judged to be free of complications, one may then decide whether to use a stationary or non-stationary model. This choice should not only be based on examination of the semi-variogram but also on the knowledge of the spatial continuity of the variable. A digital terrain model (DTM) includes the spatial distribution of terrain attributes. A digital terrain model is a topographic map in digital format , consisting not only of a DEM, but also the type of land use, settlements, types of drainage lines and so on. The DTM model was further improved being the base of other special maps such as the map of direction of runoff water, the map of slope exposition and important part of the erosion model.

Conclusions

Coincidently with Moore et al. (1993) we declare the raster based digital elevation model (DEM) can not handle exactly abrupt changes in elevation easily and they often skip important details of land surface mainly in plain area. The main advantages of our TIN DEM GIS techniques can be enumerated as follows: a large number of variables and complex interactions can be accommodated with lower computer storage capacity; data storage is standardised (reference, features, cartography); the simulation/modelling language can be a means of communication ideas; models can be continuously updated and modified; the modelling process identifies particularly important inputs to each modelled system.

Acknowledgement

It would have been impossible for the authors to put the bases of the research without the help of international CEEPUS Programme and also the useful and unselfish scientific help and cooperation of Hungarian Academic Partner namely Dr. János Tamás and his staff at Department Water and Environmental Management, University of Debrecen.

References

Aumann G., H. Ebner and L Tang, (1990) Automatic derivation of skeleton lines from digitized contours. Int. Archives of photogramm. and Remote Sensing, vol. 28, Tsukuha, pp. 330-337.

Bíró T., Tamás J. (2002) Modelling of contamination events in the hungarian section of the Berettyó river In: Analele Universitátii din Oradea. Fascicula Agricultura, I.S.S.N. 1-7.

Bhaskar, N.R., James W.P., Devulapalli R.S. (1992) Hydrologic parameter estimation using Geographic Information System, J. Wat. Resour.. Planning and Management ASCE 118, pp. 492-512.

Burrough P.A. (1993) The technological paradox in soil survey: new methods and techniques of data capture and handling, ITC Publication, number 21, pp. 15-22.

Cressie, N.A.C. (1991) Statistics for Spatial Data, John Wiley and Son, Inc., New York, 900 pp.

Dobos E., Micheli E. M. F. Baumgardner, Larry Biehl, Todd Helt, (2000) Use of combined digital elevation model and satellite radiometric data for regional soil mapping. Geoderma. 97:367-391.

Kertész, Á., Márkus, B., Tózsa, I. (1997) Land Use Change Analysis by GIS. In Land Use and Soil Management, Edited by Filep, Gy., Debrecen, pp. 265-283

Fedra K. (1993) GIS and environmental modelling, in Environmental modelling with GIS, (ed. by M.F. Goodchild), Oxford University Press, Oxford, pp. 35-40.

Gao, X., Sorooshian S., Goodrich D.C. (1993) Linkage of a GIS to a distributed rainfall-runoff Model, Environmental Modelling with GIS (ed. by M.F. Goodchild) Oxford University Press, Oxford, pp. 182-187

Isaak, E. H., Srivastava, R. M. (1989) An introduction to Applied Geostatistics, Oxford University Press, New York, 561 pp.

Maidment, D.R.. (1993) GIS and hydrologic modelling, in Environmental modelling with GIS, (ed. by M.F. Goodchild), Oxford University Press, Oxford, pp. 147-167.

Makarovic, B. and A.M. Thuladmar, (1998) Upgrading DTMs from contour lines photogrammetric selective sampling. ITC Journal 1988-4, 339-344.

Meijerink, A.M.J., de Brouwer H.A.M., Mannaerts C.M. (1994) Introduction to the use of Geographic Information System for Practical Hydrology. ITC Publication, number 23 pp.107-109, pp. 114-153.

Moore, I.D., Grayson, R. B. (1991) Terrain-based catchment partitioning and runoff prediction using vector elevation data. Wat. Resour. 27(6), pp. 1177-1191.

Moore, I.D., J.C. Gallant and Guerrra L. (1993) Modelling the spatial variability of hydrological processes using GIS in: Application of GIS in Hydrology and water resources Management. Proceedings of Vienna Conference, April 1993. IAHS publ No 211. pp. 161-169.

Nemani, R., Running S.W., Brand L.E., Peterson D.L. (1993) Regional hydrogeological simulation system: an illustration of the integration of ecosystem models in a GIS, in Environmental Modelling with GIS (ed. by M.F. Goodchild) Oxford University Press, Oxford, pp. 297-304.

Pilouk, M. and K. Tempfli (1992) A digital image processing approach to creating DTMs from digitized contour, I.S.P.R.S. XVIIth Congress, Commission IV, Int. Arch. Photogramm. and Remote Sensing, Vol XXIX, Part B4, pp. 956-961.

Priestnal G., Downs P.W. (1996) Automated parameters estimation for catchment scale river channels studies: the benefit of raster-vector integration, Application of Geographic Information Systems in Hydrology and Water Resources Management, IAHS Series of Proceedings and Reports, No 235, pp. 215-223.

Schultz, G.A. (1993) Applications of GIS and remote sensing in hydrology. In Application of geographic Information System in Hydrology and Water Resources Management (ed. by K. Kovar and H.P. Nachtnebel) IAHS Publ. Number 221, pp. 145-154.

Tamás J., Lénárt Cs. (1997) GIS tools and solution in water and groundwater management systems-An environmental protection perspective. Environmental Problems and Solution, Wageningen University EJC, 58-72.

Tamás J., Juhász Cs. (1997) Simulation of hidrological limiting conditions based on integrated computer models In: Nagy, J.(eds.) Soil, Plant and Environment Relationships, Current plant and soil science in agriculture. Hungary173-186.

Tamás J. (1998) Application of Geographical Information Systems to Characterise Polluted Sites. In: Czudra K. und Szabo I. (Hrsg) Abfallentsorgung und Altastensanierung. Schriftenreihe Angewandte Geologie Kartsruhe 77-92.

Tamás J. (1999) Analysis of uncertaintinity in the design of sampling strategy In: Analele Universitatii din Oradea, Fascicula Agricultura si Horticultura 5. 7-14.

Tamás J. (2000) Térinformatika I-II. Kiadó. Debreceni Egyetem. 1-399.

Tamás J. (2001 Precíziós Mezőgazdaság Kiadó: Mezőgazdasági Szaktudás. Budapest1-144.

Tamás J., Lénárt Cs. (2002) Using geoinformatics in regional environmental modelling In: Proc. Annual Conference of the International Association for Mathematical Geology. Berlin. 495-500.

Tamás J., (2003) Problems and solutions of field scale agro-ecological data acquisition and data interpretations in agroinformatical domain Applied Ecology and Enviromental Research, International Scientific Journal, Budapest. (1-2):143-159.

Tamás J., Buzás I., (2003) Spatial analysis of point datasets to explore sugar beet variability In: Proc. 14th International Symposium of Fertilizers, Debrecen, Hungary, Volume I. 636-647.

Tamás, J., Lénárt, Cs. (2003) Analysing of small agricultural watershed with remote sensing technics1st. International Conference, Studying land use effects in coastal zones with remote sensing and GIS. NASA -LCLUC Program, Turkey35-45.

Tamás J, Takács P, Juhász Cs (2004) Integrated field scale water management technology In: Proc. III. Alps-Adria Scientific Workshop, Dubrovnik, Croatia112-117.

Tachikawa, Y., Takasao T., Shiba M. (1996) TIN-based topographic modelling and runoff prediction using a geomorphic informational system, Application of Geographic Information Systems in Hydrology and Water Resources Management, IAHS Series of Proceedings and Reports, No 235, pp. 225-232.

Predicting the vertical distribution of groundwater cadmium and copper contents in calcareous alluvial sediments of River Danube

Szalai, Z.[1] – Jakab, G. – Madarász, B.

Introduction

One of the largest subsurface water reservoirs of Europe can be found along the Hungarian section of the River Danube. This reservoir is stored in series of alluvial fans. The main component of these geological and geomorphologic formations is the gravel, which has been accumulating since the Pleistocene (Góczán, 2002.). Recently the gravel accumulation is decreased by the hydroelectric power plants. The bellow situated gravel bed is covered by an overlaying strata, which are composed of fine (sand, silt, clay) material. The greatest part of freshwater reservoir is situated in the gravel bed. This part of the alluvial fan is always saturated and the majority of the drinking water reservoirs are based on this water body. The water body of cover sediment contains much less amount of water. The level of groundwater table correlates with the discharge of the River Danube. The deepest part of the cover sediments is always (or mostly) saturated, but the major part of fine sediments is unsaturated during the low water discharge. The whole volume of cover sediment is only saturated during the highest floodwaves. (The frequency of these floodwaves is around 6-8 years.) This amount of water is usually not used for human activities, but it serves as a water source for the riparian vegetation (and for the whole riparian ecosystem). Heavy metals (as municipal, agricultural and industrial derived pollutants) are one of most important elements (pollutants), which can cause relevant water quality deterioration. The distribution of these elements is not homogeneous, and they show significant vertical and horizontal distribution among different water bodies and within the water bodies. Present paper will introduce some regularities in spatial and temporal distribution of two heavy metals: copper, which is an essential microelement and cadmium, which is a non-essential hazardous micropollutant.

Keywords: heavy metal distribution, cadmium, copper, groundwater, alluvial sediment, Danube

Materials and methods

Study area

The study was conducted along the Hungarian section of River Danube. Three sampling sites were used to provide representativity (fig. 1.). In geographical order, the first one is on the Isle of Tát (site”C”), which is situated near to Esztergom, at the Hungarian-Slovakian frontier. The second one is on the Háros Island (site ”A”), which is situated at the Danube section at Budapest. The third one is on the Csepel Island, near to Szigetújfalu (site ”B”), approximately 35 km south of Budapest. The Háros Island and the Isle of Tát have relatively small area (approximately 100 ha). The sample areas have diverse alluvial landforms: various generation of abandoned meanders on low and high floodplains. The average groundwater table is at 3-4 m depth under high floodplains and at 1-2 m depth under low floodplains. The cadmium and copper content of sediments are completely groundwater affected bellow 50 cm depth. Above 50 cm depth the cadmium and copper contents of sediments are influenced by the groundwater and the deposition of airborne particles. This process is strongly influenced by the vegetation pattern of riparian forests. The study area of Szigetújfalu is not isolated completely from human activities. The average depth of groundwater table alters between 7-8 m. This study area is not inundated even during the biggest flood-waves.

Figure 1.

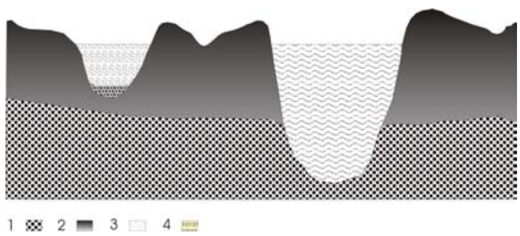


Figure 2. Idealised cross section of gravel bed river (the Danube). 1 = gravel bed; 2 = cover sediment; 3 = (surface) water; 4 = bedload

[1] Department for Physical Geography, Geographical Research Institute, Hungarian Academy of Sciences Budaorsi út 45, Budapest, Hungary; Tel: +36-20-3361049, Fax: +36 53 379869, E-mail: szalaiz@iif.hu, szalaiz@mtafki.hu

The Hungarian section of the Danube Valley has characteristic structure from the viewpoint of sedimentology. The river accumulated gravel bed of considerable thickness superimposed by loose (sand, silt, clay) cover sediments *(fig. 2)*. Gravel bed is developing continuously, but the barrage system inhibits its renewal. The thickness of cover sediments is 5-7 m and nowhere more than 10 m (Marosi and Szilárd, 1981). In case of medium discharge of the Danube the groundwater table is 1-2 m above gravel bed. Texture of cover sediment is similar in case of every study sites. Near to the surface silty clay and silty clay loam are characteristic. In these layers sand fraction is everywhere less than 15 %. Bellow 150 cm at the surface thicker and thicker loamy sand layers become dominant. Next to the boundary fine sandy layers prevail. The most of mineral components have relatively low adsorption capacity for cadmium and copper adsorption in all study site *(1.table)*. The most characteristic component is the quartz. The calcite and dolomite also are typical in the fine (sand, silt, clay) fraction. Their proportion may exceed the 30 %. Among clay minerals chlorite and mica have importance.

Table 1. Mineral composition of cover sediments (%)

	Isle of Tát	Háros Island	Sz.jfalu
montmorillonite	5	4	3
mica	16	18	19
kaolinite	2	2	2
chlorite (Fe)	8	10	12
quartz	23	28	19
K-feldspar	2	2	1
plagioclase	10	9	17
amphibole	1	1	1
calcite	14	8	9
dolomite	16	14	12
goethit	1	1	3
amorph phase	2	3	2

Sampling and chemical measurement

Sampling sites are also situated at high and low floodplain situation in Háros Island and Isle of Tát study areas. Sampling sites includes groundwater well series. The deepest well reaches down into the gravel bed. Depth of every subsequent well gets sallower by 10 cm increments. We have the longest data series from Háros Island study site, (14 flood-waves within 8 years. Control samples were taken from the Danube on every sampling occasion. Groundwater samples were taken with a vacuum pump. After the filtration they were conserved by cc. (HQ) HNO_3 (0.5 ml were added to each 50 ml water sample). The freshwater − control − samples (from the Danube) were taken from 20 cm depth. Those samples were conserved with the same procedure as the groundwater samples. Groundwater sampling has coincided with flood-waves: water samples have been taken before and after floodpeaks. Determination of cadmium and copper content of each sample was carried out by Zeiss AAS 30 electrothermical atom-absorption spectrometer (ETA-AAS).

Results

Regularities in vertical distribution of groundwater Cd and Cu content

Typical element distribution were identified between the Danube, groundwater of the gravel bed and groundwater of the cover sediment: most of the heavy metals (e.g. Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn) are usually attend in higher concentrations in the groundwater of the cover sediments than in River Danube (Szalai, 1998). These heavy metal concentrations show transitional water quality character in water body of gravel bed. However the cadmium is a typical exception, because the lowest cadmium concentration can be measured in the gravel bed. Cadmium (Fig. 3.) and copper (Fig. 4.) have slightly higher amount at Isle of Tát and Háros Island study area, while lowest concentrations could be measured at the Szigetújfalu study site. Elevated concentrations probably are resulted by industrial plants and municipal wastewater in case of Isle of Tát and Háros Island study areas.

These elements also show significant vertical distribution within cover sediment. The characteristic low cadmium and copper concentrations in the gravel bed suddenly increase in the cover sediment. The highest concentrations can be measured 10-20 cm above the gravel bed. This phenomenon is caused by the "boundary layer". The cover sediment contains the investigated elements in higher concentration in the directly above laying gravel bed than in subjacent and above situated layers. Ellis (1991) has described that the solute elements can precipitate on the surface of impermeable layers. We supposed that the same process plays role in this phenomenon because hydraulic conductivity remarkably decreases at the boundary of the gravel bed and the cover sediment. Above the "boundary layer" the cadmium and copper concentrations continuously decrease towards the surface up to 1,9-2 m height above the gravel bed. In case of low discharge the concentration decrease stops at the groundwater table. In case of medium and high discharge the cadmium and copper concentration is decreased till the measuring threshold. The copper concentration has ten times higher concentration than the cadmium. While the lowest copper concentration is around 2.5-3 ppb, the lowest cadmium concentration decreases under measuring threshold (0.8-0.6 ppb). The indicated values are counted on the basis of detectability threshold and the variance of repeated measuring. During flood-wave marks the heavy

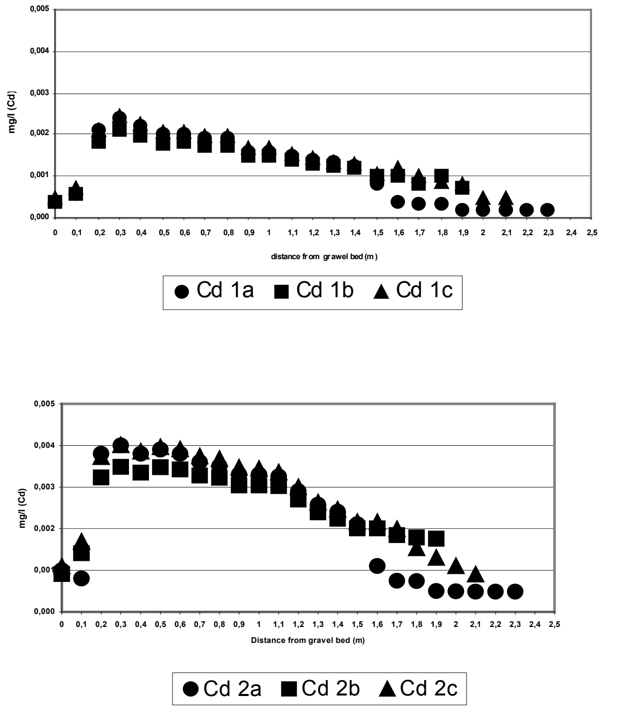


Figure 3. Spatial differences of grroundwater Cd contents among sampling sites. Cd1a: Cd conterntrations in site A, before floodpeak, Cd 1b: Cd conterntrations in site B, before floodpeak, Cd1c: Cd conterntrations in site C, before floodpeak

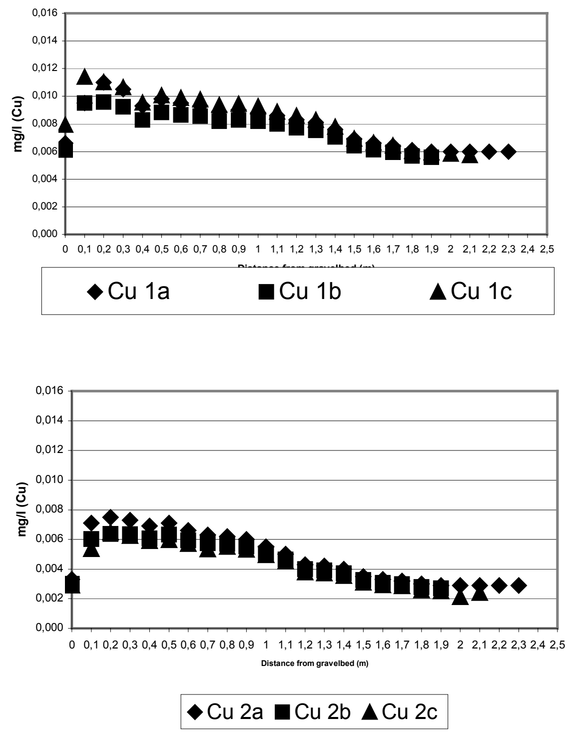


Figure 4. Spatial differences of grroundwater Cu contents among sampling sites. Cu1a: Cu conterntrations in site A, before floodpeak, Cu 1b: Cu conterntrations in site B, before floodpeak, Cu1c: Cu conterntrations in site C, before floodpeak (The signs represent the averages)

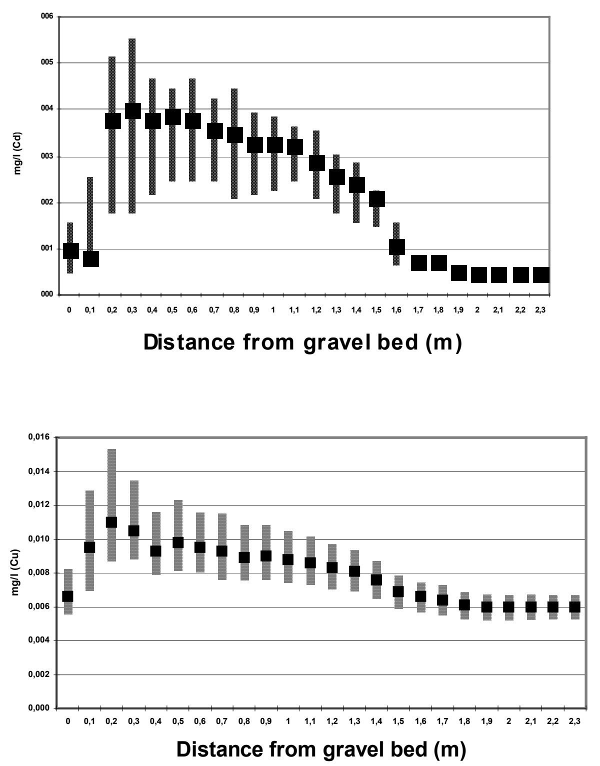


Figure 5. Minimum, average and maximum values of Cd and Cu concentrations.

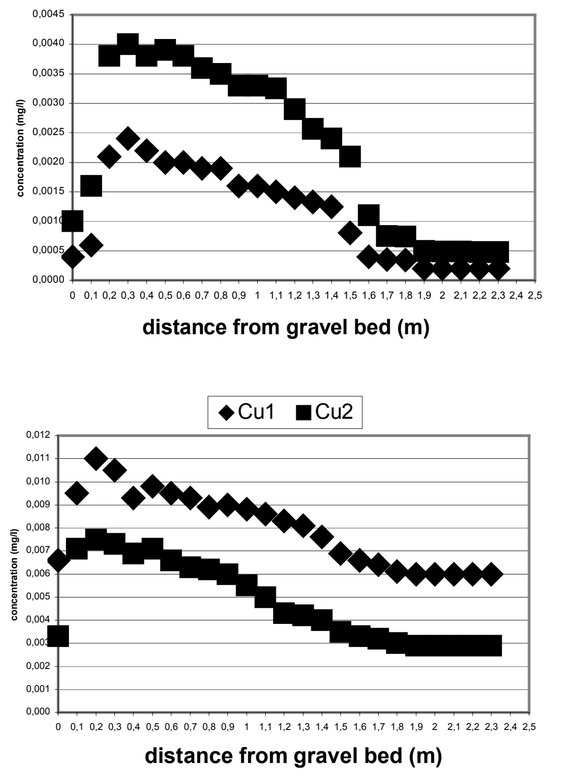


Figure 6. Temporal fluctuation of groundwater Cd and Cu content: Cd1 = BF Cd concentration; Cd2 = AF Cd concentration; Cu1 = BF Cu concentration; Cu2 = AF Cu concentration

metal concentrations decrease usually stop above approx. 2 m above gravel bed and it can slightly increase in topsoil, if it is inundated.

All investigated element concentration series have a significant variance. The variance of a particular data point alters with depth. The highest variances are experienced in the deepest part of overlaying strata, at 20-30 cm height above the gravel bed. The intervals between maximum and minimum values tighten towards the surface (Fig. 5). In case of cadmium, there is no difference in the variance in all data series.

However there are a lot of similarities among shape of data series of sampling sites A, B and C, there can be found some differences as well. While the copper concentration decreasing is unbroken towards the surface in case of each studied area, there are some differences between the sampling sites regarding the cadmium concentration decreasing (see Fig. 4). This decreasing is also continuous at the B and C site, but at 1.5 m height above the gravel bed exists a break at the A site. Above this level the groundwater cadmium content is much more lower than the 10-20 cm deeper. Firstly we supposed that this phenomenon is based on the filtering affect of iron-manganese mottles. We have analysed the whole sediment profile of the overlying strata (in the sampling site of the Háros Island) and a highly mottled layer was found in those depth. So highly mottled strata were not found in the profiles of the two other sites. The copper did not show this kind of difference. We supposed that the copper is not absorbed in such a high amount in the amorphous material of the mottles (Harter, 1979 and Kabata-Pendias, 2001), but we did not experimentally verify it.

Regularities in temporal distribution of groundwater Cd and Cu content

The studied elements show flood-wave dependent cyclic fluctuation. These fluctuations can be observed in case of each study area. The copper and cadmium have different temporal distribution, because copper is present in higher concentrations in groundwater before the floodpeak (BF), while cadmium has higher groundwater concentrations after it (AF) (Fig. 6.). This order is valid for all investigated sites. The copper AF and BF data series run parallel, so the BF/AF ratio is moving. It is 0.5 in the gravel bed and next increases around 0.75 in the 0.1m (above gravel bed). It is around 0.7 from 0.2-0.7m and it decreases continuously under 0.5. The AF and BF lines of cadmium are convergent, so the distribution of their BF/AF ratio is differ from the copper. The starting value is 2.5, that decreases around 1.9-2 between 0.2 m and 1.4 m , and next it increases again to around 2.5 from 1.5 m. We have to emphasise that the last value have considerable uncertainty, because the BF values are under the measuring threshold. The variances of data series and the average-median relationships are also changing during the floodwaves. Generally, if the average concentration is higher (e.g. cadmium AF concentration series), the range between minimum and maximum values will be higher also than the median values. If the average concentrations are lower (e.g. cadmium BF concentration series), the range between minimum and maximum values will be lower also than the median values. The location of maximum variance is also changing during the floodwaves. This phenomenon shows same pattern as the average-median relationship. If the average values (and the variance) are higher the maximum of variance will appears at 0.2 m height above the surface of gravel bed. If the average values (and the variance) are lower the maximum of variance will appears at 0.3 m height above the surface of gravel bed.

Possibilities for predicting cadmium and copper vertical distribution in saturated cover sediment

As the results of the 8 years measurements show that the groundwater cadmium and copper concentrations have typical temporal and vertical distributions at the investigated section of the River Danube. Whether can we predict the cadmium and copper concentration along whole profile of cover sediment (and the upper part of gravel bed) on the basis observed regularities? Two methods have been tested for answering this question.

In the first approach these distributions are interpreted as functions if the initial data series perform the initial stipulations. Interpolation is a prerequisite for a unified data series: data series should be standardise with the concentration of groundwater (x_n-x_0; where x_0= Cd or Cu concentration in gravel bed). For the comparability in the first step all data series were transformed to the origo. Value of first point (value of gravel bed)) is 0 [$y \rightarrow x(0)=0$]. Along Hungarian section of Danube Valley Cd and Cu distribution data series shows similar shape each in all analogous situation (e.g. before flood-peak). If the standard deviation remained bellow 10 % average of value series will be constituted. These series serve as basis for interpolation. Four interpolation methods were used for function generation: Bernstein approximation, and interpolation

Table 2. A values of Berstein polynome

i	a(i)	i	a(i)
0	1.000000 E 00	12	6.169753 E 01
1	-1.000000 E 00	13	-2.269809 E 01
2	4.782609 E 01	14	7.099096 E 00
3	-1.455570 E 02	15	-1.838895 E 00
4	3.164292 E 02	16	3.997597 E 00
5	-5.227969 E 02	17	-7.156824 E –01
6	6.819090 E 02	18	1.037221 E –02
7	-7.200281 E 02	19	-1.867520 E –03
8	6.261115 E 02	20	1.031958 E –04
9	-4.537040 E 02	21	-6.409677 E –06
10	2.761676 E 02	22	2.533469 E –07
11	1.419443 E 02	23	-4.753225 E –09

used the methods of the least squares. These methods are described in Numerical Methods (Stoyan, Takó, 1993) and these are part of "Galina, etc.).

We have used two alternative methods for predicting copper and cadmium concentrations, on the basis of above described.

1. The „Galina" has generated the „a" and „L" values of Bernstein polynome (table 2.) of the applied data series. These data series are the averages of average concentrations of three sampling sites. Practically the cadmium and the copper are characterised by two (BF and AF) average series. If we know the groundwater concentrations in the gravel bed we can calculate (Cd and Cu) concentrations in any point along the profile of (saturated) cover sediment using by the calculated table and the Bernstein polynom.
2. We have determined empirical sixth degree polynomes using by MS Excel (or by other spreadsheet software). The calculation is based on similar way as in case of Bernstein polynome, but in this case four different equations should we used.

The second approach is based on the relationship between the actually measured and the known concentration range in an individual point (i, i=1 if the point is situated 10 cm height above the gravel bed). The investigated elements appear a tighter-wider range in an individual point along the investigated profiles. The maximum of these ranges (f_1) are calculated from the average values of the maximum data series of sampling sites, while the minimums (f_2) are calculated from the average values of the minimum data series of sampling sites. These ranges are divided by the f_3 series, which is made from the average of average data series. The following procedure can make prediction for whole cover sediment profile using one only one measured value from one any point of the profile. Moreover the predicted values are placed proportionally among the known minimum, average and maximum values.

If $x_i \geq f_3$ then $f_g = x_i - f_3 / f_1 - f_3$. If $x_i < f_3$ then $f_g = x_i - f_3 / f_3 - f_2$.

If $f_g \geq 0$ then $f_x = (f_1 - f_3) + f_3$ else $f_x = (f_3 - f_2) + f_3$.

This formulae can be applied also with a spreadsheet software and can test with new measurements.

Conclusion

The mineralogical quality of fine alluvial sediments is relatively homogenous along the Hungarian section of river Danube. The medium term measurements reinforce that the spatial (2D) and temporal cadmium and copper distributions show relevant similarities. This phenomenon is probably based on the sedimentological properties. The developed predicting methods are empirical methods, so a relevant difference of an affecting factor can cause serious error in the prediction. The most probable this kind of factor can be an extended highly mottled layer. These approaches also was not tested for serious cadmium or copper pollution.

Acknowledgements

This research was financed by Hungarian Scientific Research Fund (OTKA, project no. T38122) and Environmental Fund the Department of Environment Protection and Water Management (KAC). The authors would like to thank to Balázs Szalai for his advices in data processing, to Péter Kovács-Pállfy and to X-ray measurements and to Mária Baloghné di Gléria for sedimentological measurements.

References

Ellis, B.: *„Urban runoff quality in the UK: problems, prospects and procedures"*. Applied Geography, 11. 1991. pp. 187-200.

Góczán, L. „Kisalföld". Magyar Könyvklub, Budapest, Pannon Enciklopédia. 2002. pp. 324-327. (in Hungarian)

Harter, R.D.*"Adsorption of copper and lead by Ap and B2 horizons of several Northeastern United States Soils"*. Soil Sci. Am. J. 43. 1979. p.679.

Kabata Pendias, A.; Pendias, H. *„Trace Elements in Soil and Plants"*. CRC Press. Boca Raton. 2001. 315 p.

Stoyan G.; Takó, G. *„Numerical Methods"*, Typotex Press, Budapest. 1993. 354 p. (in Hungarian)

Szalai, Z. Trace element distribution in alluvial sediments and soils of natural like riparian ecosystems. Geographical Bulletin, 47. 1998. pp. 19-30. (in Hungarian)

Dynamic of twenty-four hours methane emission from the Lake Moszne in the Poleski National Park (east part of Poland)

Stępniewska, Z.[1,2] – Szafranek, A.

Abstract

Methane is an important greenhouses gas, which can be formed in the lake sediment. Process of methanogenesis require low redox potential and high content of organic matter and that conditions occur in lakes bottom.

The aim of this paper was to show dynamic emission of methane from the lake Moszne during twenty–four hours observation. The Lake Moszne which has 17.6 ha area and maximal depth 2.5 m is situated in Łęczyńsko-Włodawskie Lake District in the east part of Poland. It is one of the natural lakes in this region which has small anthropogenic influences. That lake bottom characterizes rich content of humus and organic matter, it is surrounded by peat and overgrown by plants and forest. Organic matter flows down from peat to lake and cause turbidity of water and the water is faintly stir.

During the summer (in middle of July 2002) air samples were taken by twenty four hours. The summer season was selected because characterizes much higher emission of methane than cold season during the year. In order to estimate of methane emission from tasted lake samplers of air were collected inside chamber located by shore lake in the sutface of water. Formed bubbles of gasses were taken from chamber by syringe and next analyzed by gas chromatograph with flame ionization and temperature capture detectors. It was affirmed that concentration of methane in air samples ranged from 3.5 % to 56.6 %.

This results showed that investigation lake is a serious sours of methane, where emission was determined on the level 3.327 Mg CH_4 ha^{-1} $month^{-1}$.

Introduction

Methane is an important greenhouse gas, which like carbon dioxide and nitrous oxide contributed in climate changes. The tropospheric lifetime of methane is about 7 years and it absorbs radiation in the wavelength range from 3 to 4 µm and 7 to 8,5 µm. Methane concentration in atmosphere is estimated as 1.8 ppmv (part per million by volume) and increase about 0.5% to 1% per year. It is also consider the most abundant reactive trace gas in the troposphere, its reactivity is important to both tropospheric and stratospheric chemistry [7, 12]. For that reasons it has been reported in about 20% participation to the greenhouse effect.

Process of methanogenesis occurs under anaerobic conditions and presence organic compounds with participation methanogenic microbial comunities. Methanogens consume H_2 formated in intermediate fermentation of organic acids and alcohols and gaining energy by reducing CO_2 and the methyl groups of methanol, methylamines and acetate to CH_4. About 70% of the methane is formed from acetate and the remaining 30% from carbon dioxide and hydrogen. Gaining in this way energy they use for their own cell maintenance and growth [9, 11]. The concentration of CH_4 can be consumed in the presence of O_2 by methanotrophic bacteria [6]

Methanogenic degradation of organic matter in lake sediments occurs in a wide range of temperature including psychrophilic to extreme thermophilic conditions. An exponential dependence of methane production rate was found between 2 and 30 ˚C [10].

Emission of methane depends from the season of the year. During the winter, when lake surface is cover by ice and water is not stirring, gasses emission to the atmosphere is diminished. During the open water period lakes can release CH_4 into the atmosphere. For that reasons there are often large CH_4 emission in the summertime, where the production of CH_4 can be favored by high amounds of easly degradable organic matter and in the O_2 deficient sediment [6].

Methane emission from sediments occurs in two ways: molecular diffusion throughout bubbles and by plants. Air channels in plants and roots simplify methane emission from vegetated sites and seasons [1,13].

The rate of methane emission depends on the concentration of methane in the bubles [2]

Lakes, swamps, peatlands are great source of methane emission and amounds to half the methae flux into the atmosphere from various source and contributes 15% to the greenhouse effect [3. 4].

Methane emission from wetlands is correlated significantly with the mean water table level. Vascular plants regulate the CH_4 emission from peatlands by substrate supply from primary production and also by transporting CH_4 throughout aerenchymatous tissues into the atmosphere [8].

[1] Catholic University of Lublin, Department of Biochemistry and Environmental Chemistry, al. Kraśnicka 102, 20-718 Lublin, Poland. Tel.: (+48) 81 445 46 15; Fax: (+48) 81 445 46 10; E-mail: stepz@kul.lublin.pl

Methods and materials

The dynamics of methane emission from the Moszne lake were led during summer (in the middle of July 2002). The lake Moszne has 17.6 ha area and maximal depth 2.5 m. It is situated in Łęczyńsko-Włodawskie Lake District in the east part of Poland. It is natural lake surrounded by muddy plants, swamps and natural pine forest. Remains of plants flows down to bottom of the lake and cause rich content of humus and organic matter. In sediments at the bottom where anaerobic conditions are presented occurs process of methanogenesis.

Air samples were taken from the surface and from the shore of the lake during period of twenty-four hours. Samples were collected in two kinds of chambers. On the surface of the lake by the shore first chamber were located (Fig.1 a) and at the beginning of measurement was completely fill by water and second (Fig 1.b) on the soil on shore of the lake was situated. The first chamber was made of plastic and had load in order to preserve it before emerge from water. The second chamber was consist of two parts: base made of metal, which lower edge was located on the depth 5 cm in the ground and plastic lid tightly connected with base by seal with water coat. Samples were taken in three replications. In each case with takeing gas samples measurements of temperature both in the lake water as in soil were realized. Temperature of lake water and soil was tested by termometr constructed for soil measurements.

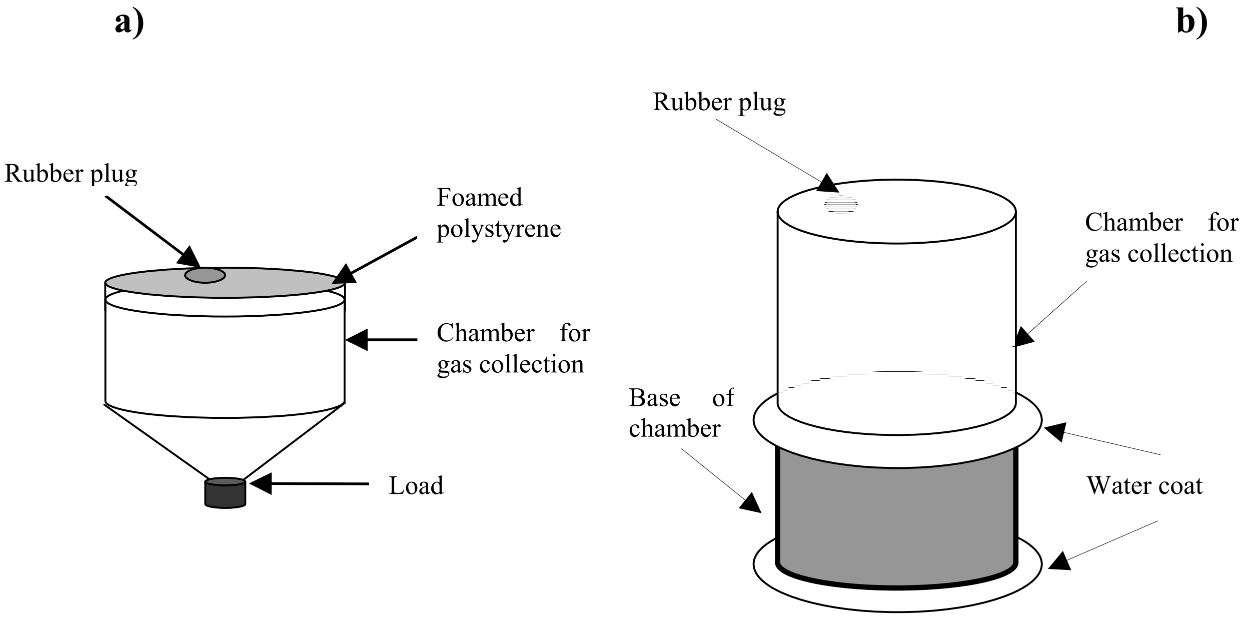


Figure 1. Scheme of gasses chambers, a) for colection of gasses from the lake surface, b) for colection of gasses emitted from the lakes shore.

Gasses bubbles from the lake and air samples emitted from shore were taken by using syringe with needle by rubber plags on the surface of the chambers and collected in deaerated and air-tight glass vials. Samples were analyzed by using of gas chromatograph with flame ionization and temperature capture detectors. .

Results and discussion

Done measurement shown dynamic enission of CH_4 from sediments layer of the lake and shore. Concentration of methane in gas bubbles and in air from chamber situated on the shore as a function of time is presented in Fig.2. and 3. That figures shown that methane emission was not constant in each measurement period in both point. Level of methane emission during the night and the day from float chamber was comparable and equals about 30%. In the case standing chamber emission during the night was lower than during the day and properly amounted to 0.0041 and 0.254 %.

There were statistically significant difference between CH_4 emission and time of experiment in both case ($p<0.00005$).

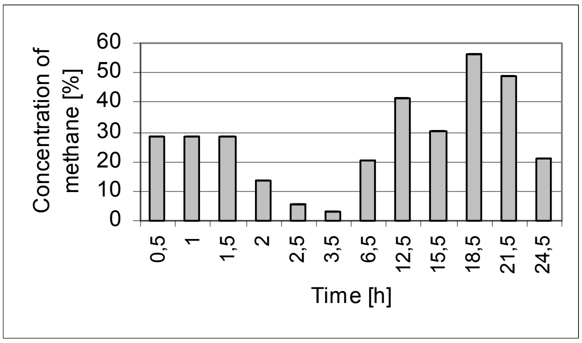


Figure 2. Daily concentration of methane in gas samples emitted from the lake surface.

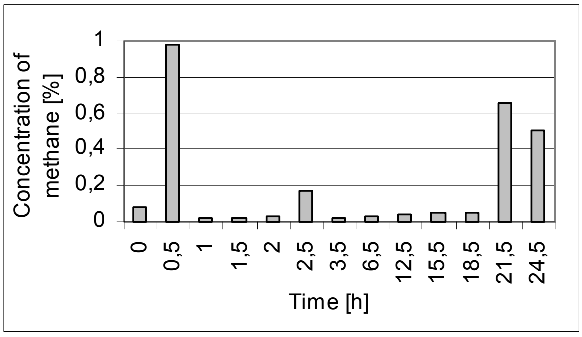


Figure 3. Daily concentration of methane in gas samples emitted from the shore of the lake.

Relation between CH_4 concentration and temperature of the lake water and soil on tke lake shore are presented in Fig.4. and Fig.5. In each case positive correlations, meaning that increase of temperature in littoral zone caused increase of methane emission.

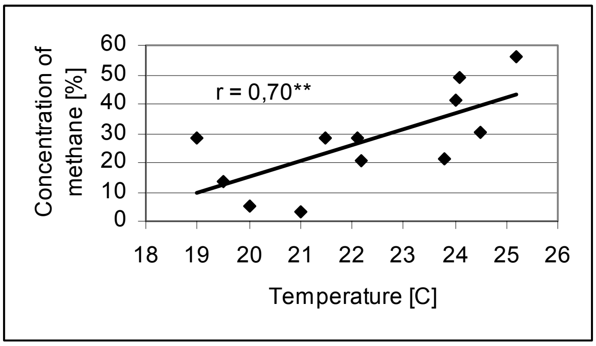


Figure 4. Concentration of methane as a function of the lake water temperature (in littoral zone).

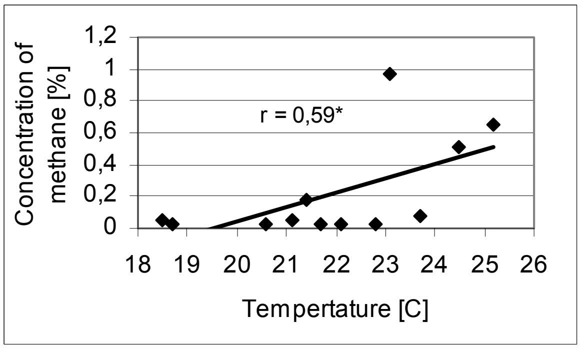


Figure 5. Concentration of methane as a function of soil temperature (shore of the lake).

Table 1. The effect of time on CH_4 concentration; mean value ±L SD (95% half interval of confidence). Mean values followed by the same letter are not significantly different at 5% level.

Time [h]	Methane [%]	
	lake surface	lake shore
0.0	-	$0.077{\pm}0.139_a$
0.5	$28.56 \pm 0.43_e$	$0.976{\pm}0.171_c$
1.0	$28.46 \pm 0.61_d$	$0.022{\pm}0.139_a$
1.5	$28.46 \pm 0.61_d$	$0.024{\pm}0.171_a$
2.0	$13.69 \pm 0.61_b$	$0.026{\pm}0.171_a$
2.5	$5.34 \pm 0.61_b$	$0.175{\pm}0.140_a$
3.5	$3.35 \pm 0.61_a$	$0.024{\pm}0.140_a$
6.5	$20.48 \pm 0.61_d$	$0.029{\pm}0.171_a$
12.5	$41.15 \pm 0.61_g$	$0,045{\pm}0.140_a$
15.5	$30.39 \pm 0.61_f$	$0.05{\pm}0.139_a$
18.8	$56.39 \pm 0.35_h$	$0.054{\pm}0.139_a$
21.5	$48.76 \pm 0.61_g$	$0.656{\pm}0.140_b$
24.5	$21.12 \pm 0.61_d$	$0.508{\pm}0.140_b$

Daily mean measured values of methane concentration in air samples teken from two measurement sites presents Tab. 1.

It was affirmed, that methane concentration in air samples taken from the lake surface, ranged from 3.5 % to 56.6 %. In the chamber situated on the shore considerable lower of CH_4 content values amounted from 0.022 to 0.656 %, what consists maximally only 1.2% gas emission from lake sediment wos observed. Results presented by others autors obtained from measurement leaded on eutrophic lake Postilampi in Finland indicated highest methane concentration in emitted gasses on the level 55.5-69.2% [5].

This results showed that investigated lake district is a serious sours of methane, particularly in littoral zone very modified by temperature. Emission during summertime was estimated on the level 3.327 Mg CH_4 ha^{-1} $month^{-1}$ from the surface of the tested lake.

References

Bazhin N. M., Gas transport in a residual layer of a water basin. Chemosphere-Global Change Science 3 (2001) 33-40.

Bazhin N. M., Influence of plants on the methane emission from sediments. Chemosphere 54 (2004), 209-215.

Cao M., Gregson K., Marshall S., Global methane emission from wetlands and its sensitivity to climate change. Atmospheric Environment Vol. 32, No. 19 (1998) 3293-3299.

Edwards C., Hales B. A., Hall G. H., Mcdonalds I. R., Murrell J. C., Pickup R., Ritchie D. A., Saunders J. R., Simon B. M., Upton M., Microbiological processes in the terrestrial carbon cycle: methane cycling in peat. Atmospheric Environmental vol. 32 (1998), No. 19, 3247-3255.

Huttunen J. T., Alm J., Saarijarvi E., Lappapainen K. M., Silvola J., Martikainen P. J., Contribution of winter to the annual CH_4 emission from a eutrophied boreal lake. Chemosphere 50 (2003) 247-250.

Huttunen J. T., Hammar T., Alm J., Silvola J., Martikainen p. J., Greenhouse gases in non-oxygenated and artificially oxygenated eutrophied lakes during winter stratification. Jurnal Environmental Quality 30 (2001) 387-394.

Huttunen J. T., Lappapainen K. M., Saarijarvi E., Vaisanen T., Martikanen P. J., A novel sediment gas sampler and a subsurface gas collector used for measurement of the ebullition of methane and carbon dioxide from a eutrophied lake. The Science of the Total Environment 266 (2001) 153-158.

Huttunen J. T.,Nykanen H., Turunen J., Martikainen P. J., Methane emission from natural peatlands in northern boreal zone in Finland, Fenoscandia. Atmospheric Environment 37 (2003) 147-151.

Lay J. J., Miyahara T., Noike T., Methane release rate and methanogenic bacterial populations in lake sediments. Water Research Vol.30, No. 4, (1996), 901-908.

Nozhevnikova A. N., Holliger C., Ammann A., Zehnder A. J. B., Methanogenesis in sediments from deep lakes at different temperatures (0-70 °C). Water Scientific Technology Vol.36, No. 6-7 (1997) 57-64.

Reeve J. N., Morgan R. M., Nolling J., Environmental and molecular regulation of methanogenesis. Water Scientific Technology Vol.36, No. 6-7 (1997) 1-6.

Wuebbles D. J., Hayhoe K., Atmospheric methane and global change. Earth-Science Reviews 57 (2002) 177-210.

Yu K. W., Wang Z. P., Chen G. X., Nitrous oxide and methane transport through rice plants. Bio. Fertil. Soils 24 (1997) 341-343.

Determination ability of aquatic fern *Azolla caroliniana* to remove biogens from municipal wastewater

Bennicelii, R.P.[1] – Stępniewska, Z. – Banach, A. – Szajnocha, K – Górski A.

Abstract

Azolla carolinina Willd. (*Azollaceae*) is a small water fern which occurs on the surface warm, eutrophic still waters. It lives in symbiosis with cyanobactrium *Anabena azollae* Strasb. (*Nostocae*) that can transform atmospheric nitrogen to accessible form (ammonium) for the fern. This feature makes *Azolla* sp. useful in agriculture as a green manure (for example on rice fields) and animals' feed.

The aim of our study was determination if *A. caroliniana* can take up nitrogen compounds from its grow medium. This ability will allows for using *A. caroliniana* to purification waters (for example wastewaters).

The experiment was conducted for 15 days in sewage treatment field "Hajdów". *A. caroliniana* was cultured in containers placed in a ditch with wastewater after second step of purification. During experiment we determined redox status of medium (both Eh and ODR) and concentration of nitrogen and phosphorus forms content. Obtained biomass was weighted to determine fern's ability to grow on wastewater.

Obtained results have showed that after 15 days of growing *A. caroliniana* removed 75% of nitrogen and 50% of phosphorus form medium. The fern grown well in experimental conditions and their biomass was about 700% higher then on the start of cultivation. On the 8th day of treatment has occurred the increase of amounts available of oxygen (200 μg O_2 $m^{-2}s^{-1}$) as compared to initial value (17 μg O_2 $m^{-2}s^{-1}$).

These data suggest that *A. caroliniana* can be used to purify wastewaters from nutrients rich in nitrogen and phosphorus compounds and to increase aeration conditions of wastewaters.

Keywords: *Anabena azollae, Azolla,* oxygen, nitrogen, phosphorus, purification, waste water.

Introduction

Nitrogen and phosphorus are very necessary elements for plants. Many farmers use the additional sources of these nutrients to improve their crops. They often use to many mineral manures which are leaching and contaminating waters what causes their eutrophication and leads to death of aerobic organisms. They are also wasted by other reactions occurring in soil (e.g. forming of CH_4, N_2O or N_2, adsorption). Also other human activity is a significant source of biogens pollution (e.g. municipal waste water). Surface runoff, falls and stock-farming may introduce 1-30 kg N ha^{-1} yr^{-1} and municipal wastes has about some to tens mg biogens l^{-1} (Mazur, 1991; Dojlido, 1995; Fotyma and Mercik, 1995, Tab. 1).

Table 1. Chemical composition of waste water after second step of purification coming from sewage treatment plant "Hajdów".

Parameter	Values [mg l^{-1}]	Parameter	Values [mg l^{-1}]
N-NH_4	1.1-7.1	Ca^{2+}	59.7-95.2
N-NO_3	20.2-38.4	Mg^{2+}	12.6-19.7
N_{tot}	22.3-43.2	SO_4^{2-}	43.6-116.3
P-PO_4	3.1-6.8	Cl^-	67.8-121.6
P_{tot}	3.7-7.0	Zn^{2+}	18.0-800.0
Na^+	24.3-69.4	Cu^{2+}	6.0-198.0
K^+	11.8-27.7	Pb^{2+}	7.0-96.0

In this situation is a need to decrease waste of nutrients from soil and purification waters polluted by biogens. One of the ways is using aquatic plants to purify waters form these substances (Forni et al. 2001) and natural manures and one of them may be water ferns *Azolla* sp.

Azolla caroliniana Willdenow (*Azollaceae*) is a small aquatic fern which belongs to genus *Azolla*. There are known other 6 species of *Azolla* and first of them was discovered by Lamrck in 1783. They occur on surface of warm, eutrophic still waters, like ponds in tropical climates. Global warming causes that they colonize parts of Europe with temperate climates.

These ferns have short branched stems (usually 1-5 cm) with small overlapping leaves, floating on water surface and long roots. On the bottom surface of leaves a cavity is localized where a symbiotic cyanobacterium (blue-green algae) *Anabaena azollae* Strasburger (*Nostocae*) lives. This microorganism has ability to fix atmospheric nitrogen transforming it into ammonium which is easy accessible for *Azolla* sp. This

[1] Catholic University of Lublin, Department of Biochemistry and Environmental Chemistry, Al. Kraśnicka 102, 20-718 Lublin, Poland; Tel.: 48-81-445-46-19; Fax: 48-81-445-46-10; E-mail: benniric@lkul.lublin.pl

process occurs in special *A. azollae* cells called heterocyst with help a nitrogenase enzyme (Peters and Meeks, 1989; Wagner, 1997).

This feature makes *Azolla* sp. very useful plant in agriculture as green manure especially in rice fields (paddy soils) in Asia where in optimal conditions it can bind about 500-1000 kg N ha^{-1} yr^{-1}. In the first rice crop is about 28-40% of nitrogen provided by *Azolla*-manure (Giller and Wilson, 1991; Watanabe et al. 1992). Also it has high amounts of proteins (26.2% of f.w.) and it is used as animal feed e.g. pigs, ducks and fishes (Duran, 1994; Wagner, 1997; Nobuyuki and Shunji, 2001).

The aim of our study was find answer on the question: does *A. caroliniana* takes up nitrogen forms (like nitrates and ammonium) from grow medium or does it only use the nitrogen supported by *A. azollae*. This experiment can also estimate adaptation ability of the fern to variability of nitrogen and phosphorus forms contents in waters and changes of temperate in open field conditions as green manure for water purification.

Materials and methods

The experiment was conducted with three stages:

- plant preparation in the laboratory conditions,
- introduction of prepared *A. caroliniana* on waste water after second step of purification and observation of its grow and environmental parameters,
- qualitative and quantitative analysis of obtained material.

Plant preparation

Cultivation of *A. caroliniana* was conducted in laboratory of Department of Biochemistry and Environmental Chemistry in Catholic University of Lublin. The culture of fern was taken from The Warsaw Botanical Garden.

In the first stage of experiment the fern was cultivated in glass aquariums with nutrient medium prepared according to International Rice Research Institute (IRRI, Watanabe et al. 1992). This medium contains fundamental elements for *Azolla* sp. without any nitrogen forms to support the fern nitrogen only fixed by *A. azollae*. In this stage we used 4 aquariums each with 3 l of medium and 20 g of *A. caroliniana*. Artificial light (fluorescent lamps Philips TLD 36 W/89 Aquarelle, The Netherlands) was used to provide an 18.-hour photoperiod. There were obtained about 200 g of plants after 2 weeks which were used in next stage.

Field experiment

The main part of the study was conducted near the sewage treatment plant "Hajdów" situated on the north-east of Lublin during summer (July). In this area was constructed a ditch draining with waste water flow after second step of purification to Bystrzyca River. Bed of the ditch was hardened with cement panels and plythene foil. *A. caroliniana* (50 g) was put into 5 containers with openwork walls witch were placed into the ditch and remained there for a 7-days adaptation period.

Fifteen-days analytic cycle was stated after ending adaptation period. During the experiment the following measurements were taken:

- temperature of waste water and air (maximum – t_{max} and minimum – t_{min}),
- pH, redox potential (Eh) and oxygen diffusion rate (ODR),
- analysis of water samples from each container for biogens levels (forms of nitrogen and phosphorus).

These measurements were performed each day between 9 and 16 o'clock. At the end of this stage of experiment biomass of *A. caroliniana* was collected and determination of its increase was done (fresh weight).

Measurements

- temperature was measured by mercury and liquid (min-max) thermometers scaled in Celsius degrees (°C),
- reaction of water (pH) was determined by pIONneer 65 meter with combined pH electrode pHC5977 (Radiometer Analytical, France),
- ODR determination was based on the method of polarization of platinum electrodes to oxygen decomposition potential (-0.65 V) and current intensity was measured during depolarization of these electrodes during O_2 diffusion. The calomel electrode was used as a reference. ODR values were calculated with the following equation:

  $$ODR = I_{mean} \cdot 12.75\ [\mu g\ m^{-2}\ s^{-1}], \qquad [1]$$

  where a constant is calculated on the basis of Pt-electrode surface according to Gliński and Stępniewski (1985).
- redox potential (Eh) was measured by Pt-electrode versus calomel electrode (reference) with a meter made by Cole Parmer Instrument Company (USA). Eh values were calculated as following:

  $$Eh = E_m + 247\ mV,\ \text{where} \qquad [2]$$

measured value (E_m) was increased by potential of calomel electrode versus hydrogen electrode in 20°C equals 247 mV. Before each measure Pt-electrodes were checked in Michaelis buffer at Eh = 167 mV (Zausig, 1995).

- contents of orthophosphates, ammonium, nitrites and nitrates were determined by spectrophotemetric method with FIAstar 5010 analyser (TECATOR, Sweden). Ammonium ions was marked with TECATOR indicator (5000-0295), nitrites by reaction with an acidic sulphanilamide solution and nitrates by reduction with cadmium according to Application Notes AN 50/84, AN 50-02/92, ASN 112-01/92 and ASN 110-01/92. Orthophosphates content was determined by molybdate method (Clesceri et al. 1998).

Results and discussion

During adaptation period *A. caroliniana* grown well in optimal air's temperature between 10-16°C (t_{min}) and 23-29°C (t_{max}), and it was stable in waste water (19-23°C). In the experimental period temperature was higher and it grew up to 36 (t_{max}) and 22°C (t_{min}). Also in waste water we noticed a increase of the temperature to 31°C (Tab. 3).

Table 3. Temperature of air (minimum and maximum) and waste water during all periods (all values in °C).

Day	Adaptation period			Experimental period		
	t_{min} (air)	t_{max} (air)	t (water)	t_{min} (air)	t_{max} (air)	t (water)
1	19,0	25,0	14,0	12	21	20
2	20,0	23,0	13,0	14	22	22
3	19,5	28,0	14,0	17	27	22
4	20,0	25,0	19,0	17	27	24
5	21,0	27,0	15,0	14	28	25
6	21,0	29,0	10,0	13	28	24
7	23,0	25,0	12,0	12	25	23
8	22,0	26,0	14,0	12	27	22
9	21,0	27,0	16,0	22	36	31

Redox potential in the medium increased from 151 to 400 mV during experimental period and it was highly correlated with time (Fig. 1A) – there were found a positive linear dependence between Eh and time of the experiment which is described by the equation: $y = 17.38x+151.79$ (Pearson's correlation coefficient $r = 0.86$, significant in $p = 0.001$). The reaction of water was weakly alkaline and oscillate between 7.95 and 8.24 pH units in this time.

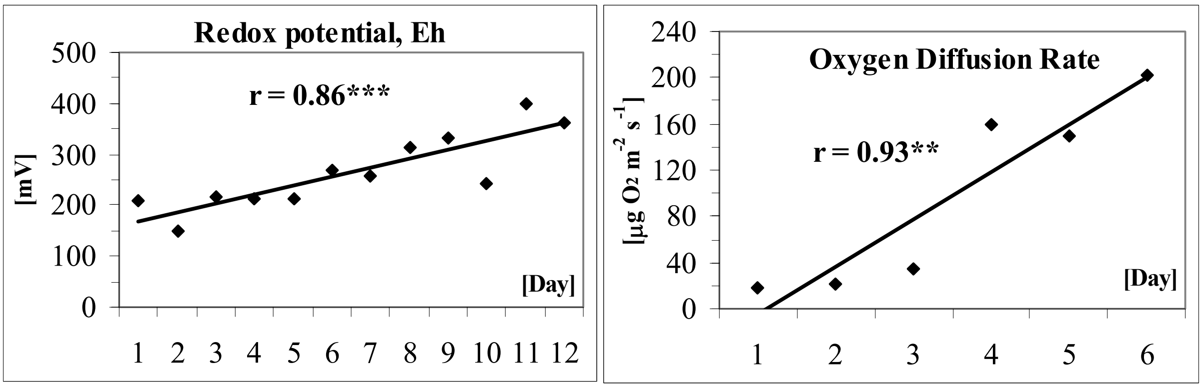


Figure 1. Redox (A) and aeration (B) state of *A. caroliniana* medium during the experiment.

Aeration of medium was expressed as a microdiffusion of oxygen (ODR). The initial ODR value was 17.29 μg O_2 m^{-2} s^{-1} and it grown rapidly and exceeds 200 μg O_2 m^{-2} s^{-1} (Fig. 1B) which express extremely good aeration conditions. A strong increase of ODR was observed after 10 days from *A. caroliniana* introduction when it covered whole surface of the containers. This ODR escalation has a linear character which can be described by linear equation: $y = 41.07x-45.95$ and there were a positive linear correlation ($r = 0.93$, significant in $p = 0.01$).

Concentration of nitrates in waste water was about 9.8 and 2.6 mg l^{-1} at start and end of the experiment, respectively and it was about 75% reduction of nitrates. Similar results were obtained from Forni's experiment (Forni et al. 2001) with *Azolla filiuloides* Lam. We also recorded presence of nitrites on the stable level about 1.0-2.7 mg l^{-1}, only on the 12th day (6th point) it rapidly increased up to 6 mg l^{-1} (+7%). This value decayed on the next day and nitrites level was similar to concentrations during initial days. Forni's (2001) experiment showed smaller amounts of nitrites in water (0.1-0.3 mg l^{-1}). The origins of ammonium levels were low 1.0-1.8

mg l^{-1} and they rose during second part of cultivation up to 5.5 mg l^{-1} what was a 191% increase. Experiment conducted by Forni (2001) showed very high ammonium removal from sewage water to 95-100% during spring and summer. This phenomenon may be a result of release of produced by *A. azollae* ammonium to water. The high ammonium concentration in water caused a disturbance between *A. filiculoides* and *A. azollae*: high amounts of bound nitrogen (as a ammonium) were released to water and the fern can not use it in such high concentrations.

Concentrations of phosphates in waste water was on the level 3.5 mg l^{-1} at the beginning of the experiment, and decreased to 1.9 3.5 mg l^{-1} on the last day of measurements. This means that *A. filiculoides* took up about 50% of phosphates presented in waste water (Fig. 2). Also Forni (2001) showed low phosphates values in medium (below 0.3 mg l^{-1}).

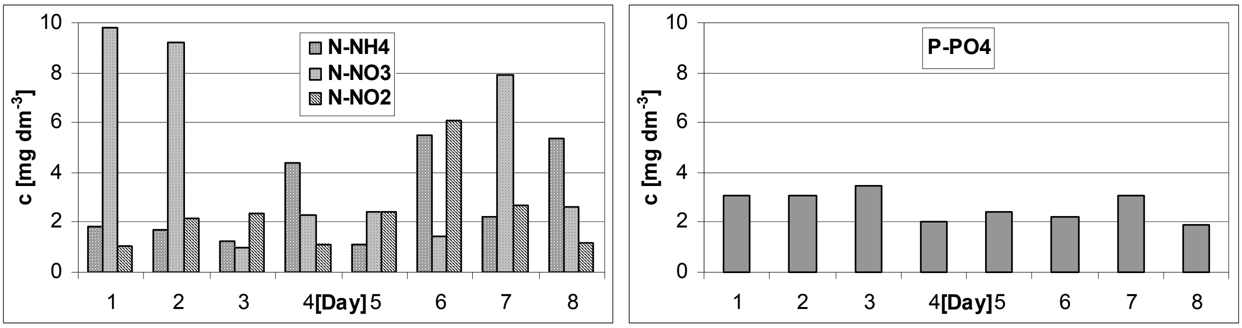


Figure 2. Concentrations of ammonium, nitrates, nitrites and phosphates in *A. caroliniana* medium.

At the end of the experiment obtained biomass of *A. caroliniana* reached 356 g – it was a 7 times greater in compare to initial 50 g of biomass.

Conclusions

Experiment proved that *A. caroliniana* can grow well (biomass about 700% greater) on waste water after second step of purification and use biogens forms to build its biomass. The fern removed both nitrates (75%) and phosphates (50%). The fern used the nitrogen both from medium and fixed by *A. azollae* what was also recorded (Forni et al. 2001). During its growth *A. caroliniana* caused a strong aeration of medium what was confirmed by such aeration factors like Eh and ODR (up to 400 mV and 200 µg O_2 m^{-2} s^{-1}).

This means that it can adopt to live in such conditions in temperate climate and it can be used for cleaning water by biogens.

References

Clesceri LS, Greenberg AE, Eaton AD (1998) Standard Methods for the Examination of Water and Wastewater 20th edition. American Public Health Association, the American Water Works Association, and the Water Environment Federation.

Dojlido JR (1995) Chmistry of superficial waters (in Polish). Ekonomia i Środowisko, Białystok, Poland.

Duran AO (1994) Row Palm Oil as the Energy Source in Pig Fattening Diets and *Azolla filiculoides* as a substitute for Soya Bean Meal. In: Livestock Research for Rural Development 6(1).

Forni C, Chen J, Tancioni L, Caiola MG (2001) Evaluation of the fern *Azolla* for growth, nitrogen and phosphorus removal from wastewater. Water Research 35(6), pp 1592-1598.

Fotyma M, Mercik S (1995) Agricultural chemistry (in Polish), PWN, Warsaw, Poland.

Giller KE, Wilson KJ (1991) Nitrogen fixation in Tropical Cropping System. C.A.B. International.

Gliński J, Stępniewski W (1985) Soil Aeration and Its Role for Plants. CRC Press. Boca Raton, Florida, pp 181-186.

Mazur T (1991) Nitrogen in cultivated soils (in Polish), PWN, Poland.

Nobuyaki S, Shunji K (2001) Culture of *Azolla* in a pond, Nutrient Composition, and Use as Fish Feed. Soil. Sci. Nutr. 47(1), pp 27-34.

Peters GA, Meeks JC (1989) The *Azolla-Anabaena* Symbiosis: Basic Biology. Annu. Rev. Plant Physiol. Plant Mol. Biol. 40, pp 193-210.

Wagner GM (1997) *Azolla*: A Review of Its Biology and Utilization. The Botanical review 64(1), pp1-21.

Watanabe I, Roger PA, Ladha JK, Van Hove C (1992) Biofertilizer Germplasm Collections at IRRI. IRRI, Manila, Philippines, pp 8-9.

Zausig J (1995) Redox potential measurement. In Methods in Applied Soil Microbiology and Biochemistry eds. Alef K, Nannipieri P. Academic Press, Harcourt Brace & Company Publishers, London, pp 274-276.

The ability of Azolla filiculoides to remove precious metals (Ag(I), Au(III), Pt(IV)) from water solution

Bennicelii, R.P.[1] – Stępniewska, Z. – Szajnocha, K. – Banach, A.

Abstract

The aim of this paper was to investigate the capacity of a small water fern, *Azolla filiculoides* Lam. (*Azollacae*), to purify waters containing Ag, Au and Pt.

A. filiculoides is a floating water fern, which appears on the surface of eutrophic, warm, still waters in temperate and tropical climates and lives in symbiosis with blue-green algae *Anabaena azollae* Strasb. (*Nostocae*), that fixes atmospheric nitrogen. *A. filiculoides* plants are used for centuries as a nitrogen biofertilizer and stimulated many studies (for example on its ability to phytoremediation). The addition of *Azolla* sp. brings about a number of changes in the biological, chemical and physical properties of the soil and soil-water: liberate organic compounds and photosynthetic O_2, prevent a rise in the pH and reduce water temperature and suppress weeds.

During 8 days of the laboratory experiment conditions *A. filiculoides* was grown on the nutrient solution containing Ag(I), Au(III), Pt(IV), each in a concentration 0.1, 0.5 and 1.0 mg dm^{-3}.

In the presence of Ag(I), Au(III) 17-37% inhibition of *A. filiculoides* growth in comparison to the control was observed. However in Pt(VI) treatments the influence on plant biomass production has not been recorded.

In the *A. filiculoides* tissues the concentration of Ag ranged from 31 to 49 mg kg^{-1} d.m., of Au 622 to 4896 mg kg^{-1} d.m. and of Pt 18-42 mg kg^{-1} d.m. These data suggest that *A. filiculoides* can be used in the phytoremediation, to clean waters polluted by selected metals, particularly by Au(III).

Keywords: *Azolla,* phytoremediation, precious metals

Introduction

The aquatic fern *Azolla filiculoides* Lam. (*Azollaceae*) (Tab. 1) is a small plant, common in many parts of the world, especially in tropical environments (Watanbe et al., 1992, Dawar et al 2001). A specific feature of this fern is its symbiosis with the cyanobacterium *Anabaena azollae* Strasb. (*Nostoceare*) which can bind atmospheric nitrogen. Due to this *Azolla* sp. is used as a green manure, especially in rice fields in Asia (Carrapiço, 2001). The fern has other applications and one of them is the bioaccumulation of heavy metals (Bennicelli et al., 2004).

Table 1. Systematic affiliation of *A. filiculoides*.

Kingdom	Plants
Type	Vascular
Group	*Pteridophyta*
Class	*Pteridopsida*
Subclass	*Shizaeatae*
Order	*Marsileales*
Family	*Azollacaeae* (previously *Salviniaceae*)

Group of metals like gold, silver and platinum are very valuable for men and they are called "precious". These elements have a high chemical resistance and are not much widespread in the environment (0.00001% in Earth's crust).

Precious metals are known by humans from centuries and used in many parts of industry. First of them were jewellery and coins production. Later they found application in electronics, photography, dentistry, chemistry and as pigments of glass and porcelain. These humans' activities and mining are main sources of precious metals emission into the environment.

High amounts of these metals are toxic for living organisms and one of the methods for decrease these metals concentrations is the phytortemediation. This method has many applications for different substances e.g. heavy metals, pesticides, explosives and other organic substances. There are some plants which can bind precious metals (e.g. *Eriogonum ovalifolimu*, *Phacelia sericea*). Also dried biomass of *A. filiculoides* can remove 86-100% Au(III) from solutions (Antunes et al., 2001).

[1] Catholic University of Lublin, Department of Biochemistry and Environmental Chemistry, Al. Kraśnicka 102, 20-718 Lublin, Poland; Tel.: 48-81-445-46-19; Fax: 48-81-445-46-10; E-mail: benniric@kul.lublin.pl

Materials and methods

A. filiculoides was obtained form Warsaw Botanical Garden and cultured in laboratory. The fern was put into aquariums containing 3 dm^3 of liquid nutrient medium (Tab. 2) prepared according to International Rice Research Institute (IRRI) recommendation (Watanabe et al., 1992). The examined metals were introduced into each aquarium (in form: $AuCl_4Haq$, Ag_2SO_4, $H_2[PtCl_6]$) in 3 concentrations: 0.1, 0.5 and 1.0 mg dm^{-3}. The nutrien solution did not contain nitrates so that the *A. filiculoides* could use the nitrogen provided by the *A. azollae*. In this way 9 treatments (3 per metal) were obtained. A 10^{th} aquarium was used as a control which contained only a nutrient medium. Fluorescent lamps (Philips TDL 36 W/89 AQUA RELLE, the Netherlands) were used to support an 18.-hour light period during *A. filiculoides* cultivation. The parts of aquarium below water table were covered by aluminum foil to support natural conditions for fern's roots. Air temperature was 27±2°C, the air humidity about 50±5% and the initial *A. filiculoides* biomass w 20 g.

Table 2. The IRRI nutrient medium composition.

Element	Chemical compound	Concentration in solution [ppm]
P	$NaH_2PO_4{\cdot}H_2O$	20.0
K	K_2SO_4	40.0
Ca	$CaCl_2{\cdot}2H_2O$	40.0
Mg	$MgSO_4{\cdot}7H_2O$	40.0
Mn	$MnCl_2{\cdot}4H_2O$	0.50
Mo	$Na_2MnO_4{\cdot}2H_2O$	0.15
B	H_3BO_3	0.20
Zn	$ZnSO_4{\cdot}7H_2O$	0.01
Cu	$CuSO_4{\cdot}5H_2O$	0.01
Co	$CoCl_2{\cdot}6H_2O$	0.01
Fe	$FeSO_4{\cdot}7H_2O$ $EDTA{\cdot}7H_2O$	0.50

The fern was cultured for 8 days with 5 control points during this time. The following actions were performed during each point:

- temperature and humidity of air by mercury's and liquid (minimum and maximum temperature) thermometers and hygrometer,
- observations of the fern,
- drawing of samples for concentration of Ag(I), Au(III) and Pt(VI) determination in the solution (50 ml stabilized by concentrated HNO_3).

At the end of the experiment, the biomass of *A. filiculoides* was collected, washed with deionized water and weighed to verify its fresh weight. After that the dry weight of the plants was determined after drying at 80°C and used to find out the metals content in the biomass. These measurements after mineralizing by acid digestion (HNO_3) in a microwave closed system were conducted by GFAAS (graphite furnace atomic absorption spectrometry) method (AAS spectrometer Z-8200, Hitachi, Japan).

Results and discussion

Fig. 1 shows a decrease in the content of metals in the nutrient solution. In the treatments containing Au(III) ions during the first three days of the experiment a significant reduction of them to: 0.023, 0.061 and 0.227 mg dm^{-3} , was observed. On the next days the concentration of examined metal increased to 0.034, 0.1 and 0.354 mg dm^{-3}, what constitutes 23%, 12% and 23% of the initial doses.

Treatments containing 0.1, 0.5 and 0.5 mg dm^{-3} Ag(I) were characterized by very low concentrations of the metal on the first day, which amount 0.33, 0.02 and 0.131 mg dm^{-3}, respectively. In the next days the content was variable and achieve of the level of 0.009, 0.442, 0.717 mg dm^{-3}.

After the analysis of nutrient solutions from Pt(VI) treatments the presence of the metal was not stated, because its concentrations was below the GFAAS detection limit (the method sensitivity amounts to 10 ppb).

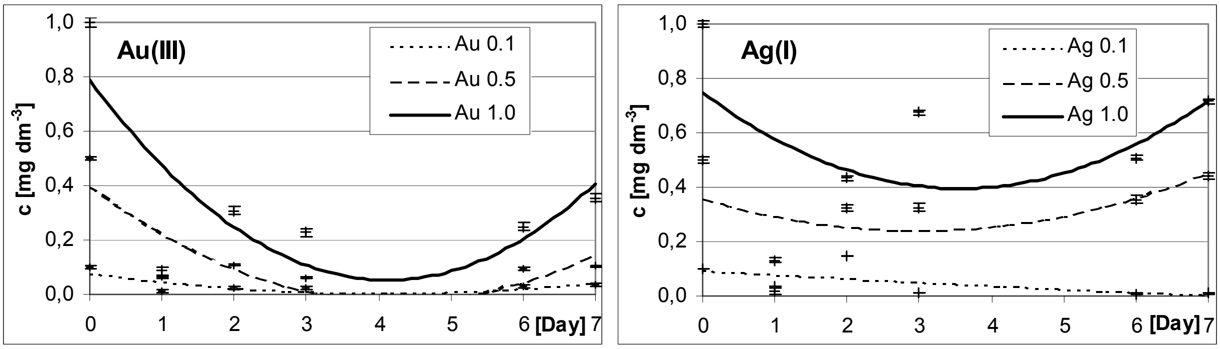


Figure 1. Decrease of Au(III) and Ag(I) from all treatments.

The highest increase of plant biomass was observed in Pt(IV) treatments and was comparable to the control (Fig.2.). The fern, which was cultured in this aquariums was dark green and well developed. A negative influence of this metal was not stated, because its salts precipitated.

However plants from Ag(I) treatments were characterised by the lowest biomass increase: 83%, 68%, 63% with reference to control. Fern leaves had yellow stains and withered brims. Fern cultured on the medium enriched in Au(III) grew weakly than the control plants (75%, 81%, 87%) and were of the green colour.

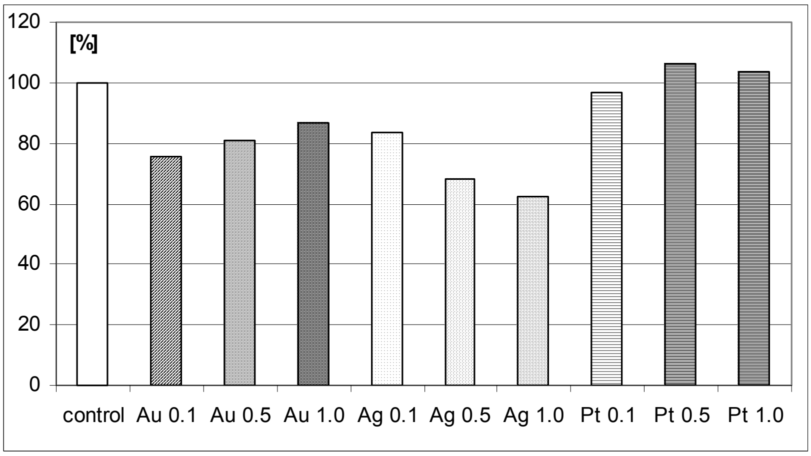


Figure 2. Increase of *A. filiculoides* biomass at different treatments.

During the experiment *A. filiculoides* took and cumulated the tested precious metals. Contents of metals under examination in dry mass are shown in Fig. 3. At the Au(III) treatments the metal concentration was at the level: 622 do 4895 mg kg^{-1} dm and its increase showed a positive, strong functional dependence of the metal concentration in the fern and in the solution (r = 0.95). The presence of gold has a negative influence of the growth and development of the examined plants.

The Ag uptake by plants was visibly lower. At the 0.1 mg dm^{-3} treatment it amounted 30.7 $mgkg^{-1}$ d.m, at 0.5 mg dm^{-3} 53.5 mg kg^{-1} d.m. and at 1.0 mg dm^{-3} 48.5 $mgkg^{-1}$ d.m, what equalled 7%, 2% and 1%, respectively. The correlation between Ag(I) dose and accumulated amounts in biomass was as strong as in case of Au(III) treatments (r = 0.97).

These results show the increase of precious metals content in biomass in all the treatments accompanied by a decrease of their amounts form the solution. The fern absorbed the most of Au ions (even about 5000 mg kg^{-1}) but the others metals were taken in lower amounts because they were partially precipitated and not available for *A. filiculoides*.

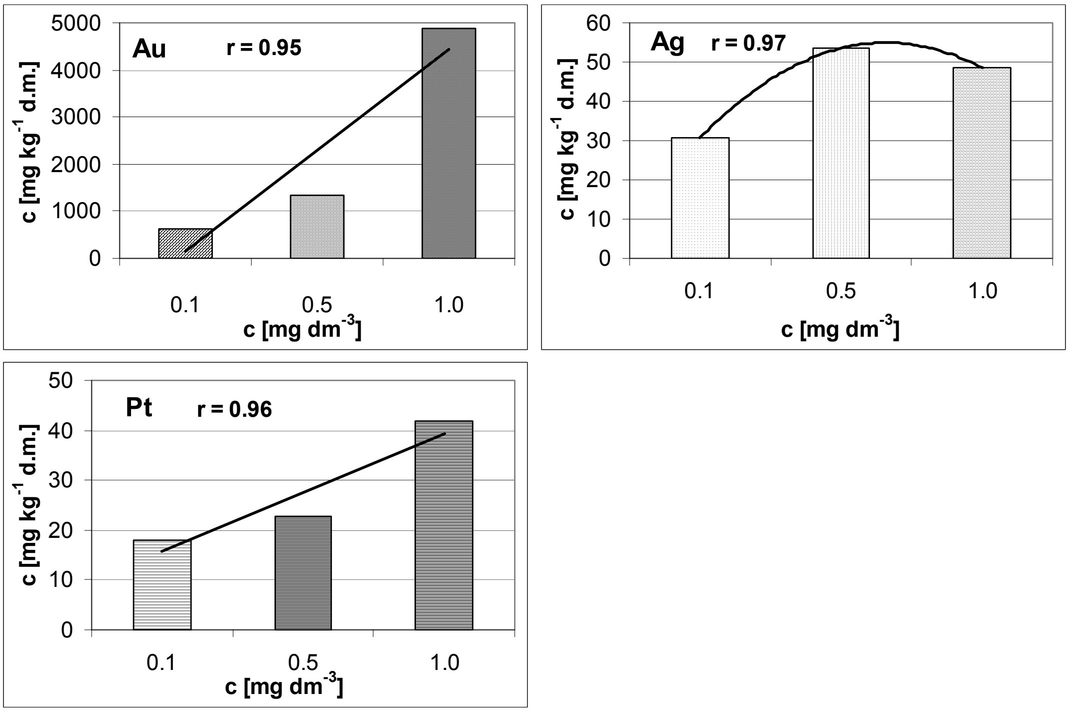


Figure 3. Accumulation of Au, Ag and Pt by *A. filiculoides* biomass.

Conclusions

Observed decreases of selected precious metals from medium and increase of their amounts in biomass confirm ability of *A. filiculoides* to remove these metals form water solutions and their accumulation in plant's tissues.

This ability, especially binding of gold's ions by the fern may be used not only for purification and detoxification of polluted waters but also for precious metals recovery presented in small amounts in water solutions. Natural habitats of this plant are still enlarging (also in Europe) what increases chance for the fern's cultivation for these purposes. Utilization of *A. filiculoides* in this way may help in metals loss limitation during their processing.

References

Antunes, A.P.M., Watkins, G.M., Duncan J.R. (2001) Batch studies on the removal of gold(III) from aqueous solution by *Azolla filiculoides,* Biotechnology Letters **23**: 249-251, 2001.

Bennicelli, R., Stępniewska, Z., Banach, M., Szajnocha, K., Ostrowski, J. (2004) The ability of *Azolla caroliniana* to remove heavy metals (Hg(II), Cr(III), Cr(VI)) from municipal waste water. *Chemosphere* 55 (1),141-146.

Carrapiço, F. (2001) The *Azolla-Anabaena*-Bacteria System as a Natural Micro-cosm. *Proceedings of SPIE* **4495**, 261-265.

Dawar, S. and Singh, P.K. (2001) Growth, nitrogen fixation and occurrence of epiphytic algae at different pH in the cultures of two species of *Azolla*, *Biol Fertil Soils* **34**:210-214.

Mandal, B., Vlek, P.L.G. and Mandal, L.N. (1999) Beneficial effects of blue-green algae and *Azolla,* excluding supplying nitrogen, on wetland rice fields: a review, *Biol. Fertil. Soils* **28**, 329-342.

Watanabe, I., Roger, P.A., Ladha, J.K., Van Hove, C. (1992) Biofertilizer Germplasm Collections at IRRI. *IRRI*, 8.

Nitrate (V) elimination from waste water trough sorption on the rock spoils of different degree of weathering.

Stępniewska, Z.[1] – Ostrowska, A.

Groundwater pollution by nitrate is a serious problem in the European Countries and in the Poland groundwater, in recent years, because NO_3^- concentrations often exceed acceptable contamination limits. Nitrate and its metabolites are toxic for the human body, and can be particularly harmful to infants. The nitrate (V) sorption is not a common effect, because a little soil colloids had positive charge to absorb anions.

The aim of the work was to examine nitrate (V) sorption on the rock spoils of different degree of weathering. The possibility of use this material as natural barrier in the soil environment characterizing by increased $N\text{-}NO_3^-$ concentration was tested.

The experiment was carried out on the rock spoils (including clay minerals) from the coal mine Bogdanka situated in the Lublin Coal Basin. Five different types of rock spoils were examined: fresh material, material accumulated for one, three, five and for ten years.

The sorption value was measured for waste water and for nitrate (V) solution in the range 5-20 mg $N\text{-}NO_3^- dm^{-3}$ content. The pH of the rock spoils was naturally differentiated, which was the effect of the rock spoils weathering and pyrite oxidation. The result indicates maximal nitrate (V) sorption value about 6 mg $N\text{-}NO_3^- dm^{-3}$ (43 mval kg^{-1}) on the rock spoils weathered for five and ten years on the soil surface that is consist about 5% of capacity of anion resin.

The results found are important with regard to the study of the nitrate (V) elimination from waste water before received by them natural waters in rivers or lakes.

[1] Katholic Uniwersity of Lublin, Kraśnicka 102, 20-718 Lublin, Poland; Tel.: 48 (081) 445-46-19; Fax: 48 (081) 445-46-10; E-mail: stepz@kul.lublin.pl

Enzyme activity in soil contaminated by chromium (III, VI) forms

Stępniewska, Z.[1] – Wolińska, A.

Abstract

Soil biological properties are influenced by heavy metals. Chromium compounds can have detrimental effect on soil microorganisms and their enzymatic activity, which responds for fertility of the soil. Therefore enzyme activities can be considered effective indicators of soil quality changes resulting from environmental stress or management practices. Between them dehydrogenase is considered an indicator of overall microbial activity because it occurs intracellulary in all living microbial cells, and it is linked with microbial redox processes. Catalase activity has been related to both the number of aerobic microorganisms and soil fertility. Whilst soil phosphatase activity plays a major role in mineralization process and is crucial in decontaminating of terrestrial environment polluted by organophosphate pesticides.

The aim of the experiment was to tested the influence of Cr (III) and Cr (VI) compounds on dehydrogenase, catalase and phosphatase activity of selected mineral soil. Soil sample was taken from the bank of Polish soils, gathered in the Institute of Agrophysics of the Polish Academy of Sciences. The air dry soil was amended with Cr (III) in the form of $CrCl_3$ and with Cr (VI) as $K_2Cr_2O_7$ in the concentration range from 0 to 20 mg dm^{-3}.

It was stated that soil enzymatic activity decreased with the increase of chromium concentration. Only in the soil samples amended with Cr (VI) salt at the range 2-5 mg dm^{-3} an initial increase of phosphatase activity was found. The supplement of Cr (III) caused reduction of enzymatic activity to 55–90% with reference to samples without enrichment. Results suggest the negative effect of chromium contamination on the activity of soil enzymes.

Introduction

Heavy metals are common in human activity and constitute a serious health risk because they easily accumulate in soils, water and organisms. Chromium is one of the heavy metals located in the soil. It is very specific kind of metal.

The environmental and biological behavior of chromium depend most of all on its oxidation state (Welp, 1999, Cervantes, 2001, Stewart, 2003, Tokunaga, 2003). Chromium is known to exist on all oxidation states from 0 to VI, however the two most common oxidation states found in the environment soil are: Cr III and Cr VI. These two forms are different in charge, physicochemical properties, and chemical and biochemical reactivity. The anionic Cr (VI) is considered to be highly mobile in soils, while the Cr (III) cation is believed to be significantly less mobile [Cervantes, 2001, Stewart, 2003]. Although, Cr (III) is generally thought less harmful than its oxidized form, it may be of concern due to its potential to be oxidized to Cr (VI) (Welp, 2001, Tokunaga, 2003).). Chromium compounds are stable in the trivalent state and occur in nature in this state in ores, such as ferrochromite, whilst Chromium (VI) is usually produced from antropogenic sources (Cervantes, 2001).

Soil enzyme activities are considered to be sensitive to pollution and have been proposed as indicators of soil degradation (Trasar-Cepeda, 2000, Ledin, 2000). Studies of enzyme activities provide information on the biochemical reactions occuring in soil (Dąbek-Szraniawska, 1996, Stewart M.A., 2003).

Dehydrogenase is considered an indicator of overall microbial activity because it occurs intracellulary in all living microbial cells, and it is linked with microbial redox processes (Camina, 1998, Welp, 1999). Dehydrogenases play a significant role in the biological oxidation of soil organic matter by transferring protons and electrons from substrates to acceptors (Brzezińska, 2001).

Catalase is an intracellular enzyme found in all aerobic bacteria and most facultative anaerobes, but absent in obligate anaerobes (Trasar-Cepeda, 1999, Anderson, 2002). Catalase activity in the soils is thought an indicator of aerobic microbial activity and has been related to both the number of aerobic microorganisms and soil fertility (Guwy, 1999, Trasar-Cepeda, 1999).

Phosphatases are among the enzymes, which transform P from non – available, organically bound forms into phosphate ions, that can be absorbed by microorganisms and plants (Baum, 2003). Acid and alkaline phosphatase catalyse the hydrolysis of various phosphate–containing compounds and act as transphosphorylases at acid and alkaline pH$_s$, respectively (Kramer, 2000). Phosphatase enzymes can be a good indicator of the organic phosphorus mineralization potential and biological activity of soil (Kramer, 2000).

The aim of the experiment was to tested the influence of Cr (III) and Cr (VI) compounds on dehydrogenase, catalase and phosphatase activity of selected mineral soil.

[1] Catholic University of Lublin, al. Kraśnicka 102, 20-718 Lublin, Tel.: +48 81 445 46 19; Fax.: +48 81 445 46 10; E-mail: stepz@kul.lublin.pl

Materials and methods

The experiments were performed under model laboratory conditions on the Eutric Cambisol-loam soil taken from the bank of soils, situated in the Institute of Agrophysics of the Polish Academy of Sciences. The main characteristic of the soil investigated is presented in a Tab.1.

Table 1 Characterization of the soil material

Granulometric composition [%]								
Type of soil	Depth [cm]	1-0.02	0.02-0.002	<0.002	t_{300}	t_{400}	Organic matter [%]	pH in H_2O
Eutric Cambisol - loam	20 - 25	75	22	3	9	3	2,19	5,86
	85 - 90	77	10	13	12	3	1,25	5,91

The air dry soil samples were enriched with Cr (III) in the form of $CrCl_3$ and with Cr (VI) as $K_2Cr_2O_7$ in the concentration range from 0 to 20 mg dm^{-3}. Non–amended soil samples were used as a control.

Dehydrogenase activity was determined by Casida et all method (1964) with use TTC (2,3,5-triphenylotetrazolium chloride). Soil, (6 g), was placed in 50 ml glass flasks, where 1 ml 3% aqueous solution TTC, 120 mg $CaCO_3$ and 4 ml distilled water were added. The soil samples were incubated for 20 hours in thermostatic chamber at 30 C. After incubation the soil samples were extracted with ethanol, and filtered. Absorbance was measured by means of HITACHI UV-VIS U-2001 spectrophotometer at 485 nm.

Phosphatase activity was determined using the method of Tabatabai and Bremner (Tabatabai, 1969), according to one gram of soil was placed in a 50 ml centrifuge tube with 25 ml of toluene, 4 ml of MUB – phosphate (pH 6.5 for acid and pH 11 for alkaline phosphatase) and 1 ml of 15 mM p-nitrophenyl phosphate solution. After one hour incubation to every soil samples 1 ml of 0.5 M $CaCl_2$ and 1 ml of 0.5 M NaOH were added. The contents of tubes were immediately filtered. Absorbance was measured by means of HITACHI UV-VIS U-2001 spectrophotometer at 400 nm

Catalase activity was assayed by Johnson and Temple method (Johnson, 1964). Soil, (2 g), was placed in a 125 ml Erlenmeyer flask with 40 ml of distilled water, 5 ml 30% H_2O_2 and was shaken for 20 min. Next, 5 ml 3N H_2SO_4 was added. The contents of tube were filtered and immediately titrated by 0.1N $KmnO_4$.

All determinations of enzymatic activities were performed in triplicate, and all values reported are averages.

Results

Realized laboratory experiments showed that it is possible to state relationship between soil enzymatic activity and Cr concentration in the soil environment. The highest enzymatic (dehydrogenase, phosphatase, catalase) activity in the control samples without Cr contamination were noted. High values of enzymatic activity in the controls were caused by biotic and abiotic natural processes which has a place in the soil.

The influence of Cr (III) and Cr (VI) compounds on soil dehydrogenase activity is presented in Fig.1. Dehydrogenase activity showed a tendency to decrease as chromium concentration increased. The lowest concentrations of both Cr (III) and Cr (VI) at the level 2 mg dm^{-3} reduced soil dehydrogenase activity to 51 and 66%, respectively. Meanwhile the highest Cr (III) and (VI) addition at the level of 20 mg dm^{-3} limited enzymatic activity to 6% and 15%. These results are compatible with observations of Welp (1999) and Trasar –Cepeda et all. (2000). As a consequence of analysing Fig. 1. it is possible to say that Cr (III) forms caused stronger inhibition of activity than more dangerous Cr (VI) forms.

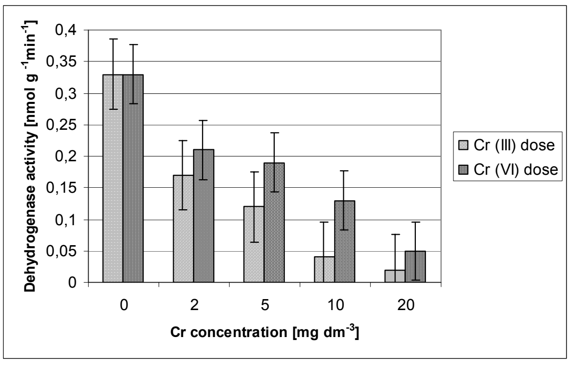


Figure 1. Changes in the soil dehydrogenase activity as a result of Cr (III) and Cr (VI) amendment

One possible explanation for this fact is that more dangerous form of Cr (VI) was reduced to less toxic form of Cr (III) by microorganisms living in the soil.

The effect of Cr on soil acid and alkaline phosphatase activity is shown in Fig. 2. Both enzymatic activities displayed a linear drop in the soil samples amended both with Cr (III) as Cr (VI) forms. However, acid form of enzyme seemed to be more resistant to Cr contamination than its alkaline counterpart.

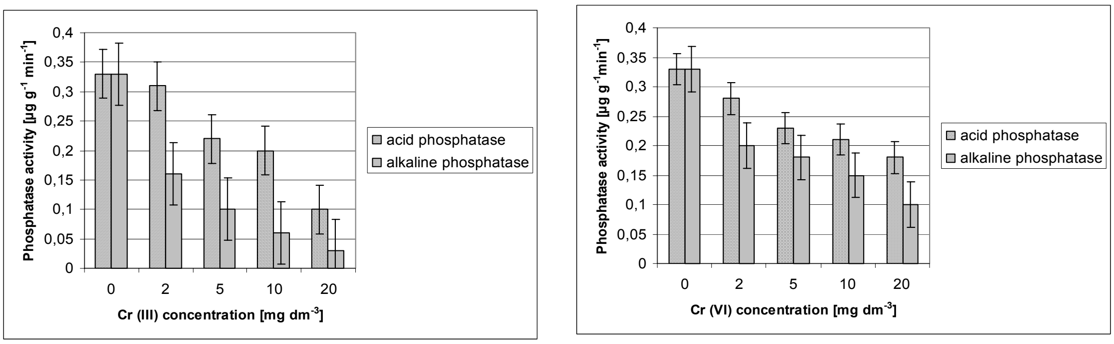


Figure 2. Changes in the soil phosphatase activity as a result of Cr (III) and Cr (VI) amendment

Moreover, it was stated that Cr (III) compounds are responsible for stronger inhibition of soil phosphatase activity. Cationic form of Cr (III) exerts a significant influence on soil enzymatic activity (Stewart et all., 2003). The risk imposed by Cr (III) form is connected with its ability to be oxidized to Cr (VI) salts (Fendorf, 1995). The lowest values for phosphatase activity as an effect of 20 mg dm^{-3} Cr (III) and Cr (VI) addition were observed, whilst the highest after 2 mg dm^{-3} of both Cr (III) and Cr (VI) doses were found. As a consequence of 20 mg dm^{-3} Cr (III) concentration acid phosphatase activity was reduced to 30% and alkaline to 9% in relation to the control. Whereas, the same Cr (VI) concentration level caused 54% drop of acid kind of the enzyme and 30% for the alkaline phosphatase.

Changes in the soil catalase activity in the environment contaminated by Cr forms are presented in Fig. 3. Catalase activity seemed to be also sensitive to presence of chromium in the soil. Even the smallest doses of Cr at concentration 2 mg dm^{-3} caused 50% reduction of enzymatic activity. In the samples, which were enriched with higher Cr concentration (5, 10, 20 mg dm^{-3}) activity of catalases were reduced by 70-80%.

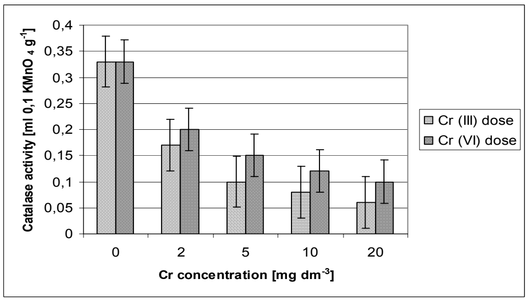


Figure 3. Changes in the soil catalase activity as a result of Cr (III) and Cr (VI) supplement

The effect of depth of soil profile on soil dehydrogenase, phosphatase and catalase activity is shown in Fig. 4. Every kind of enzyme demonstrated diminishing trend as the depth of soil profile is growing. The highest values of enzmatic activity achieved their maximum at surface layer (20-25 cm) and were reduced at subsoil (85-90 cm).

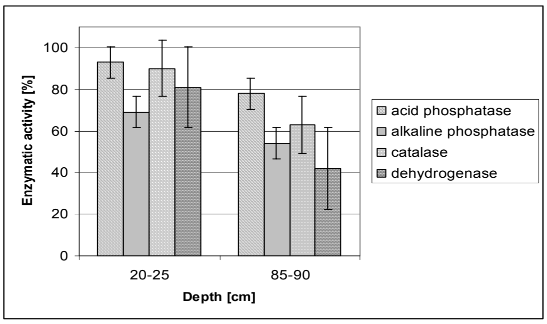


Figure 4. The effect of depth of soil profile on soil phosphatase, catalase and dehydrogenase activity

This phenomenon was connected with humus placing, quantity of which decreasing in the deeper layers. Moreover, in the surface layer the optimum conditions for living of microorganisms are occurred.

Summary

The study showed that, chromium pollution in the soil environment have a negative effect on soil enzymatic activity. Chromium is a dynamic element that has many industrial uses and as a consequence can be found throughout the environment.

Both Cr (III) as Cr (VI) forms have ability to reduce soil enzymatic activity. Dehydrogenases, phosphatases and catalases seemed to be little resistant to Cr presence in the soil. Cr (III) forms caused stronger inhibition of enzymatic activity than Cr (VI) salts. Although, Cr (III) is generally considered to be less harmful it may be of concern due to its ability to accumulate in some soils (Fendorf, 1995, Stewart, 2003). The relationship between the depth of soil profile and enzymatic activity was stated. Enzymes activity reached maximum at surface layer, where content of organic matter is responsible for the most favourable conditions for living of microorganisms.

Soil enzyme activity plays an important role in the maintenance of soil fertility, so presence of heavy metals in the soil environment is very disadvantageous for their activity and proper soil functioning.

References

Anderson J.A. Catalase activity, hydrogen peroxide content and thermotolerance of pepper leaves. Scientia Horticulturae 95 (2002) 277-284

Baum C., Leinweber P., Schlichting A. Effects of chemical conditions in re-wetted peats on temporal variation in microbial biomass and acid phosphatase activity within the growing season. Applied Soil Ecology 22 (2003) 167-174

Brzezińska M., Stępniewska Z., Stępniewski W., Włodarczyk T., Przywara G., Bennicelli R.P. Effect of oxygen defficiency on soil dehydrogenase activity (pot experiment with barley). International Agrophysics 15 (2001) 3-7

Camina F., Trasar-Cepeda C., Gil-Sotres F., Leiros C. Measurement of dehydrogenase activity in acid soils rich in organic matter. Soil Biology Biochemistry 30 (1998) 1005-1011

Casida L., Johnson J., Klein D. Soil dehydrogenate activity. Soil Sciences 98 (1964) 371-376

Cervantes C., Campos-Garcia J., Devars S., Gutierez-Corona F., et all. Interactions of chromium with microorganisms and plants. FEMS Microbiology Reviews 25 (2001) 335-347

Dąbek-Szraniawska M., Wilke B.M. Microbiological activity within various fractions of soil aggregates. Zeszyty Probl. Post. Nauk Roln. 436 (1996) 13-19

Fendorf S.E. Surface reactions of chromium in soils and waters. Geoderma 67 (1995) 55-71

Guwy A.J., Martin S.R., Hawkes F.R., Hawkes D.L. Catalase activity measurement in suspended aerobic biomass and soil samples. Enzyme and Microbial Technology 25 (1999) 669-676

Johnson J.L., Temple K.L. Some variables affecting the measurement of catalase activity in soil. Soil Sci. Soc. Am. Proc. 28 (1964) 207-209

Kramer S., Green D.M. Acid and alkaline phosphatase dynamic and their relationship to soil microclimate in a semiarid woodland. Soil Biology&Biochemistry 32 (2000) 179-188

Ledin M. Accumulation of metals by microorganisms-processes and importance for soil systems. Earth-Science reviews 51 (2000) 1-31

Stewart M.A., Jardine P.M., Barnett M.O., Mehlhorn, Hyder L.K., McKay L.D. Influence of soil geochemical and physical properties on the sorption and bioaccessibility of Chromium (III). Journal of Environmental Quality 32 (2003) 129-137

Stewart M.A., Jardine P.M., Brandt C.C., Barnett M.O., Fendorf S.E., et all. Effects of contaminant concentration, aging, and soil properties on the bioaccessibility of Cr (III) and Cr (VI) in soil. Soil and Sediment Contamination 12 (2003) 1-21

Tabatabai M.A., Bremner J.M. Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. Soil Biology&Biochemistry 1 (1969) 301-310

Tokunaga T.K., Wan J., Hazen T.C., Schwartz E., Firestone M.K., et all. Distribition of chromium contamination and microbial activity in soil aggregates. Journal Environmental Quality 32 (2003) 541-549

Trasar-Cepeda C., Leiros M.C., Seoane S., Gil-Sotres F. Limitations of soil enzymes as indicators of soil pollution. Soil Biology & Biochemistry 32 (2000) 1867-1875

Trasar-Cepeda C., Camina F., Leiros M.C., Gil-Sotres F. An improved method to measure catalase activity in soils. Soil Biology and Biochemistry 31 (1999) 483-485

Welp G. Inhibitory effects of the total and water-soluble concentrations of nine different metals on the dehydrogenate activity of a loess soil. Biol Fertility Soils 30 (1999) 132-139

Effect of waste water on wettability Eutric Histosol soil

Stępniewska, Z.[1,2] – Kosiorowska, I.[2] – Nowak, D.

Abstract

We assessed the direct and indirect effect of the waste water on *Eutric Histosol* rapidity of immersion. The method which was used TCW (*thin column wicking*) is based on Contact Angle Measurements on soil aggregates by column wicking. Soil samples were collected from control field (A -wetting by precipitation) and from field irrigated 10 times in each vegetation period with single – 60 mm (B) and double dose of waste water-120mm (C) after second step of purification mechanical and biological. Each experimental fields (A,B,C) were planted by different plants: *Populus alba* , *Salix americana* and mix of grasses .

Moisture content (MC) was establish in soil samples after drying overnight at 60 ^{o} C to the stable weight. MC is evident variable in level of tested soil depth. Significantly of MC was apparent in 0-20 cm where water content was much more lower (20%) than in 20-40 cm depth of soil.
The evident distinction is for grassland 20-40 cm (MC 32%) and 40-60cm (MC 21%) under influence of double dose of waste water.

Immersion of soils was appointed in capillars (ø 0,5 mm, 10 cm) during 300 minutes. Same of the soil samples taken from the level 20-40 cm of the field planted with *Populus alba* irrigated with single dose of waste water and from the level 40-60 cm under grassland irrigated with double dose of waste water had longer time of raise in the capillars. In control soil was observed dissimilarity with wettability except depth 40-60 cm from field with grasses and *Populus alba*.

Irrigation with waste water doses 60 and 120 mm per year during 8 years to fields *Eutric Histosol* planted by grasses, *Populus alba, Populus nigra* and *Salix americana, Salix vinimalis* has effect on decrease wettability of soil and on contact angle by water and rapid visible changes of soil surface with grassland which exist even 4-5 years when irrigation was stopped. It was shown that *Eutric Histosol* amended with waste water changed their arrange according to properties of immersion.

Introduction

Waste effluents purified can be used for irrigation of fields what is one of purpose of utililization. Even waste water sludge is very useful as source of N, P, and micronutrients which stimulate plant growth. It is known that organic matter in sewage sludge has influence on physical properties of soils. Soil can be used as filter for cleaning of ground water. Changes of soil properties are dependable on kind of plants in field and doses of waste water what has influence on hydrological relations in experimental soils.

In this paper is presented measurements of contact angles on the surface of *Eutric Histosol* irrigated by waste water to three different experimental fields (A,B,C)(levels 0-20;20-40 and 40-60 cm) which were planted by *Populus alb, Populus nigra, Salix americana, Salix vinimalis* and mix of grasses was tested.

The aim of this work was to find the influence of waste water on wettability of investigated soil.

Materials and methods

Experimental field

The soil samples collected from different depths (0-20; 20-40;40-60 cm) of the 8 ha area field located near Hajdów purification station in valley of Bystrzyca River near Lublin (Poland) was examined. Three fields 1 ha each were planted with plants. Each field was divided in the parts was wetting by: A - control (only rain water), field B and C were irrigated by waste water after second step of purification (mechanical and biological). On each control (A) field were separated other profiles A1 and A2. For each relation soil- plant was variants:
A – control soil, wetting by precipitation, ground water
B-soil irrigated by simple dose of waste water sludge (60 mm)
C- soil irrigated by double dose of waste water sludge (120 mm)

Eutric Histosol soil content 32,9 % of organic carbon and 0,39 % of total nitrate. Wetability of *Eutric Histosol* soil by different doses of waste water, was tested after 8 years irrigations.

[1] Institute of Agrophysics Polish Academy of Sciences, 20-236 Lublin, Poland
[2] Catholic University of Lublin (Poland), al. Kraśnicka 102, 20-718 Lublin. E-mail: ikosiorowska@kul.lublin.pl

Table 1. Scheme of experimental field and irrigated by single (A) and double dose (B) of waste water (planted by three types of plants).

kind of the field	A control (only rain water)	B waste doses (60 mm)	C waste doses (120 mm)
1	*Populus alba* *Populus nigra*	*Populus alba* *Populus nigra*	*Populus alba* *Populus nigra*
2	*Salix americana* *Salix vinimalis*	*Salix americana* *Salix vinimalis*	*Salix americana* *Salix vinimalis*
3	mix of grasses, mainly with species: *Alopecurus pratensis,* *Phalaris arundinacea,* *Festuca pratensis*	mix of grasses, mainly with species: *Alopecurus pratensis,* *Phalaris arundinacea,* *Festuca pratensis*	mix of grasses, mainly with species: *Alopecurus pratensis,* *Phalaris arundinacea,* *Festuca pratensis*

Species of plants on experimental fields

Experimental fields were planted by: field 1 - *Populus nigra, Populus alba*,field *2- Salix americana, Salix vinimalis,* field 3 mix of grasses mainly with species *Alopecurus pratensis, Phalaris arundinacea, Festuca pratensis*. Concentrations of nitrate and phosphate in waste water were between 1,1 and 7,1 $g\cdot m^{-3}$ N-NH_4, 20,2-38,4 $g\cdot m^{-3}$ N-NO_3 and 3,1-6,8 $g\cdot m^{-3}$ P-PO_4. Each year to the field irrigated by single dose of waste water were getting about 150 kg kg N-$NO_3\cdot ha^{-1}$.

Sample preparation

Soil samples were collected in autumn to the plastic bags in different locations of each three fields (A,B,C) from levels 0-20;20-40 and 40-60 cm.

Moisture content

Fresh soil was weighted and put in an oven (60°C). After 24 h, the dry weights of both soil and glass pot were determined. Moisture content was calculated as:

$$Moisture\,content\,(\%)=\frac{amount\,of\;fresh\,soil\,(g)-amount\,of\;dry\,soil\,(g)}{amount\,of\;dry\,soil\,(g)}x100\,\%$$

Contact angle measurements determination by thin column wicking (TCR)

Dried soil samples were cut and packed by vibrograver (MODEL 74) to the glass capillaries (10 cm heigh). Down part of each capillary was tie with not water proof material. Then glass capillaries were taken to glass box with water. For each sample was founded relation of height to which the liquid has risen in capillary (h) in time (t). Measurements were made in air temperature around 25 ^{o} C in three replication of each sample.

Appointing contact angle of soil by TCR (thin column wicking), based on access of liquid in column powder which was put into glass capillary. A liquid may penetrate spontaneously into a porous medium by capillary forces. This process, referred to as wicking, also occurs when the liquid contacts a powered soil. Wicking , i.e. the distance traveled by the liquid front (or the capillary rise of the liquid) in such materials is described by the Washburn equation (Washburn 1921):

$$h^2=\frac{R_e\gamma\cos\theta}{2\eta}\,t$$

h^2 – distance traveled by the liquid in time (t)

R_e – effective interstitial pore radius between the packed particles

θ – liquid – solid –vapor contact angle

γ- surface tension of the liquid

η- viscosity of the liquid

The wicking experiments were performed by immersing columns packed with soil particles. Thereafter, the vertical movement of the probe liquid was determined by measuring (using a stopwatch) the time *t* for the visible liquid front to reach various heights *h*. If a liquid with low surface tension as hexane is used, the liquid is expected to spread over the solid surface of the sample particles during the wicking measurements, so that $\cos\theta = 1$.

The first equation can be simplified as:

$h^2 = Kt$

where K can be determined by plotting h^2 versus capillary rise time t.

R needs to be determined using low surface liquid (hexane)

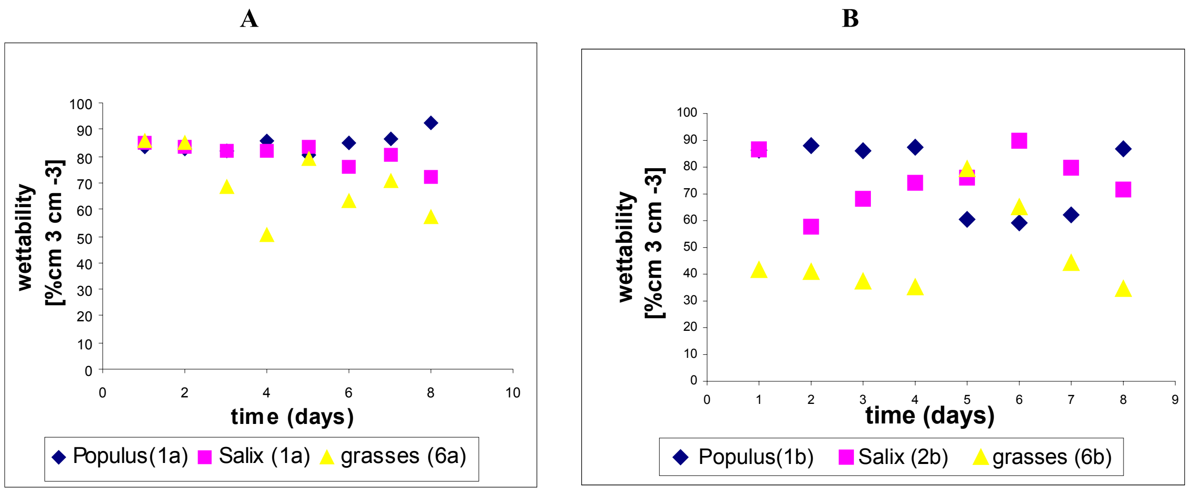
Results and discussion

The main reason for the different response in the field soil is irrigation by waste water what has persuade on reach with organic matter (OM) and change of physical and chemical properties of that soil. It has effect on wettability of fields planted by different species of plants and need of water for root system (Table 2). Irrigation of waste water to the *Eutric Histosol* soil has persuade on moissure content (MC) in dissimilar deep level of measured soil. Some of the main characteristics of the field soils confirm that the lowest moissure content is in field planted with grasses and irrigated by single dose of waste water. Increasing of MC is demonstrated in field irrigated by double dose of waste water and planted by species *Populus*.

Table 2. Relative wetability [%] of different deep levels in *Eutric Histosol* soil under influence of rain water, irrigated single and double dose of waste water in field planted by species of *Populus, Salix* and mix of grasses.

MOISSURE CONTENT [%]				
WETTED BY:	**DEPTH [cm]**	**KIND OF PLANT**		
		Populus	***Salix***	***Grasses***
RAIN WATER [%]	(0-20)	64,0	53,9	37,4
	(20-40)	66,4	68,5	62,8
	(40-60)	70,1	61,1	63,1
SINGLE DOSE OF WASTE WATER [%]	(0-20)	60,8	54,4	26,4
	(20-40)	51,7	60,5	22,1
	(40-60)	64,9	58,9	15,4
DOUBLE DOSE OF WASTE WATER [%]	(0-20)	68,0	55,8	32,4
	(20-40)	58,8	59,4	51,8
	(40-60)	70,9	58,7	32,7

Experiment has shown consequence of waste water treatment on soil properties. This relation has result on distances between interstitial pore radius and packed particles aggregates, ionic strength of capillars and content of soil water. It is visible differences of water content in field irrigated by single dose of waste water and planted by *Populus* and *Salix* compared to field wetted by rain water. In the case where soil was irrigated by double dose of waste water the lowest water content is in the field planted by mix of grasses. Wettability of soil depends on type of plants, root systems, size of plants. Increasing of angle content is result probably by contents of phosphates as composition of waste water sludge which are decreasing surface tension and water content because of easier availability.



C

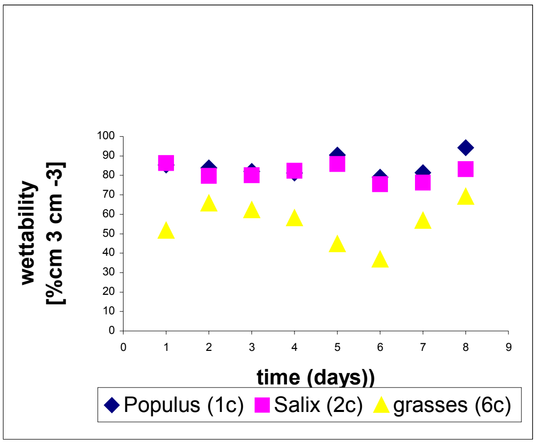


Figure 1. Wettability content [% cm ^{3}cm^{-3}] in cm *Eutric Histosol* soil under influence of rain water (A), irrigated single (B) and double dose of waste water (C) in field planted by species of *Populus,Salix* and mix of grasses.

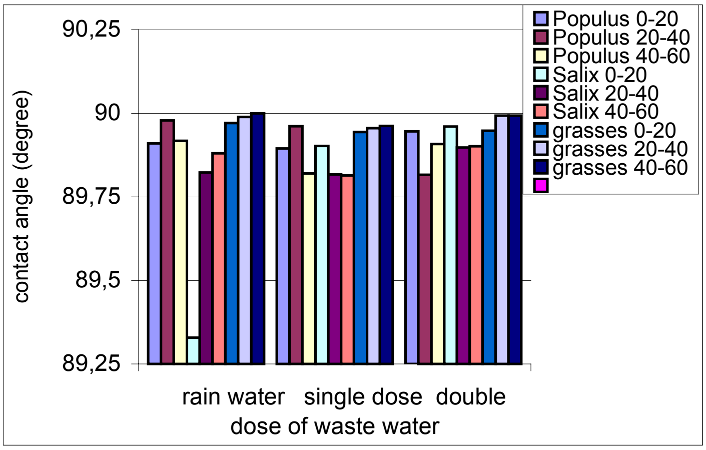


Figure 2. Contact angle *Eutric Histosol* soil under influence of rain water and irrigated with single and double dose of waste water in the field planted by different species of plants

Contact angle of *Eutric Histosol* soil was significance higher in soil irrigated by double dose of waste water compared to control field. These results are proof that waste water used as fertilizer for the soil is responsible for changes of water availability for plants including water transport to the plants and in the polluted soil environment.

References

Bachmann J., Ellies A.' Hartge K.H., Development and application of a new sessile drop contact angle method to assess soil water repellency, Journal of Hydrology, vol. 231-232, 2000, 66-75.

Decker L.E., Frank B.,Y. Suo, Garoff S., Physics of contact angle measurement, Colloids and Surfaces A: Physicochemical and Engineering Aspects, vol 156, I-III, 1999, 177-189.

Kwok D.Y., Neumann A.W., Contact angle measurement and contact angle interpretation, Advances in colloid and Interface Science, vol. 81, 1999,167-249.

Roman-Gutierrez A., Sabathier J., Guilbert S., Galet S., Cuq B., Characterization of the surface hydration properties of wheat flours and flour components by the measurement of contact angle, Power Technology, vol. 129, 2003, 37-45.

Skłodowaka A., Woźniak M., Matlakowska R., The method of contact angle measurement and estimation of work of adhesion in bioleaching of metals, Bio. Proceed Online 1999,1,114-121.

Livestock as a case study

Olubunmi, O.T.[1]

Introduction

Soil erosion originated in the early 1930s. They were stimulated largely by the persistent educational effort of such leaders as Hug hammond Bennett. Those policies were primarily concerned with maintaining farm land productivity, preserving family farm lifestyles. There is no way in which all soil degradation and conservative can not be over ruled because as its affecting the crop so its affecting the life stock. This is like a chain or cycle.

Corn production losses resulting from soil erosion, in the agro-industrial waste include maize offal, wheat offal and cassava peels. However, the energy and protein value of these by products are low. The fertility of the soil will determine the quality of the crops for feeds. An experiment was conducted as follow:
Comparative effect of urea and poultry manure on P release from rock phosphate and yield of okra (*Abelmochus esculentus*).

Objectives

To evaluate the effect of urea and poultry manure on P release from rock phosphate and yield of okra.

Methodology

Field experiments were carried out in 2001 and 2002 at the Institute of Agriculural Research and Training (I.A.R & T). The soil of the experimental site is Aquic Arenic Haplustalf. Soil samples for chemical analysis results are presented in Table 1. Also, soil samples were taken immediately in plots for P analysis following the first harvest in 2001 and prior to the second cropping and following the second harvest in 2002.

The design of the experiment was randomizd complete block with three replications. The treatments consisted of control (no fertilizer) urea, poultry manure (PM) Sokoto rock phosphate (RP) and combinations of RP with urea and PM. Urea and P were applied so that N was supplied at the rate of 100 kg. Ha -1 and 5 t. ha -1. Respectively. Sokoto rock phosphate was supplied to give P2O5 at the rate of 100 kg. ha-1. Okra (Abemoschus esculentus (L.) Moench),cv. V 35, was used as the test crop. Plant height, stem circumference, leaf area, number of fruits, and fresh fruit yield were determined. Harvesting of fruits was carried out at 3 days intervals. Yield was computed on fresh weight basis. The site was manually cleared with hoe and all the cultural operations and observations were repeated in 2002. Data collected were subjected to analysis of variance procedure and means were separated by Duncan Multiple Range Test.

Highlight of results

The effect of urea, PM, and RP applied either sol or in combination significantly affected plant height, leaf area and stem circumference in both years (Table 1) In 2001, plants treated with Rp + urea or PM and with PM alone had the tallest plants compared with control. This was followed by plants treated with RP alone. In 2002, the tallest plants were those treated with RP + PM. Those treated with urea, RP, PM and RP + urea were not significantly different. Control plants and those treated with RP were similar.

In both years the leaf area of plants treated with PM, RP + PM was among the largest. Those treated with urea alone and RP alone were less and similar to control.

In 2001, stem circumference was not affected by treatments. In 2002, plants with the largest stems were those treated with RP = PM, those with the smallest stems were control and the other were intermediate.
Number of fruits and yield were affected by treatments (Table 2). In 2001, number of fruits from plants treated with RP + PM and PM alone were among the highest. In 2002, the number of fruits treated with RP + PM, RP + urea, and PM were similar. Yield in both years were best for plants treated RP + PM. Yields of control was similar to those treated with other materials. Treatment affected P content in soil (Table 3). The plants treated with RP + PM had the highest available P. The application of PM led to higher release of P than did urea.

Conclusion

The results of this study indicated that use of RP as a P source for plant production was improved through the solubilizing effect of PM and to a lesser extent urea. The use of PM as a soil amendment could be used to improve yield of okra when the source of P was Rp.

[1] Federal College of Agriculture, IAR & T, PMB 5029, Moor-Plantation, Ibadan, Oyo State, Nigeria. E-mail: fedcolag@yahoo.com

Suggestion

This aspect of conserving the soil should not only be discuss but put into practice. This will improve the efficiency of the farm productivity.

Pollution of deeper soil horizons after long term placement of liquid manure

Füleky, Gy.[1] – Réth// áti, G.

Introduction

The Hungarian government decree (2001) in accordance with EU directive determines the maximum amount of nitrogen (170 $kgNha^{-1}yr^{-1}$) which can be distributed on agricultural land. Besides it follows with special attention the storage and placement of liquid manure.

Materials and methods

Before the declaration of decree the nitrate, ammonium, phosphorus and potassium contents of 3 m core samples were determined on an area where the liquid manure production of a pig farm was placed with bubbling/flowing technique.

In the soil samples from each 20 cm the nitrate, the AL-soluble P and K content and from some cores the organic P content were determined.

The pool was on the top of a small hill and the liquid manure (2,50 kg N, 0.34 kg P and 1.00 kg K/m^3) slowly distributed along the hillside to the direction of a river which was about 500 m from the pool
Nitrate-N content (Table 1.), ammonium-lactate-acetate (AL) soluble phosphate and potassium content (Table 2.,3) and organic phosphate content (Table 4.) of the 3m core soil samples were determined (Ballenegger-di Gléria; 1962).

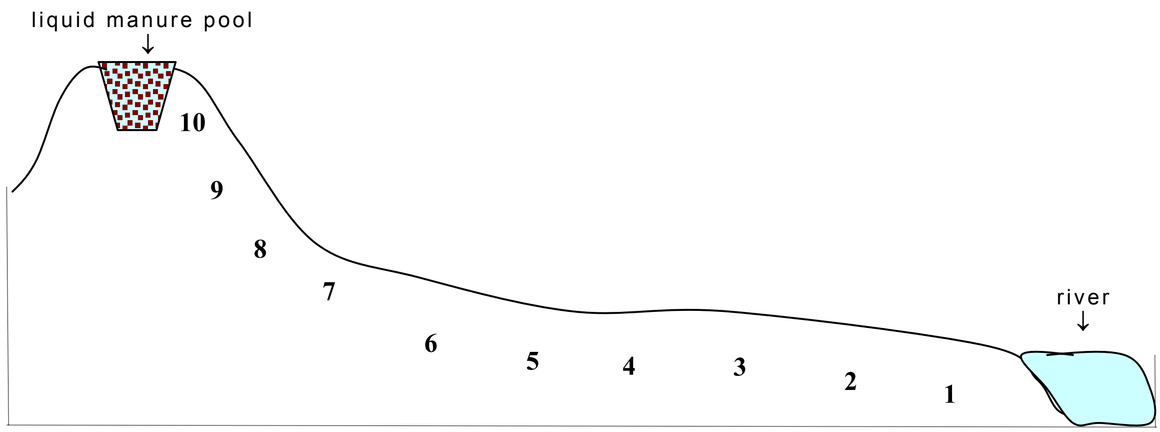


Figure 1. Place of 3m core soil samples

Results and discussion

The nitrate-N distribution in core soil samples can be seen in Table1. In the No.1. core only in the upper 1 m soil samples could be determined nitrate-N. In the other cores more or less nitrate-N could be find not only in the upper horizons but also in the deeper soil horizons. Sometimes this accumulated nitrate-N amount is very significant. The highest amount of nitrate-N was accumulated in the cores No.8. and 9. Rather high amount of nitrate-N could be found in the soil samples of core No.4.

It is clear that the highest amount of nitrate-N could be find in the soil samples of cores near to the liquid manure pool. The high amount of nitrate-N in the soil samples of core No.4. shows the role of local depressions in the nitrate-N leaching into deeper soil horizons.
The AL soluble phosphate content of soil samples are in Table 2. As the results show the accumulation of inorganic phosphate compounds depends not only on the rate of leaching but also on the chemical properties of the soil horizons. The most important chemical property effecting the AL-soluble phosphate content is the lime content of the soil. This extractum dissolves higher amount of phosphate from the calcareous soil samples.
We have to mention that the cores No.1. and 2. are on the lower terrace of the river alluvium, No.3. and 4. are on the upper terrace, No.5. and 6. on the eroded material of the small hill and the others (No.7., 8., 9., 10.) on the slope of clay hill.

[1] Szent István University Department of Soil Science and Agricultural Chemistry, Páter K. street 1, Gödöllő, Hungary; Tel.: 06-28-522-000/1817; Fax: 06-28-410-804; E-mail: Fuleky.Gyorgy@mkk.szie.hu

Rather high amount of phosphate can be found in the cores No.4., 7., 8., 9. in the upper 1 m soil horizons. Also a quite high amount of phosphate was detected in the core No.8. in the whole 3m profile, and in the cores No.4. and 5. in the deeper soil horizons.

Table 1. Nitrate-N distribution in the 3m core samples

deepth cm	**NO_3^--N kg/ha**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0-20	29	22	22	18	7	26	4	881	36	22
20-40	36	29	4	11	22	22	7	240	69	11
40-60	33	33	7	29	11	29	7	55	73	7
60-80	18	18	7	117	22	36	7	91	51	4
80-100	11	11	7	135	18	36	7	29	22	7
100-120	7	7	4	138	15	40	22	58	51	7
120-140	7	7	11	87	29	55	36	80	76	11
140-160	0	7	22	95	40	55	80	120	131	15
160-180	0	7	22	62	40	25	95	237	189	25
180-200	0	15	29	73	40	58	109	197	255	55
200-220	0	15	29	66	33	55	120	227	182	76
220-240	0	11	29	80	44	44	113	189	229	80
240-260	0	18	-*	106	33	36	117	189	277	109
260-280	0	18	-*	76	47	36	131	175	262	127
280-300	0	11	-*	87	40	36	109	164	204	138

* There was no sample for the experiment

Table 2. AL-soluble phosphate in the 3 m core samples

deepth cm	**AL-P_2O_5 mg/kg**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0-20	449	268	335	936	404	760	958	15040	590	89
20-40	408	222	169	387	319	342	458	9500	430	25
40-60	99	84	48	29	56	33	334	1271	376	50
60-80	87	112	36	8	30	35	205	779	195	56
80-100	75	168	47	8	22	41	184	312	57	68
100-120	48	46	27	8	19	21	83	92	54	52
120-140	64	46	48	9	15	8	44	292	56	64
140-160	28	75	91	20	17	6	40	180	60	60
160-180	25	56	36	109	87	39	40	525	79	94
180-200	25	97	30	51	52	39	48	572	48	94
200-220	55	114	35	128	94	33	54	1390	52	59
220-240	38	198	38	174	126	48	86	2442	34	112
240-260	31	230	-*	113	204	71	60	2175	22	25
260-280	44	170	-*	140	256	134	68	961	30	24
280-300	56	243	-*	105	234	130	115	232	44	28

* There was no sample for the experiment

The AL-soluble potassium content of soil samples are in Table 3. The same is true of the distribution of potassium, the accumulation of potassium depends not only on the leaching process but also on the properties of the soil layer, mainly on the clay content of the soil sample. This could be the explanation why is a rather high amount of potassium in the core No.1. which is fare from the pool of liquid manure but very near to the river. The explanation is the neighborhood of the river and in its floods which cover with fine materials the flooding area.

The highest amount of potassium can be found in the cores No.7., 8. and 9.

Table 3. AL-soluble potassium in the 3m core samples

deepth cm	AL-K_2O mg/kg									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0-20	444	67	381	496	1096	778	1748	3697	1319	721
20-40	405	96	291	239	881	543	1625	3071	1353	480
40-60	299	104	272	132	618	292	1551	2122	1174	113
60-80	301	138	244	150	374	147	1223	781	1186	142
80-100	255	138	207	140	254	103	942	335	715	118
100-120	262	147	228	126	277	192	825	155	426	69
120-140	244	199	239	172	320	100	376	163	322	74
140-160	108	237	260	134	338	82	271	143	302	80
160-180	93	286	274	65	313	95	244	158	297	65
180-200	133	208	282	100	287	86	297	197	294	78
200-220	135	147	285	99	202	82	252	237	294	86
220-240	175	127	299	105	138	105	294	199	247	92
240-260	228	160	-*	65	108	80	242	225	230	89
260-280	228	231	-*	105	72	92	269	177	207	99
280-300	267	281	-*	69	84	90	247	129	207	97

* There was no sample for the experiment

The distribution of organic-P in the 5 cores can be seen in Table 4. Interesting to see that the more mobile organic-P accumulates not in the cores near to the liquid manure pool, in the liquid manure impact area, but in the core No.2. which is fare from this place. There is also high amount of organic phosphate in the core No.8. in the upper soil horizons.

We can conclude that the organic phosphate in the liquid manure has not a significant role in the river and subsurface pollution. Distribution of organic-P in the core soil samples depends on the development of soil, on the composition of former river sediments and on the time to time starting soil development.

Table 4. Organic-P content of the 3 m core samples

deepth cm	Organic-P mg/kg				
	2	**4**	**7**	**8**	**9**
0-20	301	106	129	1490	147
20-40	227	164	120	112	159
40-60	193	177	115	79	111
60-80	123	153	105	24	72
80-100	228	131	83	123	83
100-120	426	156	52	121	89
120-140	197	101	90	81	64
140-160	64	136	111	62	69
160-180	142	116	104	46	37
180-200	151	91	111	4	40
200-220	62	62	97	17	29
220-240	161	68	85	62	20
240-260	12	91	59	206	20
260-280	92	59	43	6	1
280-300	32	106	30	44	0

Conclusion

Depending on the positions of the sampling places sometimes very high amounts of nitrate, phosphate and potassium contents could be determined in the 3 m soil layers.

The most mobile nitrate-N accumulated in the soil which were near to the pool and in the soils which were along the way of flowing liquid manure. The less mobile phosphate and potassium contents always were the highest in the upper soil horizons. The distribution of phosphate and potassium in the core samples shows similar picture as the nitrate-N.

The organic P content were determined only in 5 core profiles along the way of liquid manure. This more mobile phosphate form sometimes accumulated also in high amount in the samples from the deeper horizons.

References

Füleky Gy.: Nitrate movement in brown forest soil as affected by nitrogen fertilization. (1987) In: 5th International Symposium of CIEC. Balatonfüred, Proceedings. Edited by E. Welte and I. Szabolcs. Belgrade, Goettingen, Vienna, pp. 123-126.

Füleky Gy.: Leaching of Nutrient Elements from Fertilizers into Deeper Soil Zones (1991) In: Chemistry, Agriculture and the Environment. The Royal Society of Chemistry, Cambridge pp.185-208.

Füleky Gy., B. Debreczeni: Tápelem felhalmozódások 17 éves kukorica monokultúra talajában. (1991) Agrokémia és Talajtan, 40, 119-130.

Stefanovits P., Filep Gy., Füleky Gy.: Talajtan (1999), Mezőgazda Kiadó Budapest, p.470.

Ballenegger R., di Gléria J.:Talaj és trágyavizsgálati módszerek (1962), Mezőgazda Kiadó Budapest

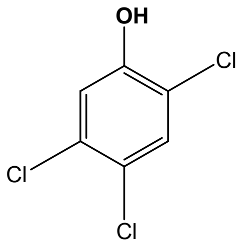
Búzás I. (ed): Talaj- és Agrokémiai Vizsgálati módszerkönyv - A talajok fizikai-kémiai és kémiai vizsgálati módszerei (1988), Mezőgazdasági Kiadó Budapest

Sorption of chlorinated aromatic compounds on soil and soil constituents

Réth※ti, G.[1] – Füleky, Gy. – Enczi, Zs.

Introduction

The aim of this study was to investigate the sorption behaviour of 2,4,5-trichlorophenol on soils and soil constituents.



Phenols are considered as priority pollutant since they are harmful to organisms at low concentration. 2,4,5-trichlorophenol is a very toxic and carcinogen contaminant in the soil environment.

Soil organic and inorganic fractions are primarily responsible for sorption of organic contaminants. Both fractions have the capability to sorb pesticides because of their large surface area and diverse functional groups.

Organic contaminants sorption to soil will affect its availability for microbial degradation and influence the effectiveness of bioremediation to clean up contaminated soil.

Materials and methods

Sorption experiments were carried out in batch condition: 1 g of adsorbent was shaken up with 10 cm^3 2,4,5-trichlorophenol solution. Because of the soil water serves primarily for chemical transport within the soil matrix, were used 2,4,5-trichlorophenols solved in water.

Laboratory equilibrium studies were performed at extended concentration ranges (from 0,5 to 800 mg l^{-1}) on soils and soil constituents (humic acid, goethite, kaolinite, montmorillonite and two different Hungarian soils - I. is a Brown Forest Soil, II. is a Chernozem).

2,4,5-trichlorophenol concentrations in the equilibrated liquid phase were quantified with high-performance-liquid cromatograph by UV (215 nm). The adsorption processes could be described by Langmuir isotherm.

The parameters calculated from the equation provide an opportunity to estimate the extent of adsorption constant and adsorption maximum.

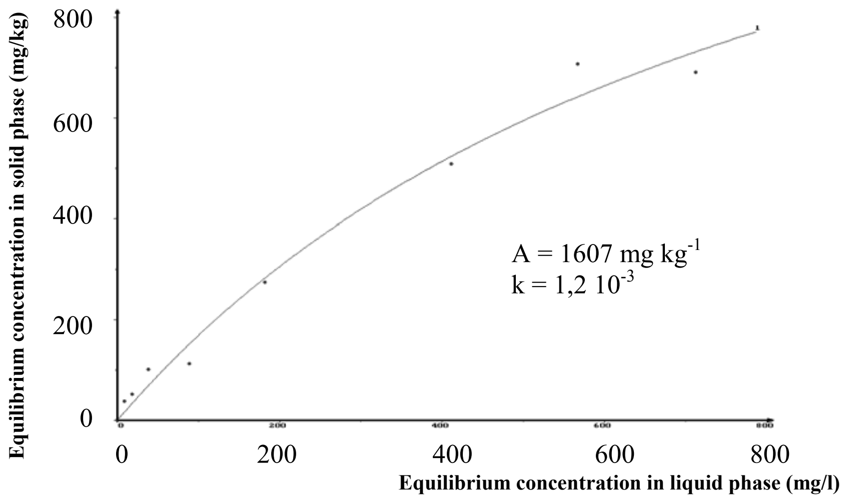
Results

Langmuir equation isoterm was fitted to the experimental data:

$$q = \frac{Akc}{1 + kc}$$

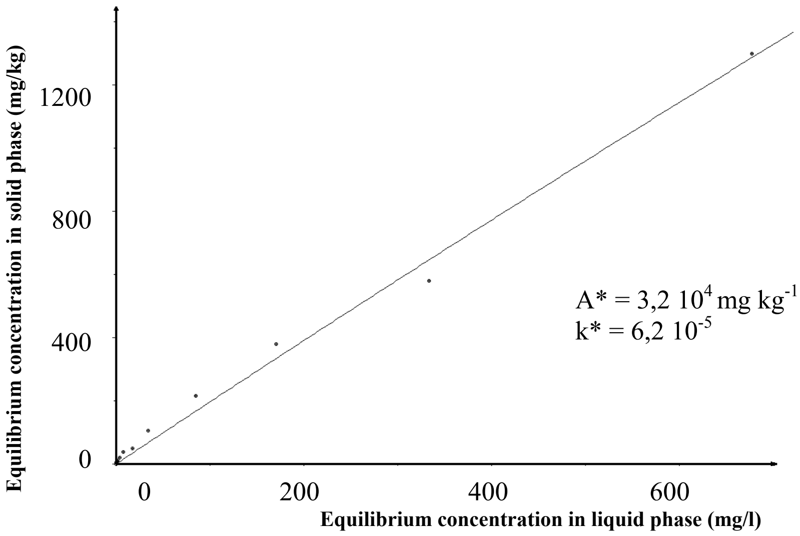
where q is the amount of adsorbed 2,4,5-trichlorophenol (mg kg^{-1}),
c is the equilibrium 2,4,5-trichlorophenol concentration in solution (mg l^{-1}),
A represents the adsorption capacity (mg kg^{-1}),
k is the adsorption equilibrium constant (mg^{-1})

Figure 1. Adsorption isotherm for 2,4,5-trichlorophenol on soil I . (Szárítópuszta)



[1] Szent István University Department of Soil Science and Agricultural Chemistry, Páter K. street 1, Gödöllő, Hungary; Tel.: 06-28-522-000/1817; Fax: 06-28-410-804; E-mail: rethg@spike.fa.gau.hu

Figure 2. Adsorption isotherm for 2,4,5-trichlorophenol on soil II. (Nagyhörcsök)



* *non realistic value because of the linear-like approximation*

Figure 3. Adsorption isotherm for 2,4,5-trichlorophenol on Goethite

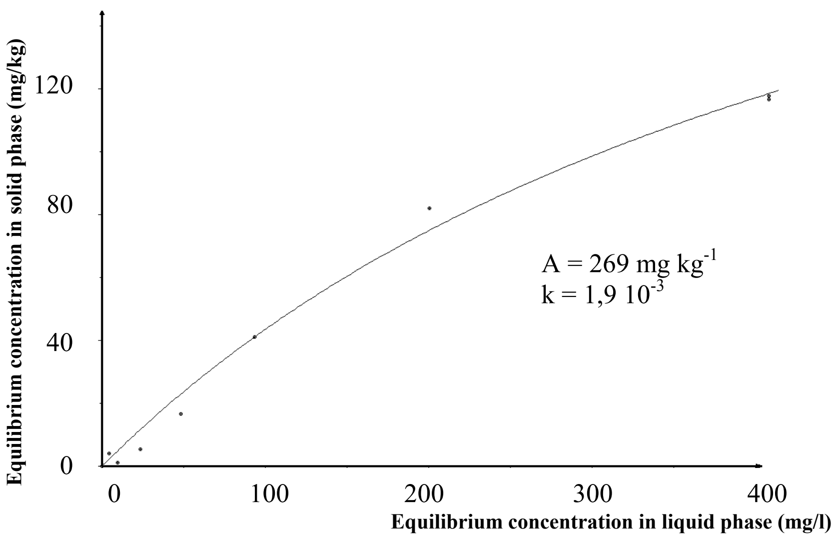


Figure 4. Adsorption isotherm for 2,4,5-trichlorophenol on Kaolinite

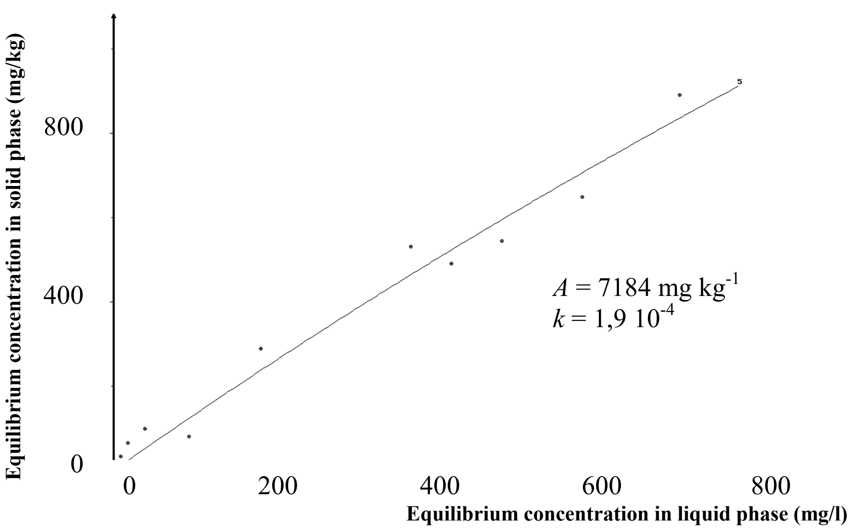


Figure 5. Adsorption isotherm for 2,4,5-trichlorophenol on Montmorillonite

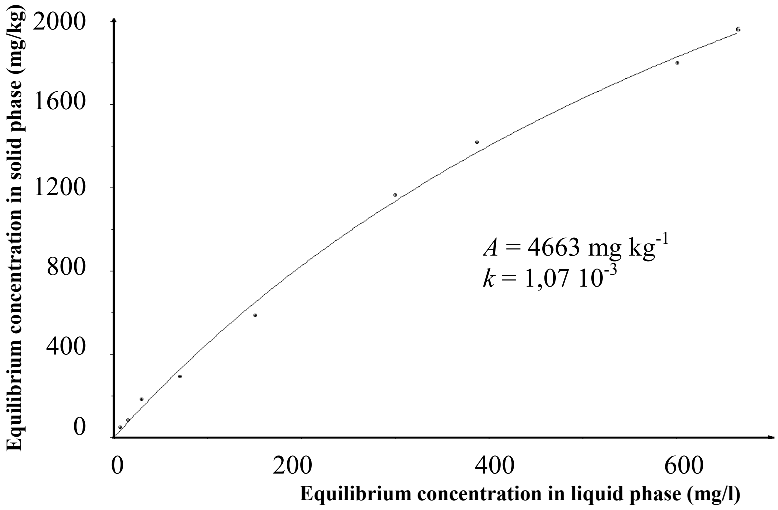


Figure 6. Adsorption isotherm for 2,4,5-trichlorophenol on humic acid

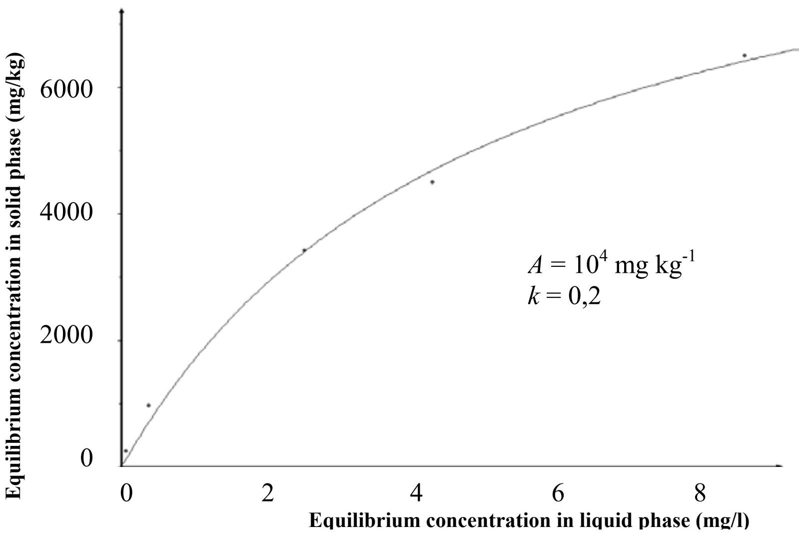
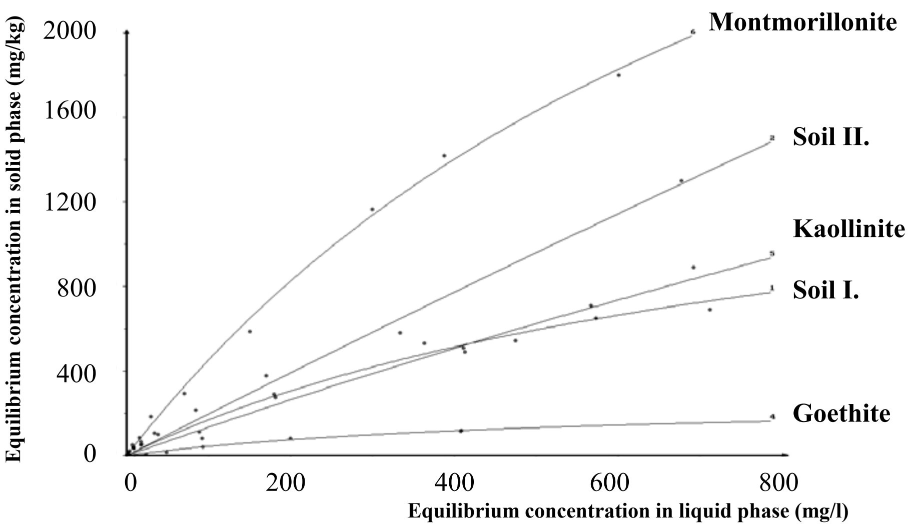


Figure 7. Adsorption isotherms for 2,4,5-trichlorophenol on soils and soil constituents



Conclusions

The sorption potential of organic pollutant to soil is partially controlled by its chemical and physical properties. The intermolecular forces which can attract organic contaminants to functional groups and subsequently sorb them have been classified as to sorption mechanisms. The nature of the sorption process is only partly understood but a number of mechanisms have been identified, such as physical binding through van der Waals forces and chemical binding through dipole-dipole interactions, cation or water bridging, H-bonding, ion exchange, covalent bonding, or ligand exchange. Several mechanisms may simultaneously contribute to organic compounds sorption and the strength of each binding mechanism probably will vary as a function of time.

Table 1. shows the percentage of adsorbed 2,4,5-trichlorophenols where the 100 % is the maximum amount of 2,4,5-tricholorophenol on 1 g adsorbent.

Table 1. Rate of adsorption of 2,4,5-trichlorophenol on different adsorbents

Adsorbents	**Adsorbed 2,4,5-trichlorophenol from 100%**
Humic acid	99
Montmorillonite	23
Soil II. (Nagyhörcsök)	16
Kaolinite	12
Soil I. (Gödöllő)	9
Goethite	6
Quartz sand	4

On the evidence of the results it can be provided that the humic acid adsorbed 2,4,5-trichlorophenol at the highest amount followed by monmorillonit, kaolinite and soils.

The adsorbed percentage displayed the following order of different adsorbents to 2,4,5-tricholophenol:

quartz sand < goethite < soil I. (Gödöllő) < kaolinite < soil II. (Nagyhörcsök) < montmorillonite< humic acid.

It can be seen from the data that the adsorption maximum depends firstly on the humus content. The second property, which positively influences the organic molecule sorption is the surface area of the adsorbent. This explains the very little adsorption capacity of quartz sand. Further experiments are necessary to explain the role of pH, the specific area of adsorbent, etc.

Refernces

I. Czinkota., R. Földényi, Zs. Lengyel, A. Márton (2002) Adsorption of propisochlor on soils and soil components equation for multi-step isotherms. Chemosphere 48. pp 725-731

N. Calace, E. Nardi, B.M. Petronio, M. Pietroletti (2002) Adsorption of phenols by papermill sludges. Environment Pollution 118. pp. 315-319

L.N. Konda; I. Czinkota; Gy. Füleky; Gy. Morovján (2002) Modeling of Single-Step and Multistep Adsorption Isotherms of Organic Pesticides on Soil. Journal of Agricultural and Food Chemistry 50. pp 7326-7331

D.C.Adriano, J.M. Bollag, W.T.Frankenberger, R.C. Sims (ed.). (1999). Bioremediation of Contaminated Soils., Agronomy, Madison, WI.

H.D. Skipper, R.F. Turco (ed.). (1995). Bioremediation Science and Applications, SSSA Spec.Publ.17. 43.Madison,WI.

W.J. Lyman, P.J. Reidy, B.Levy, Camp Dresser & McKee Inc. Cambridge, Massachusetts 02142 (1991) A Scientific Evaluating of the Mobility and Degradability of Organic Contaminants in Subsurface Environments, United States Environmental Protection Agency, Cincinnati, Ohio

Soil improvement with composted agricultural waste materials

Aleksza, L.[1] – Dér, S.[22] – Kovács, D.[2] – Füleky, Gy.[2]

Introduction

The European Compost Network, which integrates the European compost producers, trade and research institutions including the Hungarian Quality Compost Association, established a working group for the application of compost materials to soil conservation (one of the European soil conservation priorities).

Research project: Field tests with the aim of proving the soil-improving property of composts

Materials and methods

A dangerous waste material, the raw hide of rabbit, cattle manure, traw and clay were composted and it was used for the plot experiment. That was a 14-hectare area with sandy soil and levels of low productivity. Each parcel was 8 m wide and 50 m long. Each treatment was repeated four times and the control treatment eight times.

Table 1. The different treatments

1st treatment	0 –control
2nd treatment	20 t/h compost
3rd treatment	40 t/h compost
4th treatment	100 t/h compost

During the experiment 1st class IDA 3459 hybrid maize seeds were used. The date of sowing was May 5th.
The harvest was on September 30th.
For the soil examinations we used average samples taken from the parcels. Samples were taken three times.

Table 2. Time of samle collection

Samples taken	Date the samples were taken	Comment
1st sample	March 13th	before fertilizing
2nd sample	June 20th	during vegetation
3rd sample	October 10th	after harvesting

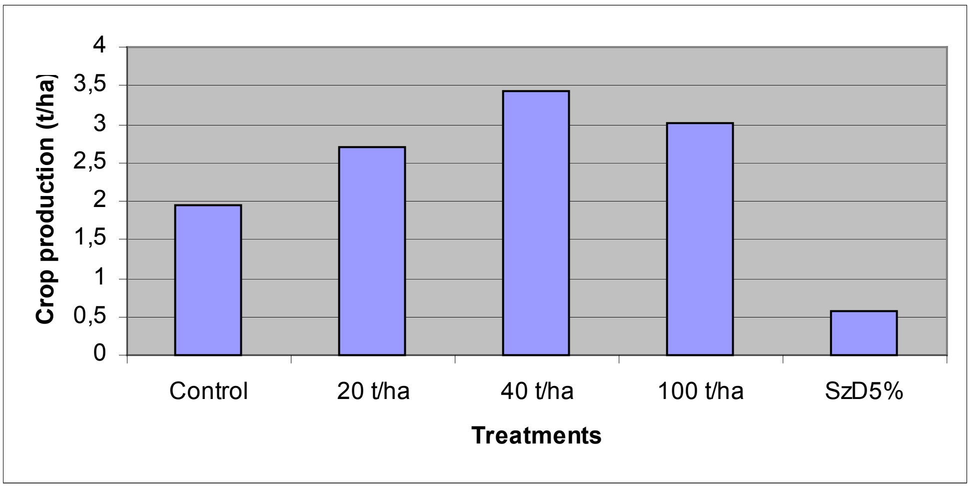


Figure 1. Yield of maize experiment

Results

The 100 t/h compost treatment did not raise the harvest volume. Compared to the 40 t/h treatment there was a reduction rather than an increase. The reason for this is that a considerable amount of biomass was worked into the soil, which hindered the growth of plants to some extent.

[1] Hungarian Quality Compost Association, Gödöllő, Hungary, 2100 Gödöllő, Hungary, Tel:+36-28/422-880
[2] Szent István University Department of Soil Science and Agricultural Chemistry, Gödöllő, Hungary, Tel.: 06-28/522-000/1817; Fax:06-28/410-804

As a result of the different compost treatments the acidity of the parcels in a depth of 0-30 cm has significantly increased. The 100 t/h treatment resulted in the highest acidity. 30-60 deep in the soil it was only the 100 t/h treatment that led to acidity figures significantly different from the results of the other treatments.

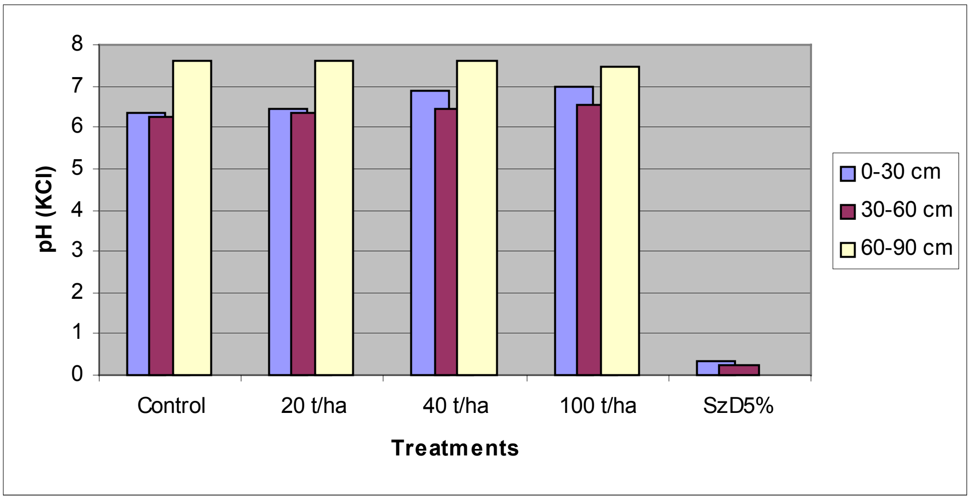


Figure 2. pH of soil in different compost treatments

The explanation for the considerable degree of acidity increase is the zero $CaCO_3$ content of the soil. The buffering capacity of sandy soils is minimal without any hidden acidity.

With the 100 t/h treatment 1979 kg/h calcium-carbonate got into the soil, which resulted in the increase of acidity. This increase, however, is not permanent since in such sandy soil poor in colloids this amount of carbonate gets soon washed away into deeper layers. This phenomenon is proved by the fact that in the case of the 100 t/h treatment the acidity increased in the 30-90 cm layer already.

In the upper layer of the soil (0-30 cm) the mineralization process of the nitrogen begins following fertilization as a reaction to spring moisture and the fast increase of the temperature characteristic of sandy soils. In the case of the treatment without any fertilization the mineral nitrogen content of the soil stays low during the whole vegetation season due to the low levels of humus content. In the case of the 40 t/h treatment the mineral nitrogen content was 98 kg/h in the upper layer of the soil (0-30 cm) when the June sample was taken. According to the Hungarian MÉM-NAK artificial fertilization guiding principles 34 kg/h nitrogen is needed for 1 ton maize harvest together with its stems in the area of the experiment. Based on the measured N-min figures in the 0-30 cm layer of the soil it is clear that in the case of the 40 t/h and 100 t/h treatments the released mineral nitrogen content of the soil was enough for harvest volumes of 4,5 – 5,5 t/h. The lower harvest average is not the result of a poor nitrogen supply.

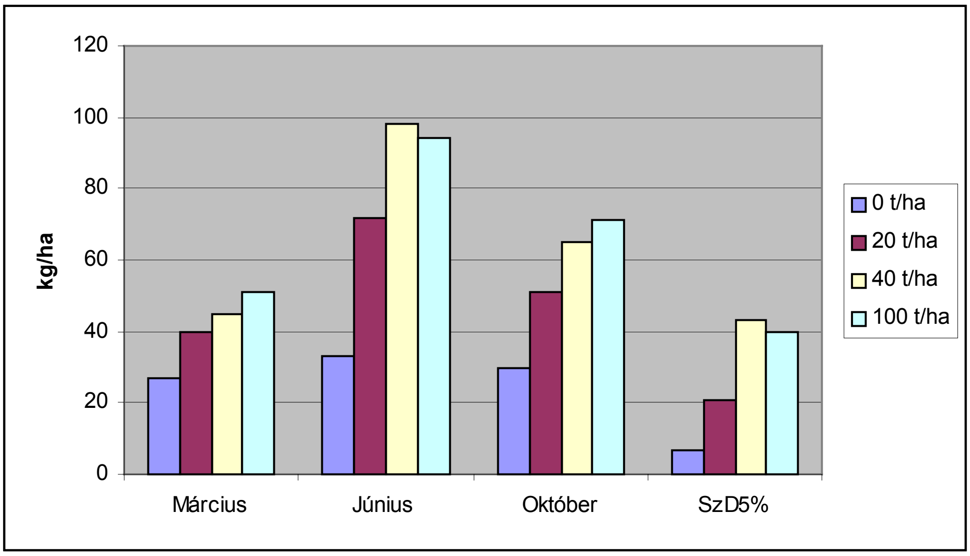


Figure 3. Mineral nitrogen content of the soil, 0-30 cm

The examination of the speed of mineralization shows that the quantity of released mineral nitrogen is proportionate with the quantity of the treatment

An examination of the mineral nitrogen content in the deeper layers of the soil shows that the nitrogen that is mineraliziert in the upper layer (0-30 cm) gradually gets into the deeper ones. The nitrogen filters into those layers as nitrate. This nitrogen movement affects only the 0-60 cm layer.

A comparison of the mineral nitrogen content of the 60-90 cm layer in relation to time shows that in autumn the nitrogen concentration is not higher than in the previous periods

The examination of the phosphorus and potassium content of composts makes it clear that the 40 and 100 t/h treatments supply the quantity necessary to reach a maize harvest of about 5 t/h. The phosphorus content of the soil increased in proportion to the treatments. The increase is evident 30-60 cm deep in the soil.

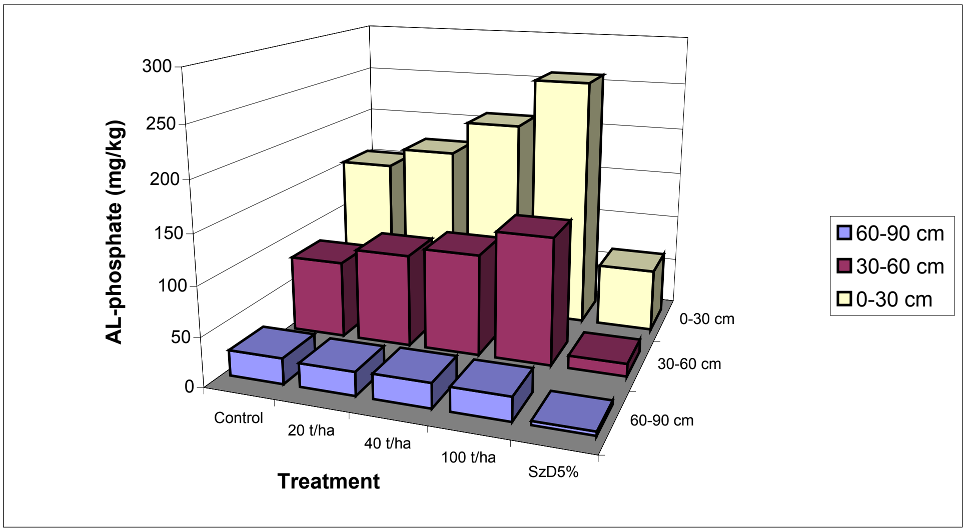


Figure 4. The AL-soluble phosphate content of the soil

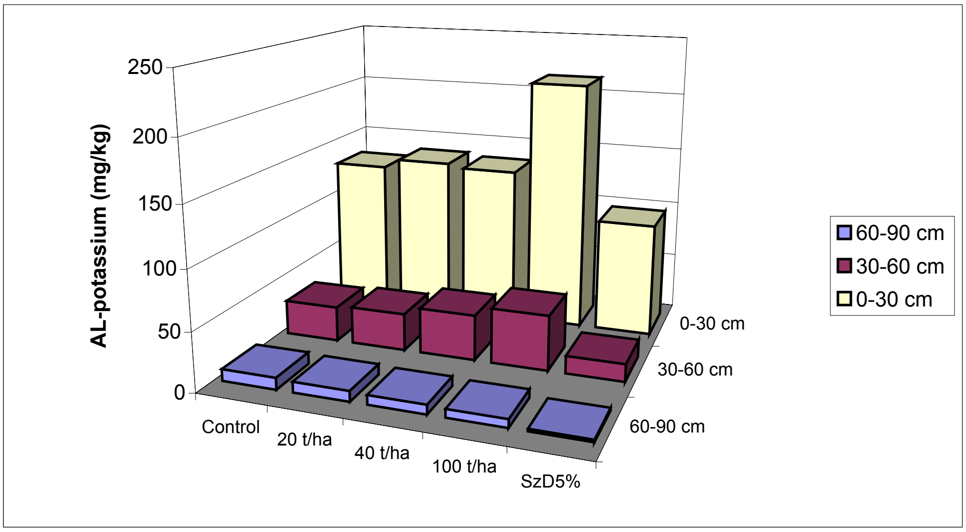


Figure 5. The AL-soluble potassium content of the soil

The results of the experiments show that the composts treatments did not lead to a considerable amount of phosphorus washed away since there is no significant difference between the figures of the treated and of the control samples in a depth of 60-90 cm.

The figures of the potassium content make it clear that the compost treatments provide enough potassium for the maize plant. At the end of the vegetation period it is only the 100 t/h treatment that leads to a measurable increase in the potassium content. The plant could draw the potassium content of the compost easily. It was only the 100 t/h treatment that resulted in a 10% rise in the potassium content in a depth of 30-60 cm.

Summary
The field tests were conducted in order to study the effects of the different compost treatments (20-40-100 t/h) on the volume of the maize harvest and on the nutrient content of the soils.

1. During the experiments the highest harvest volume (3.43 t/h) was reached with the 40 t/h treatment. This volume counts as an average harvest if one considers the results of the treatment without fertilizing (1.95 t/h).
2. Considering the chemical properties of the soil the rise in the acidity levels in the upper layers means an improvement.
3. In autumn in the deeper layers of the soil the easily solvable nitrogen content as nitrate rose to some extent as a result of (100 t/h) treatment. The 40 t/h treatment also provides enough nitrogen for the plants (4.5 t/h on harvest levels).
4. The 40 t/h treatment supplies enough phosphorus and potassium to cover the needs of maize. No significant quantities are washed away either in the case of the 40 or the 100 t/h treatment.
5. If the highest level treatment is applied each year, the nitrate and phosphorus get washed away from the root zone.

To sum up, the conclusion is to be drawn that in the case of sandy soils rich in humus the 40 t/h compost fertilizing treatment should be applied if maize is grown. The compost should be spread in spring before sowing since the Hungarian climatic conditions make it possible for the compost that is spread to cover the highest nutrient needs of maize typical in the early summer and this way one can avoid the phenomenon of winter nutrients getting washed away characteristic of wet weather conditions.

References

ALEKSZA L., DÉR S. (1995): Composting of animal origin dangerous wastes. Diplom, GATE Department of Soil Science and Agricultura, Gödöllő, 75 p.

ALEKSZA L., DÉR S. (1995): Composting technology for using of animal origin, dangerous wastes. Gödöllő. Artisjus number: 951103001T.

HARADA Y. (1990): Composting and land application of animal wastes. In Proceedings of the 5th Asian Australian Association of Animal Production (AAAP) Societies Congress, Taipei, Taiwan 27 May-1 June, 1990. Vol.1: 264-287.

Cadmium and trace element levels in some agricultural soils under various crops in the Bursa Province of Turkey

Aydinalp, C. [1]– Füleky, Gy.

Introduction

Iron, manganese, copper and zinc are important trace elements in the biosphere. These elements play significant roles in enzymes of plants and animals and its concentrations in compartments of the soil-plant animal web have been much studied both from the standpoint of a limiting nutrient in short supply and as a toxic element in abundance (Prasad, 1993). Cadmium is taken up to varying degrees by plants thereby entering the food chain (Das et al., 1997). Cadmium is a potent toxin for animals (Friberg, 1974) and the element has been increased in concentration in certain ecosystems by industrial operations and by disposal 88 of domestic and industrial wastes (Elliott and Stevenson, 1977; Torrey, 1979). Some naturally high soil levels of Cd are associated with organic-rich black shales and sulfide bearing ore deposits (Tourtelot, 1970).

The general distribution of the agricultural soil order in the Bursa Province (Anonymous, 1995) amounts to alluvial soils, cultivated for orchards, vegetables and cereals occurring on flat topography adjacent to the Nilufer River on the hilly landscape of the Uludag Mountain that occurs across the southern side of the Bursa city. This research was carried out to determine total and DTPA extractable Fe, Mn, Cu, Zn and Cd levels with some important properties of agricultural soils from the alluvial plain under various crops in the Bursa province of Turkey.

Materials and methods

The research area is located in the Bursa plain of northwestern Turkey between 40° 14′ - 40° 15′ N latitudes and 29° 08′ - 29° 12′ E longitudes ranging from 130 m to 150 m above mean sea level. The mean annual precipitation and temperature are 713.1 mm and 14.4 °C in the plain. The soil temperature and moisture regimes are thermic and xeric respectively. Ten alluvial soil sites were selected for this study. These soils were formed on calcareous alluvial sediments. The research area is cultivated for various vegetables such as tomatoes, pepper and okra. The soil samples were taken from 0-20 and 20-40 cm depth and analyzed for particle-size distribution (Gee and Bauder, 1982), pH in a 1:2 soil:water ratio (McLean), organic carbon (Nelson and Sommers, 1982), total nitrogen (Bremner and Mulvaney, 1982), calcium carbonate (Nelson, 1982), electrical conductivity (SCS, 1972), available phosphorus (Olsen and Sommers, 1982), CEC (Rhoades, 1982), exchangeable cations (Thomas, 1982) and DTPA extractable Fe, Mn, Cu, Zn and Cd (Lindsay and Norvell, 1978). Digestion of soil samples (1 g) were carried out in 10 ml concentrated HNO_3 and HCl solution (3:1 ratio) analyzed for total concentrations of Fe, Mn, Cu, Zn and Cd by ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometer).

Results and Discussion

The investigated soils showed various physical and chemical properties. The texture was loam at two depths in the first five sites. The other sites had loam texture in the surface. Then, subsurface soil horizon had loam and clay loam texture. Clay content of soils varied from 16.0 to 29.4% and increased with depth. The pH values ranged from 7.2 to 7.9. The organic C and total N values varied from 0.43 to 1.35% and from 0.05 to 0.13% respectively, and both decreased consistently with depth. C/N ratios ranged from 8.0 to 11.5. The low organic carbon and total nitrogen values were due to rapid decomposition of organic matter under Mediterranean climate in the northwestern Turkey. The $CaCO_3$ content of the soils increased with depth and values ranged from 1.0 to 4.5%. The highest values were shown at the lowest horizons due to calcareous parent material. Electrical conductivity values varied from 0.21 to 0.70 dS m^{-1}. The results indicated that these soils are not saline. Available P values ranged from 4.35 to 15.64 mg kg^{-1} and decreased with depth. CEC values were highest in the subsurface horizons and the similar trend was observed in the clay contents of the soils. CEC values varied from 15.1 to 25.9 cmol (+) kg^{-1}. Exchangeable Ca and Mg ranged from 11.3 to 22.6 cmol (+) kg^{-1} and 1.4 to 2.0 cmol (+) kg^{-1}, respectively. Exchangeable K varied from 0.5 to 1.9 cmol (+) kg^{-1} and decreased with depth. Exchangeable Na ranged from 1.0 to 1.9 cmol (+) kg^{-1} and increased with depth. Base saturation was 100% in all the profiles due to the presence of free $CaCO_3$.

The total metal concentrations of the soils varied in each soil sites. The values of Fe and Mn ranged from 6,907.000 to 13,742.000 mg kg^{-1} and 502 to 893 mg kg^{-1}. Cu and Zn varied from 34.08 to 81.62 mg kg^{-1} to 72.46 to 110.57 mg kg^{-1}. Cd ranged from 2.80 to 3.45 mg kg^{-1}. These soils had higher total heavy metal concentrations in the surface horizon than the lower horizon. The DTPA extractable metal concentrations of the

[1] Uludag University, Faculty of Agriculture, Department of Soil Science, 16059 Bursa, Turkey. Tel.: +90-224-4428970; Fax: +90-224-4428077; E-mail: cumhur@uludag.edu.tr

soils are were found in higher concentrations in the surface horizon and decreased with depth. The values of Fe and Mn ranged from 4.80 to 10.56 mg kg^{-1} and 5.18 to 9.43 mg kg^{-1}. Cu varied from 4.23 to 8.12, Zn from 1.20 to 1.31 and Cd from 0.51 to 0.89 mg kg^{-1}. These metals were accumulated in the surface horizons both total and DTPA extractable forms in the studied soils.

Table 1. The total and DTPA-extractable metal concentrations of the soils at two sampling depths.

Site	Depth (cm)	Total Concentrations, mg kg^{-1}					DTPA-extractable metal concentrations, mg kg^{-1}				
		Fe	Mn	Cu	Zn	Cd	Fe	Mn	Cu	Zn	Cd
1	0-20	12,853.000	893	80.27	108.04	3.31	9.39	9.43	7.85	1.30	0.80
	20-40	8,627.000	771	63.51	92.63	3.17	6.81	8.15	5.63	1.27	0.71
2	0-20	13,742.000	696	81.62	101.27	3.22	10.56	7.64	8.12	1.28	0.75
	20-40	9,160.000	502	72.03	87.45	3.04	7.27	5.48	6.90	1.25	0.69
3	0-20	12,037.000	795	78.94	110.57	3.20	9.09	8.91	7.54	1.31	0.70
	20-40	10,451.000	653	69.37	98.61	2.97	8.14	6.72	6.07	1.28	0.64
4	0-20	11,288.000	871	70.59	107.38	3.45	8.67	9.30	6.81	1.30	0.89
	20-40	8,136.000	667	57.21	100.45	3.37	6.05	7.46	4.45	1.26	0.80
5	0-20	11,094.000	750	79.06	104.72	3.40	8.83	8.09	8.04	1.28	0.84
	20-40	7,812.000	608	64.83	97.36	3.28	5.20	6.27	5.63	1.25	0.78
6	0-20	8,205.000	643	76.47	92.14	2.95	6.74	6.80	7.41	1.23	0.63
	20-40	6,947.000	591	72.11	85.02	2.91	5.03	5.19	6.82	1.20	0.57
7	0-20	10,839.000	682	74.23	94.53	2.93	7.81	7.56	6.93	1.26	0.60
	20-40	7,905.000	623	61.08	91.47	2.86	6.36	6.08	5.04	1.23	0.54
8	0-20	10,163.000	717	66.39	96.25	2.99	7.32	7.92	5.77	1.27	0.67
	20-40	7,242.000	659	63.72	78.61	2.88	5.08	6.34	5.06	1.21	0.61
9	0-20	7,585.000	678	70.16	98.12	2.92	6.11	7.43	7.12	1.25	0.55
	20-40	6,737.000	651	68.35	72.46	2.80	4.80	5.18	6.45	1.20	0.51
10	0-20	7,143.000	732	60.91	104.07	3.14	5.77	8.25	5.34	1.28	0.60
	20-40	6,907.000	680	34.08	88.91	3.01	4.92	6.77	4.23	1.26	0.57

The values of extractable Fe, Mn, Cu and Zn are lower than toxic limits in the studied soils (Martens and Lindsay, 1980; Kabata-Pendias, and Pendias, 1992). However, DTPA extractable microelements are in sufficient levels for plant growth (Martens and Lindsay, 1980; Mengel and Kirkby, 1979). Nevertheless, Cd values were high for plants. Local farmers fertilized these soils with phosphorus fertilizer intensively in the studied area for a long time. This facility was caused Cd pollution in the soils and concentration reached to toxic levels for the plants. Aydinalp et al., (2002) stated that some differences were occurred at soil properties of irrigated alluvial soils with the polluted water from the Nilufer River in the alluvial plain. The main differences were observed the total and DTPA-extractable heavy metal concentrations. The investigated ten soil sites had low Cd values than the irrigated sites. Nevertheless, these values were reached the toxic levels for the plants. Pollution does not exceed the allowed limits (Kabata-Pendias, and Pendias, 1992) for Fe, Mn, Cu and Zn.

Conclusion

The intensive use of phosphorus fertilization was affected the total and DTPA-extractable Cd content of the studied agricultural soils under intensive various plant cultivation. The results indicated that Cd values were at toxic levels for plants and this would cause the accumulation of Cd in the cultivated crops. In the longer term, Cd accumulation could affect the human health, if it enters the food chain.

References

Anonymous. 1995. *Bursa Ili Arazi Varligi*. T.C. Basbakanlik Koy Hizmetleri Genel Mudurlugu Yayinlari. Il Rapor No: 16, Ankara.

Aydinalp, C. and Marinova, S. 2002. Distribution of some heavy metals in the alluvial soils of the Bursa plain, Turkey. *J. of Agricultural Science and Forest Science*. I (2-4): 84-88, Sofia, Bulgaria.

Bremner, J.M. and Mulvaney, C.S. 1982. Nitrogen-total. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds.), *Methods of soil analysis,* Part 2: Chemical and microbiological properties. 2nd ed. American Society of Agronomy, Madison, WI, pp. 595-624.

Das, P., Samantaray, S. and Rout, G. R. 1997. Studies on cadmium toxicity in plants – a review. Environ. Poll. 98:29-36.

Elliott, L. F. and Stevenson, F. J. 1977. Symposium on soils for management of organic wastes and waste waters. Proc. of symp. Soils for management of organic wastes and waste waters. Muscle Shoals, AL. 11-13 Mar. 1975.

Friberg, L. 1974. Cadmium in the environment. 2d ed. Cleveland. CRC Press.

Gee, G.W. and Bauder, J.W. 1982. Particle-size analysis. In: Klute, A. (ed.), *Methods of soil analysis,* Part I: Physical and mineralogical methods. 2nd ed. American Society of Agronomy, Madison, WI, pp. 383-412.

Kabata-Pendias, A. and Pendias, H. 1992. *Trace Elements in Soils and Plants*. CRC. Press, Inc. Boca Ratón, Florida, p. 315.

Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. *Soil Sci. Soc. Am. J.*, 42: 421-428.

Martens, D.C. and Lindsay, W.L. 1980. Testing soils of copper, iron, manganese and zinc. *In Soil Testing and Plant Analysis*, 3rd Ed.; Westerman, R. L., Eds.; Soil Science Society of America: Madison, WI, pp. 229-260.

McLean, E.O. 1982. Soil pH and lime requirement. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds.), *Methods of soil analysis,* Part 2: Chemical and microbiological properties. 2nd ed. American Society of Agronomy, Madison, WI, pp. 199-224.

Mengel, K. and Kirkby, E. 1979. *Principle of Plant Nutrition*, 2nd Ed.; International Potash Institute: Bern, Switzerland.

Nelson, R.E. 1982. Carbonate and gypsum. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds.), *Methods of soil analysis. Part 2*: Chemical and microbiological properties. 2nd ed. American Society of Agronomy, Madison, WI, pp. 181-198.

Nelson, D.W. and Sommers, L.E. 1982. Total carbon, organic carbon, and organic matter. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds.), *Methods of soil analysis. Part 2*: Chemical and microbiological properties. 2nd ed. American Society of Agronomy, Madison, WI, pp. 538-580.

Olsen, S.R. and Sommers, L.E. 1982. Phosphorus. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds.), *Methods of soil analysis*. *Part 2*: Chemical and microbiological properties. 2nd ed. American Society of Agronomy, Madison, WI, pp. 403-430.

Prasad, A. S. 1993. Biochemistry of zinc. New York. Plenum Press.

Rhoades, J.D. 1982. Cation exchange capacity. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds.), *Methods of soil analysis. Part 2*: Chemical and microbiological properties. 2nd ed. American Society of Agronomy, Madison, WI, pp. 149-158.

Soil Conservation Service. 1972. *Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples*. U.S. Dep. of Agriculture Soil Survey Investigations Rep. No. 1. U.S. Government Printing Office, Washington, D.C.

Thomas, G.W. 1982. Exchangeable cations. In: Page, A.L., Miller, R.H. and Keeney, D.R. (eds.), *Methods of soil analysis. Part 2*: Chemical and microbiological properties. 2nd ed. American Society of Agronomy, Madison, WI, pp. 159-166.

Torrey, S. 1979. Sludge disposal by land spreading techniques. Pollution. Tech. Rev. 58. Noyes Data Corp.

Tourtelot, E. B. 1970. Selected annotated bibliography of minor-element content of marine black shales and related sedimentary rocks, 1930-65. U.S. Geol. Surv. Bull.1293.

Presence of alkylbenzene sulfonates in a Mediterranean forest soil amended with sludges

Andreu, V.[1] – Rubio, J.L. – Picó, Y.

Abstract

During the last years the use of composted sludges as organic amendment has suffered a great increase for soil amelioration. Usually, it has been applied on agriculture but other ways have been turned up like those related with forest soil restoration, in particular, after forest fires or for reforestation. In the process of sludge production high quantities of surfactants are used, between them linear alkylbenzene sulfonates (LASs) are the most commonly anionic surfactants used. Because of that the application of sludges as organic amendments is under debate since unknown contaminants, present in these products, may lead to a wide range of problems that could cause adverse effects in human population. In this case LASs can pollute soil, through the application of those organic amendments, by their biodegradation intermediates, sulfophenyl carboxylic acids (SPCs).

The aim of this work is to determine the levels of LASs present in a Mediterranean forest soil, Rendzic Leptosol, which was amended with composted sludges for reforestation. Samples were taken from three different zones: untreated soil, soil amended with sludges in a 5 % w/w ratio and soil amended with sludge in a 10 % w/w ratio.

LASs and SPCs were extracted with methanol followed by solid phase extraction (SPE) with C_{18} and determined by liquid chromatography-mass spectrometry (LC-MS). Recoveries ranged from 89 to 94 % and the linear range of the method from 0.008 to 7.4 mg/kg with a limit of detection between 0.15 and 1.5 µg/kg extracting 5 g of soil. Data obtained showed that LASs and SPCs were present also in untreated samples. However, samples treated with sewage sludges presented LASs and SPCs at concentrations between 5 and 10 times higher than those untreated. The concentration of LASs and SPCs found in the samples were depending on the amount of sewage sludge added.

Introduction

Many of the soils that characterize the Valencian Community (Spain) have been dedicated to cultivation because of the increment of agriculture. They are, mainly, of Cambisol, Calcisol and Regosol types (FAO, 1988). These soils, under the climatic characteristics of aridity that characterize great part of this Community, are usually poor in organic matter and don't show very favorable conditions for an acceptable productivity or profitability. In the last decade, the use of sludges and composts of different origins (mainly of waste treatment plants) like amendments to increase the quality of soils for their agricultural or forest management has been increased. In many cases, composition of these sludges is a little or very barely well-known, and contain chemical substances potentially toxic and polluting, among those the surfactants agents are some of the most habitual (Generalitat Valenciana, 1995; Generalitat Valenciana, 1998).

Linear alkylbenzene sulfonates (LASs) are the most widely used tensioactives. Of 6 million tons of tensioactives produced to world scale in 1994, almost 2.4 million tons were LASs, which are marketed like complex mixtures of several homologous (with alkylic chains that oscillate between 10 and 14 atoms of carbon) and isomeres (according to the position of the benzenic ring in the alkylic chain).

The incidence of the LASs in soils is scarcely documented in the different countries of the European Union. It has been settled down that the levels of LASs, are very variable, oscillating from 1 mg kg^{-1} in soils that have not been amended with sludges during more than two years, until levels of more than 47 mg kg^{-1} for soils treated with these amendments. The transport of LASs from soil to plants has been described for crops of rice, soy and oat in different experiments in those that tensioactives have been applied. However, very little is still known about the levels of LASs in natural soils, and the main reason is the lack of reliable analytical methods for its determination (Ou et al., 1997). On this situation, to undertake actions guided to correct and to recover the soil, it is primordial to know the levels, causes and evolution of the contamination that it suffers. The application of sludges and composts require an analysis in depth of their environmental impact.

Several works describe the determination of LASs in other environmental matrices, especially in sediment and waters from treatment plants and in the marine waters, using specific chromatographic methods. Solid phase extraction and liquid chromatography with detectors of mass spectrometry or fluorescence (González-Mallet & Gómez Vine, 1996; Di Corcia, 1998; Thiele et al., 1999; Vogt & Heining, 1999; Castle et al., 2000; Riu et al., 2001) have been the preferred techniques to carry out the determination.

The objective of the present study is to determine the levels of LASs by developing and fine tunning a method of analysis, generic and simple, that allows determining LASs, in a characteristic forest soil of the Valencian Community, by means of liquid chromatography- mass espectrometry (LC/MS) and solid phase

[1] Centro de Investigaciones sobre Desertificación-CIDE. Camí de la Marjal, s/n. 46470–Albal (Valencia, SPAIN); Tel.: +34 96 122 05 40; Fax: +34 96 127 09 67; E-mail: vicente.andreu-perez@uv.es

extraction (SPE). The developed method was applied to the determination of these compounds in a soil without treatments and treated with 5 and 10% in weight of sewage sludges.

Material and methods

Reagents

LASs were kindly provided by Petresa (Madrid, Spain) in a mixture with the following percentage of each homologous C_{10} (3.9%), C_{11} 37.4%), C_{12} (34.4%), C_{13} (21.3%) and C_{14} (0.2%). Methanol (Merck, Darmstatdt, Germany) and the deionized water, obtained with a MilliQ system, were filtered through a Nylon filter of 0.45 µm Scharlau (Barcelona, Spain). The solid phase used C_{18} was acquired of Analysis Vínicos (Tomelloso, Spain).

Soils and sampling

Eight soil samples, of the superficial horizon (A), were taken from a burned forest area that was prepared for reforestation with a previous amendment with sludges, four of them corresponding to a zone amended with sludges in a ratio of 5 % w/w (S1) and the other four in a zone amended in a ratio of 10% w/w (S2). Four samples more were taken from a zone of the same area but not affected by fire (S0). The soil belongs to Rendzic Leptosol type (FAO, 1988). This soil showed a high content in total carbonates (45.2), pH of 7.1 and loam-sandy texture (Ingelmo al., 2003). Once in the LASoratory, they were let to dry off at room temperature, later on they were sifted through a sieve of 2 mm mesh light and homogenized. The standard analytical methods were applied for the determination of the most important physical and chemical characteristics in these samples.

Extraction

Five grams of soil were extracted three times with 20 mL of methanol during 20 minutes in an ultrasonic bath, next the methanolic extracts were evaporated to dryness in a rotavapor to 40 ºC and 337 mbar. The dry residue was redisolved in 100 mL of hot water, is acidified to pH 3 and salt is added to a concentration 0.7 M, then it is passed through a column that contains 500 mg of C_{18} previously activated with 10 mL of methanol and 10 mL of water. The retained tensioactives were eluted with 10 mL methanol that is evaporated in a N stream to a volume of 1 mL.

Liquid chromatography-mass spectrometry

The chromatographic separation was carried out with a column Zorbax SB-Aq (50 x 4.6 mm), using a gradient methanol-water and tributylamine as contraion at flow rate of 0.4 mL/mm. The detection was carried out using a mass spectrometer HP1100 equipped with an electrospay source. The conditions of the source were: voltage of the capillary, 3500 V; fragmentor 140 V; temperature and flow of the drying gas, 350 °C and 3 L/min, respectively. The EM was used in negative ionization way (NI).

Results and discussion

The different LASs were identified by the presence of the deprotonated molecule $[M-H]^-$ In Figure 1 shows the ion selected for each LAS, the cromatograms obtained when injecting a standard solution and extracts of a soil that did not contain tensioactives and a treated sample where LASs were detected. The soil extracts were clean and interfere substances did not appear.

The analytic parameters of the method are listed in Table 1. The extraction with methanol and C_{18} achieved high recoveries for all the LASs studied. Recovery and repeatability were examined on five replicate extraction and analysis of LAS-spiked soil samples. Recoveries were 89-94 %. The average recovery of the overall method was 91 % which is adequate for the demands of environmental studies.

High repeatability of the proposed extraction and analytical method was obtained. The relative standard deviation (RSD) of the overall method was < 9 %, from 4 to 9 %, average 7 %. These results show that the proposed method can be used for the determination of LAS in soil samples with high accuracy. Calibration graph 0.0008-4.6 mg/kg were linear over the whole range. The linear regression correlation coefficients were better than 0.997.

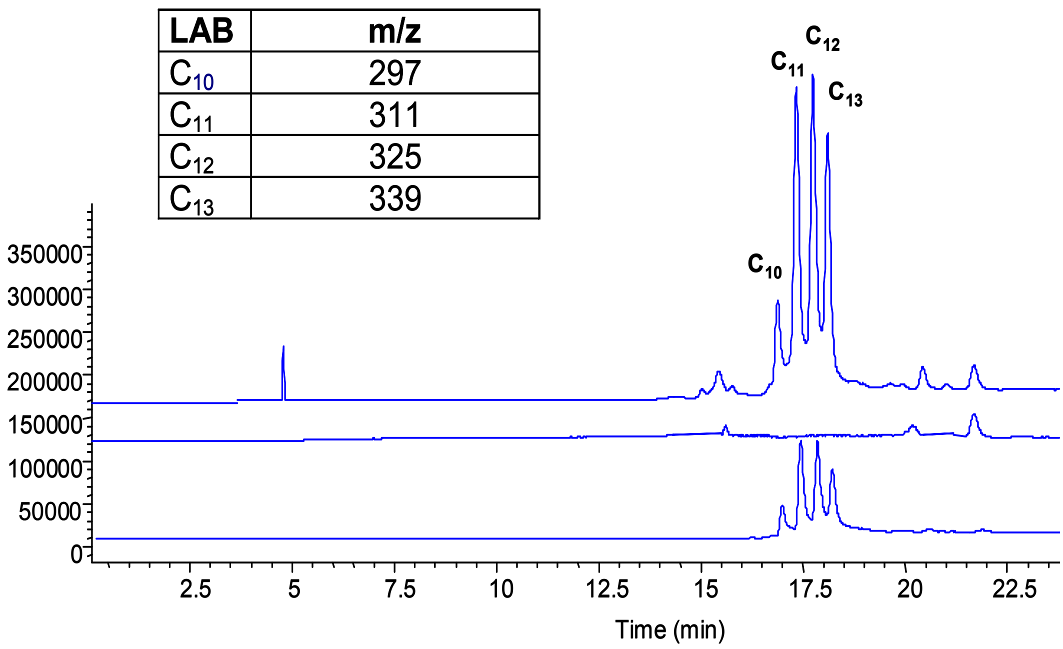


Figure 1. Cromatograms (A) standard solution that contains 0.004, 0.037, 0.035, and 0.023 mg/mL of C10, C11, C12 and C13, repectively, (B) control sample in which tensioactives weres not detected and (C) soil treated with 10 g m^{-2} of sludge (for the contents see Table 2). The ions monitored are also shown in the Figure.

Detection limits between 0.15 and 1.50 were obtained analyzing 5 g of soil depending of the LAS homologue.

The method developed in this study, which consists of methanol-ultrasonic extraction, enrichment on a C_{18} column and determination by LC-MS, has been successfully applied to the determination of LAS in soil. Besides high recovery (ca 91 %) and repeatability (RSD ca. 7 %), the method is less time consuming (1 h for the extraction) and lower solvent consumption compared with Soxhlet extraction.

Table 1. Concentration (C), Average recoveries (Rec, %), relative standard deviations (RSD, %), interval of linearity (IL), correlation coefficient (*r*), and limit of detection (LD) obtained for the soil samples (n=5).

	Accuracy and Precision			**Linearity**		**LD** (µg/kg)
LASs	C (mg/kg)	Rec (%)	RSD (%)	IL (mg/kg)	*r*	
C_{10}	0.0008	90	6	0.0008-0.8	0.997	0.25
C_{11}	0.0074	94	4	0.0074-7.4	0.999	0.15
C_{12}	0.0070	91	4	0.0070-7.0	0.999	0.15
C_{13}	0.0046	89	9	0.0046-4.6	0.998	1.50

The results obtained when analyzing the samples without amendment and the samples treated with sludges are summarized in Table 2. The concentrations of LAS in soils ranged from 0.03 to 12.50 mg/kg. These concentrations show that a substantial amount of LAS remains in soils, even in samples that have not been treated with sludges.

Analysis of soils treated with sludges confirms the higher concentrations in treated soils compared with those not amended. It must be emphasized that the amounts of LAS found is related with the percentage of sludge added to the sample.

Table 2. Concentrations (mg kg^{-1}) of the individual and total LASs in the soil samples.

Samples	C_{10}-LAS	C_{11}-LAS	C_{12}-LAS	C_{13}-LAS	Total LASs
S0	0.03	0.29	0.27	0.17	0.78
S1	0.18	1.76	1.62	1.00	4.70
S2	0.50	4.67	4.30	2.67	12.50

Conclusion

The obtained results show that to combine solid phase extraction with C18 and liquid chromatography with mass espectrometry is a simple and effective approach for the determination of LASs in soils.

LASs are present in the studied soils although they have not been treaed with organic amendments. However, a correlation exists among the treatment with muds and the levels of LASs present in the samples.

References

Castillo, M., Riu, J., Ventura, F., Boleda, R., Scheding, R., Schr H.Fr., Nistor, C., Émneus, J., U Eichhorn, P., Knepper, Th.P., Jonkers, C.C.A., de Voogt, P., González-Mazo, E., León, V.M., Barceló, D. (2000): lnter-LASoratory comparison of liquid chromatographic techniques and enzyme-linked immunosorbent assay for the determination of surfactants in waste water. J. Chromatogr. *A* 889, 195-203.

Di Corcia, A. (1998): Characterization of surfactants and their biointermediates by liquid chromatography-mass spectrometry. J. Chromatogr. *A* 794, 165-1 87.

Generalitat Valenciana (1995): Catálogo de suelos de la Comunidad Valenciana. Ed. Conselleria de Agricultura, Pesca i Alimentació, Consejo Superior de Investigaciones Científicas y Universitat de Valéncia, Valencia, 321 pp.

Generalitat Valenciana (1998): El sól com a recurs natural a la Comunitat Valenciana. Carmen Antolín Tomás (Editora). Ed. Conselleria d'obres publiques, Urbanisme 1 Transport, Generalitat \ Valénciana, Alicante, 124 pp.

González-Mazo, E. & Gómez-Parra, A. (1996): Monitoring of anionic surfactants (LAS) and their intermediate degradation products in the marine environment. Trends Anal. Chem. 15, 375-381.

Ingelmo, F., Albiach, R., Gamón, S. (2003): Organic matter of a soil amended with composted sludges and affected by simulated processes of soil degradation. Proceedings IV. International Conference on Ecosystems and Sustainable Development (ECOSUD 2003), Wesex Univ. Press, 121-126.

Ou, Z.Q., Jia, L.Q., Jin, H.Y., Yediler, A., Sun, T.H., Kettrup, A. (1997). Ultrasonic extraction and LC determination of linear alkylbenzene sulfonate in plant tissues. Chromatographia 44, 417-418.

Riu, J., Martínez, E., Barceló, D., Ginebreda, A., Tirapu, L.L. (2001): LC-MS determination of linear alkylbencenosulfonates and their carboxylic degradation products in influent and effluent water samples and sluges from sewage-treatment plants. *Fresenius J. Anal. Chem.* 371, 448-455.

Thiele, B., Günther, K., Schwuge, M.J. (1999): Trace analysis of surfactants in environmental matrices. Tenside Surf. Det. 36, 1-37.

Vogt, C. & Heining, K. (1999): Trace analysis of surfactants using chromatographic and electrophoretic techniques. Fresenius J. Anal. Chem. 363: 612-621.

Redox resistance of soils enriched with nitrates

Stępniewska, Z. [1, 2] – Szmagara, A. – Ostrowski, J.

Abstract

Addition of nitrates to soil in case of lack of oxygen leads to their consumption as electron acceptor in denitrification process. Therefore the presence of nitrates under anaerobic conditions can affect buffering of redox status in soil. Reduction of nitrates, connected with N_2O emission, appears when the amount of oxygen in soil is totally exhausted and when the water displaces the air in porous medium. Soil redox potential after reducing all available nitrates decreases below 400 mV (at pH=7).

The aim of this work was to examine a large set of soils and to determinate how an addition of nitrates affects the redox resistance of amended soils.

The selected soil samples of various properties come from arable levels of 171 mineral soils, belong to different soil units.

Both the control samples flooded only with distilled water and enriched with a nitrates solution up to 100 kg $N\text{-}NO_3^{-}\cdot ha^{-1}$ samples were incubated at the constant temperature 20°C±1°C.

The nitrates addition caused increase of t_{400} values by 0,5 day in the case of over 41% of tested soils and from 1 to 5 days for about 13% of soils as compare to control samples. In the 32% of soils did not appear any changes in redox resistance after addition of 100 kg $N\text{-}NO_3^{-}\cdot ha^{-1}$, whereas in about 13% was observed the negative effect. The difference between initial values of Eh for enriched and control samples ranged from 0 - 50 mV for over 55% of soil samples and from –50 mV to 0 for about 40% of soils.

Introduction

Nitrates introduced into soil with fertilizers, mainly in winter, are rapid taking through plants. Excess of no assimilated nitrates are leached to groundwater due to high solubility in water or undergone changes in chemical and microbiological processes.

Denitrification process, which proceeds in anaerobic conditions, is source of 70-90% of N_2O emission soils and land use practices, known as a greenhouse gas. The N_2O concentration in atmosphere is established on the level of 314 ppbv, increase about 0,2% per year and its estimated emission is equal 7 Tg year^{-1} [Khalil 2002]. It was showed that N_2O emission is correlated with soil redox potential. The beginning of N_2O emission from the light textured soils was observed at 400 mV while the in heavier textured soil below 400 mV [Włodarczyk et al. 2003].

Theoretically nitrates can also be bounded into sorption soil complex, nevertheless Polish soils are characterized by very low sorption complex to anions.

Redox potential (Eh) is an aeration parameter characterising the complex of total redox transformation occurring in soil. A progressive decrease of redox potential occurs when soils are flooded because oxygen is only sparingly soluble in water and diffuses about 10^4 times more slowly in water than in air. In these conditions proceeds in turn reduction of molecular oxygen, nitrates, oxides of manganese, oxides of iron, sulphates and carbon dioxide presented in soil solution [Schlesinger 1997].

Stability of redox potential in the environment can be describe by soil feature called "soil redox resistance" which is defined as the time, at which in the water saturated soil the redox potential decreases to the value of 400 mV corresponding to the beginning of the nitrate decomposition (t_{400}) or to 300 mV (t_{300}) characteristic to the beginning of reduction of manganese and iron oxides [Gliński et al. 2000].

The aim of this work was to investigate the effect of nitrates in Polish mineral soils on its redox resistance.

Materials and methods

For laboratory experiments, surface horizons of soil samples have been selected from the Bank of Mineral Soils of Poland situated in the Institute of Agrophysics of Polish Academy of Sciences in Lublin [Gliński et al. 1991]. The soil samples were taken from 171 soils representing 25 units of typical mineral arable soils covering Poland (Table 1).

Tested soils were air-dried and sieved (1 mm sieve), and then 30-g samples of were taken into 100-ml beakers and enriched with 30 ml of potassium nitrate solution adequate to dose 100 kg $N\text{-}NO_3^{-}\cdot ha^{-1}$, taking initial content of nitrates into consideration [Stępniewska et al. 2003]. The same amount of distilled water was added to control samples. Samples were incubated at 20°C ±1°C (Heraeus).

[1] Catholic University of Lublin, Faculty of Biochemistry and Chemistry of Environment, Al. Kraśnicka 102, 20-718 Lublin, Poland, tel. 048 81 445 46 19, e-mail: stepz@kul.lublin.pl
[2] Institute of Agrophysics, Polish Academy of Sciences, ul. Doświadczalna 4, 20-290 Lublin 27, Poland.

Eh values were measured in soil suspension by pH/redox meter (CPI-551 ELMETRON) equipped with platinum electrodes 0,5 x 4 mm and calomel electrode as reference electrode. The first measurements were made after 3 hours, and next in following days until Eh values reached level below 100 mV. Every platinum electrode was calibrated in Michaelis buffer before measurements. The Eh values are mean from measurements carried out with three platinum electrodes [Gliński and Stępniewski, 1985].

Table 1. Studied soil units and number of tested soil samples.

Number of soil unit	Soil unit	Number of soil samples
1	Rendzin Leptosols IB 1a	7
2	Rendzin Leptosols IB 1b	5
3	Haplic Phaeozem	4
4	Haplic Luvisols and Dystric Cambisols - loose sands	41
5	Haplic Luvisols and Dystric Cambisols – light loamy sands	10
6	Haplic Luvisols and Eutric Cambisols – loamy sands	4
7a	Eutric Cambisols – loamy sands over loams	16
7b	Haplic Podsols – loamy sands	12
8a	Eutric Cambisols – light loams	12
8b	Haplic Podsols – loamy sands	13
9a	Eutric Cambisols – medium loams	11
9b	Haplic Podsols – medium loams	11
10	Eutric Cambisols and Haplic Luvisols – heavy loams	5
11	Eutric Cambisols and Haplic Luvisols – non uniform loams	7
12	Haplic Luvisols and Distric Cambisols – gravels	11
13a	Eutric Cambisols – hydrogenic silts	4
13b	Haplic Podsols – hydrogenic silts	4
14	Haplic Luvisols and Eutric Cambisols – loess	8
15	Haplic Luvisols and Eutric Cambisols – clays	7
16	Haplic Luvisols and Eutric Cambisols – loams and skeleton loams	4
17	Haplic Luvisols – loams	16
18	Haplic Luvisols and Eutric Cambisols – clays	3
19	Haplic Luvisols and Eutric Cambisols – silts	3
20	Eutric Fluvisols – loams and silts	4
21	Distric Fluvisols – sands	4
22	Distric Fluvisols – sands	3
23	Mollic Gleysols – dev. from loams and silts	11
24	Mollic Gleysols – dev. from sands	7
25	Terric Histosols	5
Total		**171**

Results and discussion

The following charts changes value of Eh in time were obtained on the basis of Eh measurements at time.

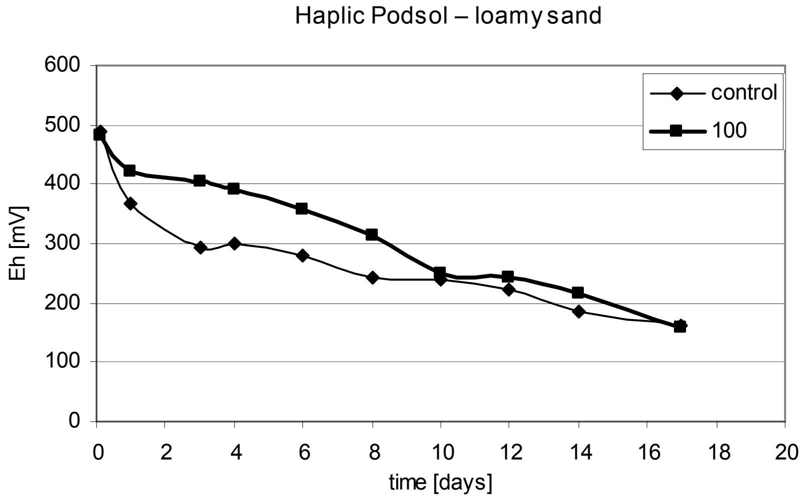


Figure 1. Dynamic of Eh changes during incubation on the example of loamy sand (Haplic Podsol) in the control and enriched with nitrates (100 kg $N\text{-}NO_3^-$ ha^{-1}).

The values of t_{400} and t_{300} were received from the Eh graphs respectively for control and nitrate enriched samples for every soil. The example of Eh dynamic during incubation period is presented on Figure 1.

The differences between initial Eh values (after 3 hours of incubation) for enriched and control samples ranged form 0 to 50 mV for over 55% and from –50 mV to 0 for about 40% of studied soils.

In order to comparison of effect of nitrates doses on rate of beginning of nitrates reduction differences between t_{400} values of enriched ($t_{400-100}$) and control soil samples ($t_{400-control}$) were calculated. It was found that about 32% of examined soils did not show any changes in redox resistance after enrichment with added dose of nitrates, for over than 41% of soils t_{400} values increase by 0,5 of day. In the case of 13% of soils negative effect was observed. In the same number of soils addition of nitrate caused increase of t_{400} values by more than 0,5 of day until even 5 days (Fig.2).

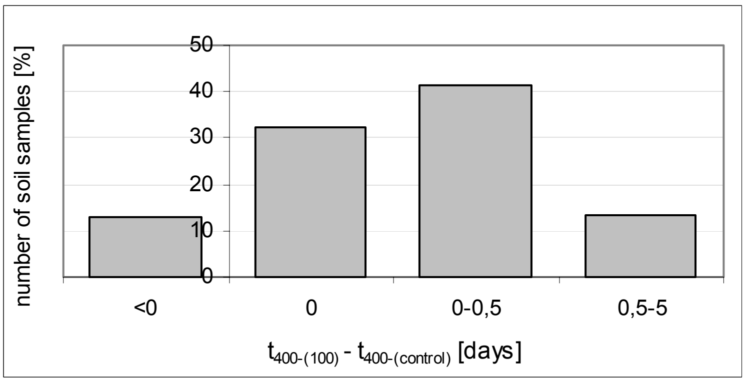


Figure 2. Histogram of soil samples number depending on difference between enriched and control t_{400} of tested soils.

In order to determination of difference between the time of nitrates reduction in control and enriched samples, t_{300} values, respectively $t_{300-(100)}$ and $t_{300-(control)}$ from 0 to 8 days and from 0 to 14 days were found. Differences between the values of $t_{300-(100)}$ and $t_{300-(control)}$ are presented in Fig. 3.

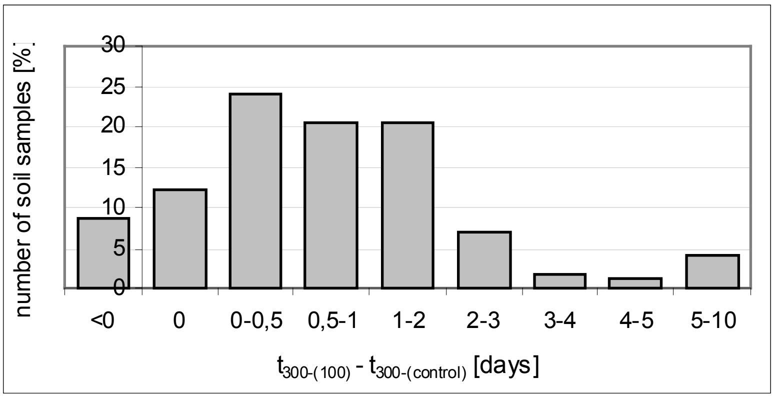


Figure 3. Histogram of soil samples number depending on differences between enriched and control samples t_{300}.

In the case of almost 9% of soils the consumption of nitrates in the first step of anaerobic condition occurred faster in enriched samples than in control samples, in about 12% did not observed any differences, but in the most of soils (79%) differences ranged from 0,5 of day even up to 10 days.

Conclusion

After first period of incubation (3 hours) Eh values of enriched and control samples differed from each other for ±50 mV.

The addition of nitrates caused the delay of reduction of nitrates by 0,5 of day in the case of over 41% of examined soils, by over than one day in 13% (maximally delay is 5 days), no effected on reduction in 32%, in 13% showed negative effect.

The t_{300}values of control samples ranged from 0 to 8 days, and nitrate enriched samples from 0 to 14 days.

The effect of addition of nitrates on time of redox resistance showed about 79% of tested soils. The highest effect of added nitrates, i.e. difference between t_{300} of enriched and control samples ranges even 10 days.

References

Gliński J., Ostrowski J., Stęniewska Z., Stępniewski W.: Bank of soil samples representing mineral soils of Poland (in Polish). Problemy Agrofizyki, 66, 1-57, 1991.

Gliński J., Stępniewska Z., Stępniewski W., Ostrowski J., Szmagara A.: A contribution to the assessment of potential denitrification in arable mineral soils of Poland. Journal of Water and Land Development No. 4, 175-183, 2000.

Gliński J., Stępniewski W.: Soil Aeration and Its Role for Plants. CRC Press Inc., Boca Raton, Florida, 1985.

Khalil M.A.K., Rasmussen R.A., Shearer M.J.: Atmospheric nitrous oxide: patterns of global change during recent decades and centuries. Chemosphere, 47, 807-821, 2002.

Stępniewska Z., Szmagara A., Ostrowski J.: Determination of ”native” contents of nitrate in arable soils of Poland (in Polish). Acta Agrophysica, 84, 129-136, 2003.

Schlesinger W. H.: Biogeochemistry: an analysis of climate change. Academic Press Inc., London, 1997.

Włodarczyk T., Stępniewska Z., Brzezińska M.: Denitrification, organic matter redox potential transformation in Cambisols. International Agrophysics, 17, 219-227, 2003.

Composition of phytocoenose and uptake of nutrients depending on soil compaction in barley field

Reintam, E.[1] – Kuht, J. – Puust, J. – Neem, P.

Introduction

On the estimation productivity of plants in agro- ecosystems the greatest attention is paid on cultural plants. Little attention is paid on weeds; which production and competition ability depends also on changes in conditions of habit. Many weed species have adapted their life cycle with cultural plants and are important components of field coenose. Weeds have an important role in formation of habit light and moisture conditions and binding of free nutrients in agro ecosystem. Total destruction of weeds means destroying many regulation mechanisms formed on earlier phases of cultural plants.

Talking about soil compaction mostly the compaction effect on soil properties is discussed. There are plenty of works focused on studying machinery and their vehicle effect and its modeling on different soil parameters, especially on soil bulk density, penetration resistance, water tension, structure and porosity of soil on different soil types (Alakukku et al., 2003; Lipiec and Hatano, 2003 etc.). As a result of changed soil parameters effect on plant growth is mostly presented as impact on cultural plant production, on yield (Boone and Veen, 1994; Arvidsson, 1997; Aura, 1999; Lipiec et al., 2003 etc.). There are also several investigations about root growth in compacted soils and nutrient uptake of some cultural plants (Tardieu, 1988; Yamaguchi and Tanaka, 1989). There are insufficient experimental data about soil compaction effect on weed flora, their nutrition and competition ability with cultural plants. Changes in weed phytocoenose depending on tillage intensity (Gill, Arshad, 1998; Bischoff and Mahn, 2000 etc.) or depending on different tillage methods are mostly investigated (Jones et al., 1995). Uptake of nutrients by weeds is investigated mostly generally (Singh et al., 1993), but also by species (Andersson and Lundegårdh, 1999) and in coenose with different cultural plants (Bockholt et al., 1995; Guil-Guerrero and Torija-Isasa, 1997).

The aim of this work was to investigate the soil compaction effect on composition of phytocoenose and nutrient uptake by some most widespread weed species in barley (*Hordeum vulgare* L.) field.

Material and methods

Data were collected from Estonian Agricultural University research field (58º23´N, 26º44´E) with different levels of soil compaction on sandy loam soil at Tartu County in 2001, 2002 and 2003. By heavy tractor (with loader; total weight 4.9 Mg) soil compaction was done for getting different levels of bulk density before showing time in spring 2001, 2002 and 2003. For all that traffic applied uniformly to cover the entire experimental plots: 1 time, 3 times and 6 times. Drilling of barley with 450 germinating seeds per m^2 was done. No fertilizers and herbicides were used. Soil type of experiment areas was *Fragi-Stagnic Luvisol* in WRB and *Fragic Glossudalf* in USDA Soil Taxonomy classification. From the diagnostic horizons the umbric, ferralic, stagnic and argillic horizons were founded in soil of experimental areas. The soil characteristics of umbric horizon of experimental area are presented in the following: C 1.4%, N 0.11%, K 164 mg kg^{-1}, P 183 mg kg^{-1}, Ca 674 mg kg^{-1}, Mg 101 mg kg^{-1}, pH_{KCl} 6.2, sand (2.0...0.02 mm) 67.9%, silt (0.02...0.002 mm) 22.9% and clay (<0.002 mm) 9.2%. The samples of soil and plants were taken in earring phase of barley. Data regarding the content of phytocoenosis were obtained from taking vegetation samples from a plot of 0.25 m^2 (n=4). The types of components were determined, counted, measured and weighed. Plant samples from each variant were taken for measuring nutrient content. Soil bulk density was measured with 50 cm^3 cylinders in 10 cm layers up to 40 cm. For the chemical analysis of plants the Kjeldhal method was used to determine the content of total nitrogen. The content of phosphorus was determined colorimetrically on the basis of yellow phosphorus-molybdatic. Potassium content was determined by flame photometer in dipping solution diluted with distilled water. Mathematical methods, namely the analysis of variance (ANOVA) and correlation analysis were used to process the collected data.

Results

To determine the effect of soil compaction on the plants, the bulk density from the soil parameters was measured (table 1). As compaction did not cause great changes in soil bulk density the first year, there was also no significant decrease of plants total phytomass. Significant (by LSD_{95}) decrease was observed only on barley mass on the level of 6-times compaction (figure 1). With compaction also weed dry mass and number of plants per square meter decreased, but it was not statistically significant. The first year the most widespread weed

[1] Estonian Agricultural University, 64 Kreutzwaldi St., 51014 Tartu, Estonia; Tel.: +372-31-35-37; Fax: +372-31-35-39; E-mail: endla@eau.ee

species were white goosefoot (*Chenopodium album* L.), field pennycress (*Thlaspi arvense* L.), common fumitory (*Fumaria officinalis* L.) and chickweed (*Stellaria media* (L.) Cyr.). Second year compaction increased weeds

Table 1. Soil bulk densities (Mg m^{-3}) of experiment field depending on compaction times in plough layer (average of 30 cm) with 4.9 Mg tractor in different experiment years

Year	Control	Times of compaction		
	(0x)	1 times (1x)	3 times (3x)	6 times (6x)
2001	1.54	1.59	1.62	1.63
2002	1.54	1.59	1.60	1.72
2003	1.46	1.55	1.59	1.64

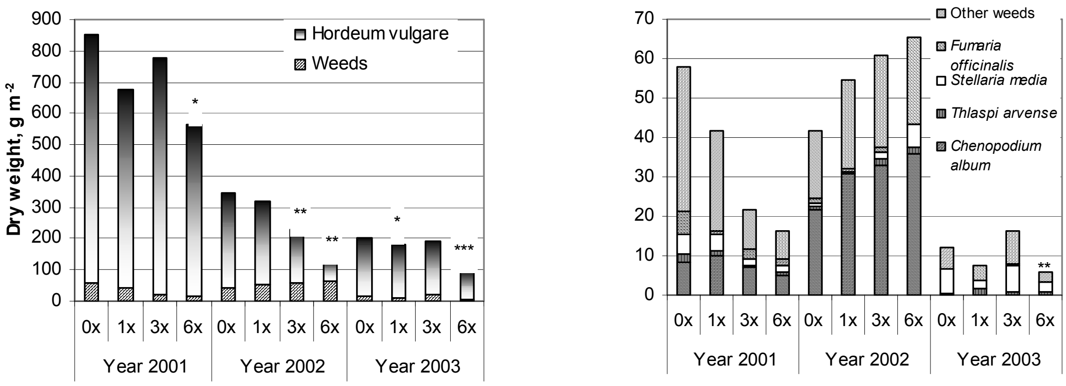


Figure 1. Soil compaction effect on phytomass and composition of phytocoenose in different experiment years on spring barley (*Hordeum vulgare* L.) field; significance: *–LSD_{95}; **–LSD_{99}; ***–$LSD_{99.9}$

share in phytocoenose from 12% in control up to 52% in 6-times compacted variant and decreased significantly share of barley. The third year the changes were not so drastical. Still the increase of weeds in coenose was observed. After three years of soil compaction without fertilizers use, the total phytomass and also barley yield was only ¼ from first year phytomass and even in control variant. From weed species the common fumitory was most sensitive. Compaction decreased his biomass already the first year by 80%. The second and third year there was no one plant of common fumitory detected on 6-times compacted variant. At the same time the share of chickweed and great plantain (*Plantago major* L.) increased with increasing of soil bulk density, especially the third, rainy year (figure 1). Also the number of corn spurry (*Spergula arvensis* L.) increased and corn mayweed (*Matricaria inodora* L.) plants in phytocoenose (data not presented).

Most of investigated weed species had higher nitrogen content in their shoots than barley, especially white goosefoot. The first year only barley had higher nitrogen content than white goosefoot, common fumitory and field pennycress and lower nitrogen content than chickweed (figure 2). Phosphorus (figure 3) and potassium (figure 4) content was highest in chickweed and in white goosefoot. Common fumitory and barley had lowest phosphorus and field pennycress lowest potassium content in their dry matter.

Compaction did not cause any significant changes in plant nitrogen, phosphorus and potassium content after first year soil compaction. Second year soil compaction decreased nitrogen content in most investigated weed species up to 3-times compaction variant. 6-times compaction increased the nitrogen content again. Nitrogen content in barley dry matter increased with increasing of soil bulk density. The same was observed after the third year soil compaction (figure 2). No positive correlation between nutrient content and soil compaction was observed in case of phosphorus and potassium. Compaction inhibited phosphorus and potassium uptake of all investigated species (figure 3 and 4).

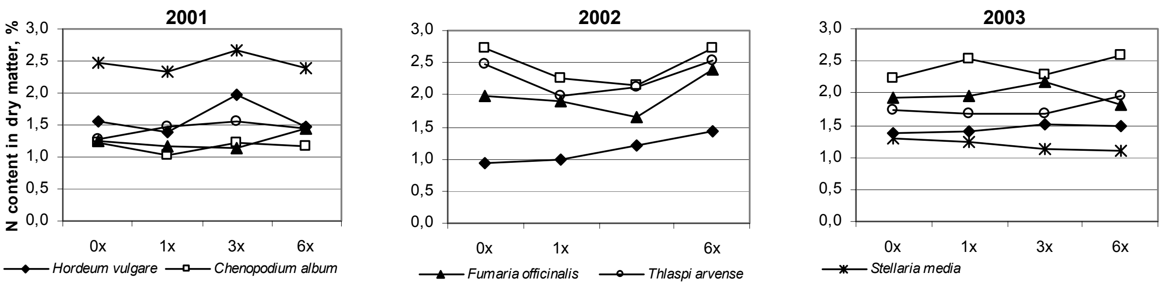


Figure 2. Plant nitrogen content in dry matter depending on soil compaction in different experiment years

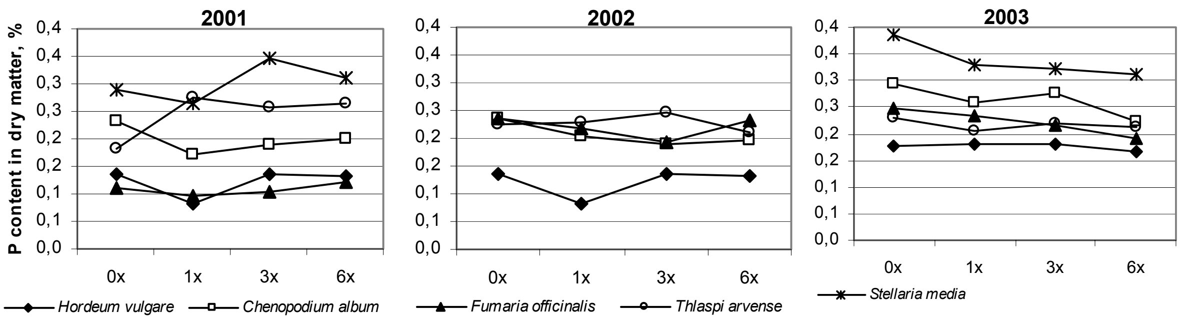


Figure 3. Plant phosphorus content in dry matter depending on soil compaction in different experiment years

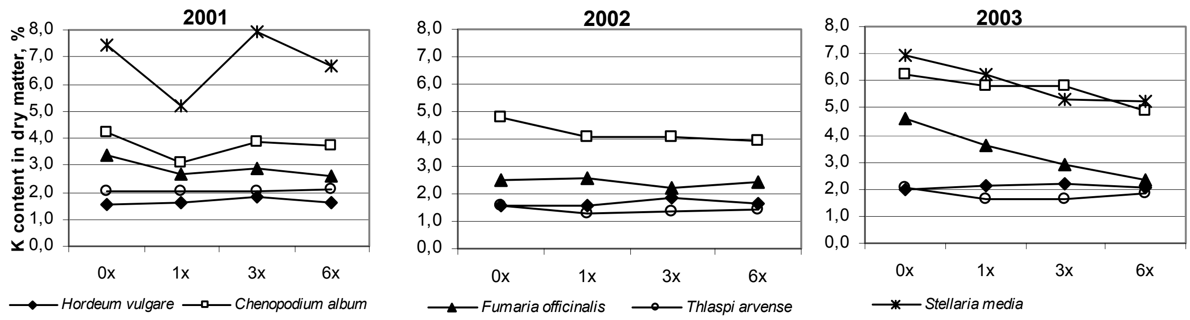


Figure 4. Plant potassium content in dry matter depending on soil compaction in different experiment years

Discussion

Changes of dominant weed species in phytocoenose during three years were caused by changes in soil conditions: decrease of available nutrients in soil, higher soil penetration resistance and soil bulk density. Like cultural plants also weeds have different preferences on environment parameters. Common fumitory and field pennycress prefer fertile and sandy loam soils. Great plantain and corn mayweed are common on edges of field and waysides, corn spurry on soils with low fertility. Increase of the share of corn mayweed and corn spurry on compacted soil was detected also in earlier experiments (Kuht et al., 1999; Reintam and Kuht, 2002).

Most of weeds have higher nutrient content in their dry matter. The higher weeds nutrient content compared to the cultural plants observed also Quasem and Khattari (1993). The lower nitrogen need of many weed species can give them advantage in competition with cereals (Di Tomaso, 1995). One of serious competitors in case of most important nutrients for all cultural plants is white goosefoot (Quasem and Khattari, 1993). In weed coenose existing species at different age have the essential role on higher nutrient uptake by weeds. Some weed species, such as corn mayweed and chickweed, grow during vegetation period 2...3 generations, but the young plants are more rich in nutrients. Also Bockholt et al. (1995) observed the high nutrient, especially potassium assimilation of young chickweed plants.

The main problem why the nutrient content in plants dry matter will decrease is connected with plant root distribution in compacted soil. Result of soil compaction is decreased root size, retarded root penetration and smaller rooting depth (Unger and Kaspar, 1994) and in compact wet soil poor aeration (O´Sullivan and Ball, 1993). Decreased root size results in greater distances between the neighboring roots and affects water and nutrient uptake (Tardieu, 1988; Yamaguchi and Tanaka, 1989). Soil aeration influences the content of mineral nitrogen in the soil by its effect on nitrogen mineralization and denitrification (Lipiec and Stepniewski, 1995). Slow growth due to mechanical resistance may induce morphological and hormonal changes in the plants. There is also an interaction between compaction and soil water status; carbon mineralization increases with increasing water content in loose soil but decreases in compact soil (Arvidsson, 1997). The increase of nitrogen content in barley and weed species dry matter with increasing of soil bulk density in 2002 may be explained with weather conditions that year. The growing period was mostly dry, but before earring phase there was little rain and in dense soil moisture was kept longer. Mengel and Kirkby (1987) also observed that in a dry year, due to thicker soil, uptake of elements, which are moving into the plant with water, such as nitrogen, calcium and magnesium might increase. In moist soil there are more nitrates than in dry soil. Also the light conditions were better for plants growing on 6-times compacted variant because of lower number of plants per square meter.

Conclusion

Soils overcompaction inhibits in the first place nutrition of cultural plants and decreases their ability in competition with weeds. Changing the field conditions also the competitors for the cultural plants will change.

On compacted soils and without fertilizers use easier controlled weed species will be replaced with harder preventive weed species. Weeds are serious competitors on cultural plants, they accumulated free nutrients from soil, especially in dense soil. The nutrient assimilation by weeds stopped their irrigation from soil during vegetation period and stored the nutrients as organic matter also for the next growing period. But on very dense soil even weeds are not able to grow and free nutrients may start to pollute the environment.

Acknowledgements

The study was supported by Estonian Science Foundation grant No 5418 and 4991.

References

Alakukku, L., Weisskopf, P., Chamen, W.C.T., Tijink, F.G.J., Van der Linden, J.P., Pires, S., Sommer, C., Spoor, G. 2003. Prevention strategies for field traffic-induced subsoil compaction: a review: Part 1. Machine/soil interactions. Soil & Tillage Research, 73, 145–160.

Andersson, T.N., Lundegårdh, B., 1999 a. Growth of field horsetail (*Equisetum arvense*) under low light and low nitrogen conditions. Weed Science, 47(1), 41–46.

Arvidsson, J. 1997. Soil compaction in agriculture – from soil stress to plant stress. Doctoral thesis. Agraria 41, SLU, Uppsala.

Aura, E. 1999. Effects of shallow tillage on physical properties of clay soil and growth of spring cereals in dry and moist summer in southern Finland. Soil & Tillage Research, 50, 169–176.

Bischoff, A., Mahn, E.-G. 2000. The effect of nitrogen and diaspore availability on the regeneration of weed communities following extensification. Agriculture, Ecosystems and Environment, 77, 237–246.

Bockholt, R., Schnittke, C. 1996. Nähr- und Mineralstoffgehalt von Kräutern des Niedermoorgrünlandes unter intensive Bewirtschaftung. Wirtschaftseigene Futter, 42(3), 209–216.

Boone, F.R., Veen, B.W. 1994. Responses of temperate crop to soil compaction. In: Soane, B.D., van Ouwerkerk, C. (Eds.), Soil Compaction in Crop Production. Elsevier, Amsterdam, Netherlands, pp. 237–264.

Di Tomaso, J. M. 1995. Approaches for improving crop competitiveness through the manipulation of fertilization strategies. Weed Science, 43: 491–497.

Gill, K.S., Arshad, M.A. 1998. Weed flora in the early growth period of spring crops under conventional, reduced, and zero tillage systems on a clay soil in northern Alberta, Canada. Soil & Tillage Research, 33(1), 65–79.

Guil-Guerrero, J.L., Torija-Isasa, M.E. 1997. Nutritional composition of leaves of Chenopodium species (C. album L., C. murale L. and C. opulifolium Shraeder). International Journal of Food Sciences and Nutrition, 48(5), 321–327.

Jones, O. R., Smith, S. J., Southwick, L. M., Sharpley, A. N. 1995. Environmental impacts of dryland residue management systems in the Southern High Plains. Journal of Environmental Quality, 24(3), 453–460.

Kuht, J., Ries, M., Reintam, E. 1999. About influence of soil properties on the composition of phytocoenose on compacted soils (Estonian). Transactions of the Estonian Agricultural University 205, 18–23.

Lipiec, J., Stepniewski, W. 1995. Effect of soil compaction and tillage system on uptake and losses of nutrients. Soil & Tillage Research, 35, 37–52.

Lipiec, J., Hatano, R. 2003. Quantification of compaction effects on soil physical properties and crop growth. Geoderma, 116, 107–136.

Lipiec, J., Arvidsson, J., Murer, E. 2003. Review of modelling crop growth, movement of water and chemicals in relation to topsoil and subsoil compaction. Soil & Tillage Research, 73, 15–29.

Mengel, K., Kirkby, E. A. 1987. Principles of Plant Nutrition. International Potash Institute, Bern, Switzerland.

O'Sullivan, M.F., Ball, B.C. 1993. The shape of the water release characteristic as affected by tillage, compaction and soil type. Soil & Tillage Research, 25, 339–349.

Quasem, R.J., Khattari, S.K. 1993. Competition on nutrients between weeds and their associated vegetable crops. Jordan Univ., Amman (Jordan). Dirasat (Jordan), 20B(4), 18–32.

Reintam, E., Kuht, J. 2002. Impact of soil compaction and sowing density of barley on uptake of nutrients. In: Turka, I., Kreismane, Dz., Selegovska, E., Adamovich, A. (Eds) Scientific aspects of organic farming: Proceedings of the conference held in Jelgava, Latvia 21–22 March, 2002. pp. 167–171.

Singh, S., Katyal, S. K., Yadav, S. K. 1993. Nutrients drain by weeds and their control in cowpea (*Vigna unguiculata* (L) Walp). Haryna Agricultural University Journal of Research (India), 23(4), 237–240.

Tardieu, F. 1988. Analysis of the spatial variability of maize root density: I. Effect of wheel compaction on the spatial arrangement of roots. Plant Soil, 107, 259–266.

Unger, P. W., Kaspar, T. C. 1994. Soil compaction and root growth: a rewiew. Agronomy Journal, 86, 759–766.

Yamaguchi, J., Tanaka, A., 1989. Quantitative observation on the root system of various crops growing in the field. Journal of Soil Science and Plant Nutrition, 36, 483– 493.

Soil and water protection – principles and realizations in agriculture

Uhlířová, J.[1]

Soil and water are two natural media with significant relationships. Water in a soil profile influences soil characteristics, attributes of soil profile influence rate of water outflow and infiltration. The matter exchange proceeds between soil and water solution. Water erosion carries away the soil surface and the consequence is usually pollution of water streams and basins, namely by suspended solids. This is way it is necessary to solve soil and water protection in reciprocal context, simultaneously. Common goals of water and soil protection are:

- restriction of soil erosion (stopping of soil profile shortening and rising of skeleton),
- sanitation of degraded agricultural soils,
- support of propitious water content in soil for plants,
- retardation and dispersion of overall flow off and increasing of water retention in a countryside,
- improvement of water hygienic quality.

New legislative documents of Czech Republic have brought positive changes to the sphere of solving of soil and water protection. The amendment of the water act (254/2002) determines common water protection, new system of drinking water sources protection and vulnerable areas in terms of the EU nitrate instruction. Vulnerable areas are sub-watersheds of the drinking water sources, where nitrate concentrations exceed or can achieve 50 mg/l or watersheds, where undesirable decline of water quality happens or can happen as a result of agricultural activities. In these areas government, by a direction, regulates storage of fertilizers, crop rotation and proceeding of erosion measures. Soil protection abides by the act 231/1999, which says, that owners or users of lots have to farm on agricultural soil fund with respect to the soil, food web and drinking water sources conservation and to protect cultivated lots according to confirmed projects of land arrangement.

Complex land consolidation creates conditions for rational farming, through this lots are spatially and functionally modified, integrated or divided and accessibility and adjustment of its boundaries are established (act 139/2002). At the same time measures for soil conservation, cultivation of countryside and enhancement of its ecological stability are designed and realized by virtue of public interest. Project of protective and ecological measures is constituted in the form of plan of common arrangement, which creates conditions for complex solving erosion and flood protection. In practice, the plan is usually aimed mostly to erosion and flood protection including raising of land water retention, but it contents too suitable treatment for accumulation and infiltration areas. To restrict area surface flow off and to increase land retention are in our conditions used following protective measures:

- grassing (or forestation) of areas or belts,
- insertion of a road with infiltration belt or interceptive ditch,
- balks (hedges) with ditches and accompanying greenery,
- polders and retention reservoirs.

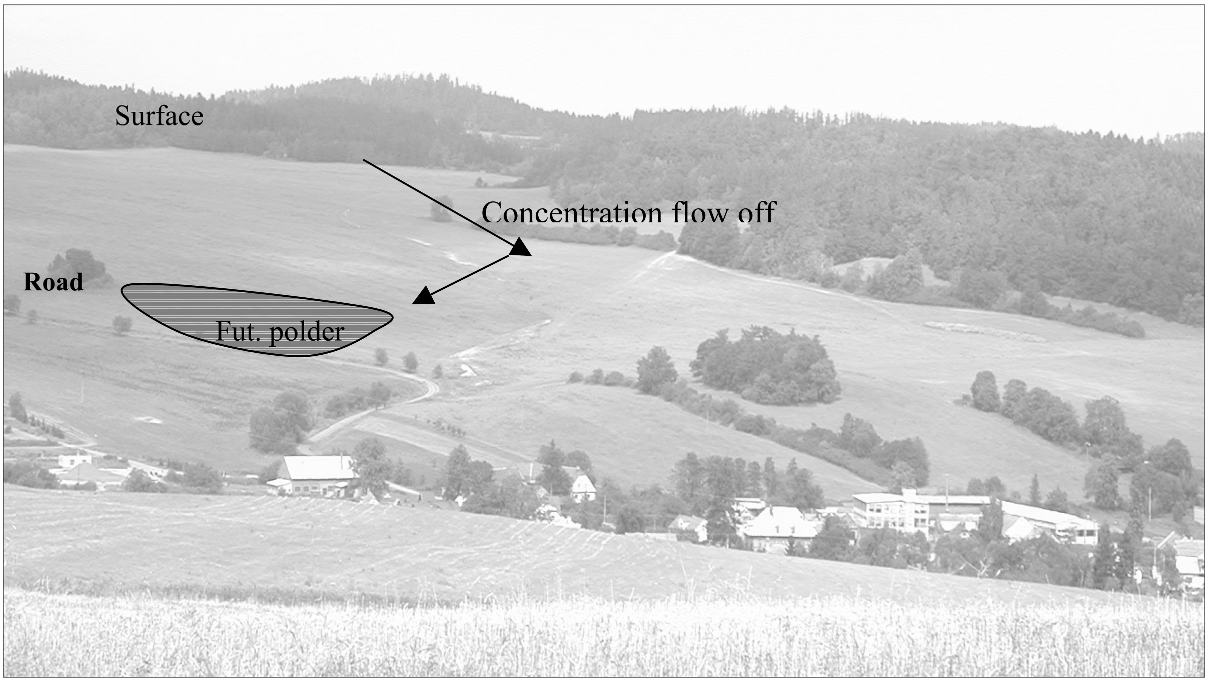
Protective measures use to be polyfunction, with reference to requirements of nature conservation and improving of landscape aesthetics. Picture part of the poster shows examples of realized or projected integrated soil and water protective treatments.

An example of integrated solving of soil and water protection through the complex land consolidation (adjustment) is cadastre Lichnov situated in hilly country of northern Moravia. There are problems with surface and rill erosion on steep arable land. Soil survey showed consequential soil degradation on 18% of agricultural land – loss of surface layers, changes of soil profile. Former Haplic Luvisols and Albiluvisols (1978) were now (1999) classified as Cambisols and Stagnosols. In the 1997 the village was damaged by strong flood. Fluvial deposits and denundations changed Fluvisols into Lithic Leptosols and Gleysols (WRB 1998). Project of land arrangement contains a system of erosion and flood measures (pict. 1 and 2). Markedly steep lots should be grassed and on some parts there should be plant forest. Above the village will be system of intercepting and conducting grass belts (with balks and ditches). Five dry basins (polders) were designed in thalwegs and conducting protective elements exhausts into them. Grassed belts should be planted with trees and bushes to conserve and improve country impression.

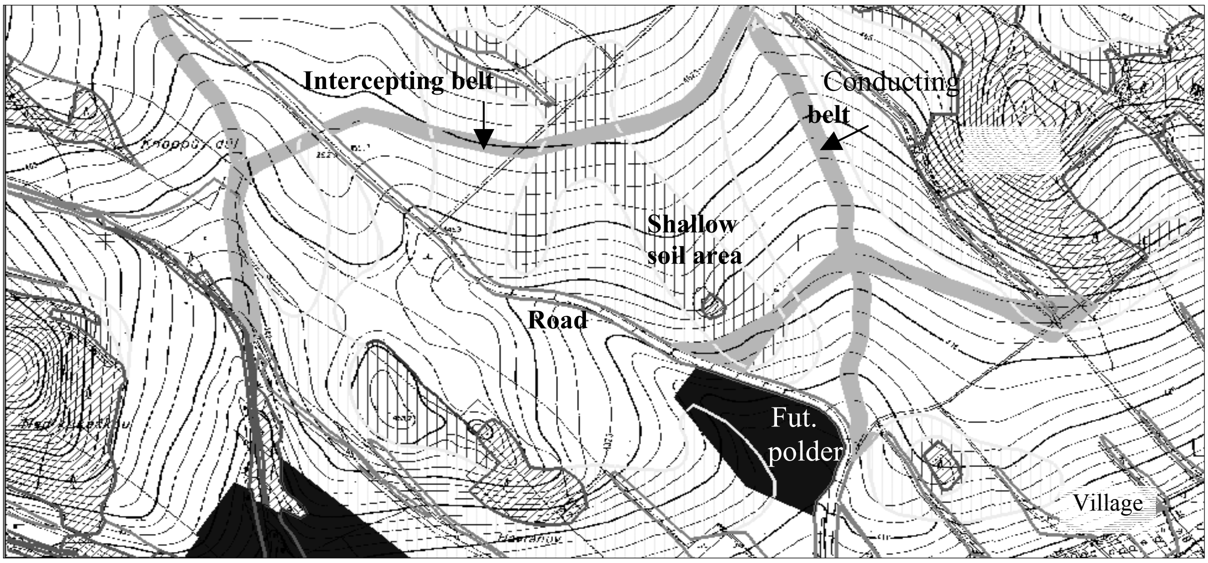
When the complex land consolidation is set forth in a cadastre near drinking water source, it is necessary to solve protection of water quality and quantity too. Such example is cadastre Hubenov on Moravia highland (project on pict. 3), where measures have been realized. Arable land near watershed is duly grassed, infiltration zones on tops of hills are forested or grassed. Slopes were interrupted by balks with accompanying trees. Above watershed intercepting ponds were built for retention storm water and floating solids.

[1] Research institute for soil and water conservation Praha, dep. of land use adjustment Brno, Lidická 25/ 27, 657 20 Brno, Czech Republic. Tel.: 00420 541321124; E-mail: uhlirova@vumopbrno.cz

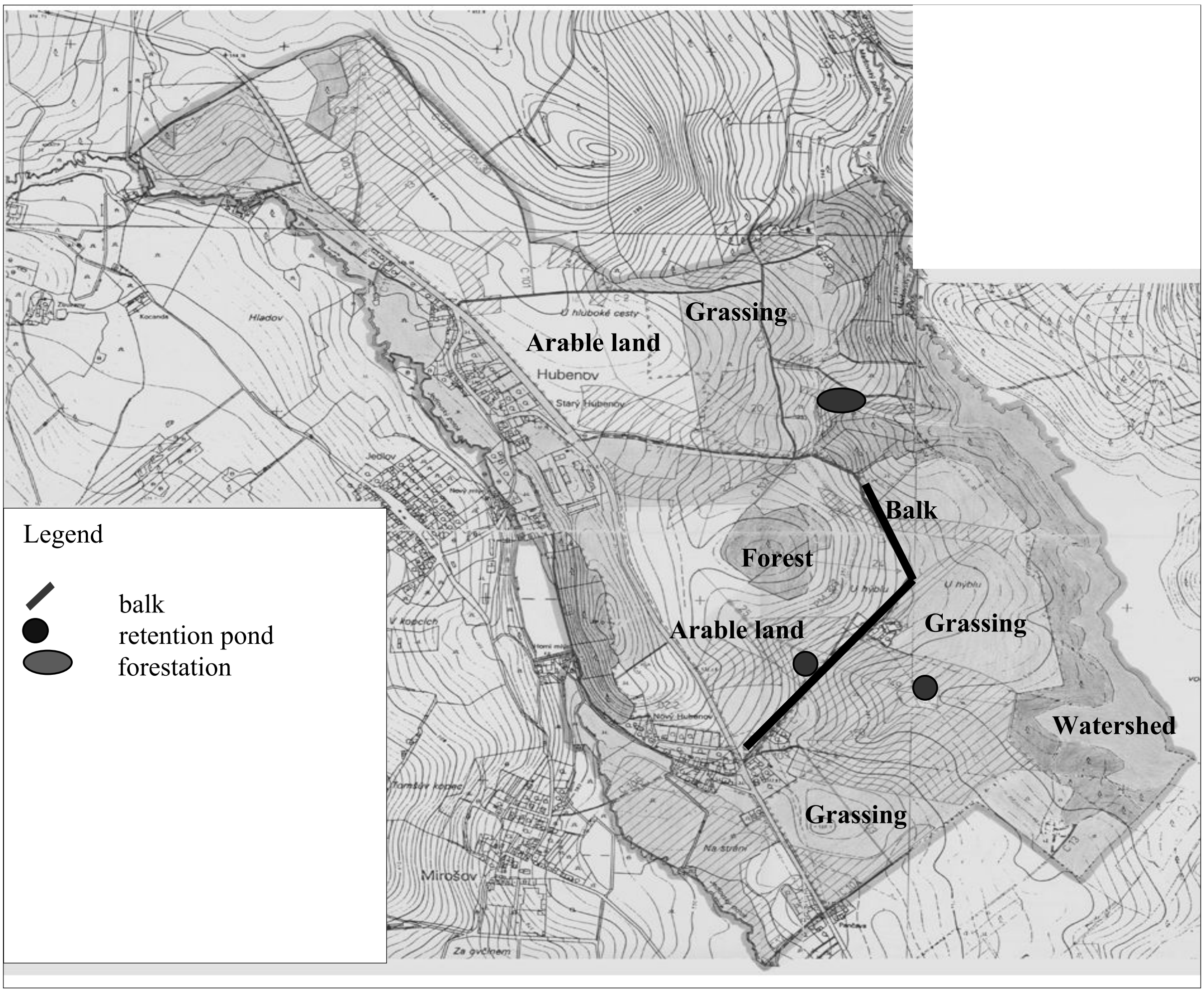
Picture 1. Agricultural land in Lichnov



Picture 2. Lichnov – project of erosion and flood measures (almost the same area as on pict. 1)



Picture 3. Hubenov – project of soil and water protective measures



References

DUMBROVSKÝ, M. – MEZERA, J. a kol.: *Metodický návod pro pozemkové úpravy a související informace.* (Methodical instruction for land use adjustment and related information.) Uživatelský výstup projektu NAZV ČR EP 0960 996156. Praha: VÚMOP Praha, 2000. 189 s. ISSN 1211-3972.

NOVÁK, P. a kol.: *Zpracování a vyhodnocení celkového stavu narušení a trendů degradace půd ČR.* (Treatment and interpretation of general state of disturbance and degradation trends of soils in Czech Republic.) Závěrečná zpráva projektu PPŽP 620/7/97. Praha: VÚMOP Praha, 1998. 150 s.

PODHRÁZSKÁ, J. – UHLÍŘOVÁ, J.: Diferencovaná ochrana vodárenských nádrží v povodí Moravy. (Differentiated protection of drinking water basins in the Morava river watershed.) *Vědecké práce VÚMOP Praha,* 2001, č. 12, s. 83 – 91. ISSN 1210-1672.

UHLÍŘOVÁ, J.: Soil and water conservation through the land consolidation. In *Interdisciplinary approaches in small catchment hydrology*. Demanovská dolina: ERB, FRIEND5, 25. – 28. 9. 2002, s. 170 – 172. ISBN 80-968480-6-2.

Government direction 545/2002 about land consolidation pursuance

Law 139/2002 about land consolidation

Law 254/2001 about water

Law 231/1999 about agricultural soil fund conservation

Water retention capacity of soils in the Czech Republic

Novak, P.[1] – Vopravil, J. –Tomasek, M. – Vetisková, D.

Motivation

Recently there were two catastrophic floods in the Czech Republic, one in the Morava river basin in 1997 and the other one in the Vltava and the Elbe river basins in 2002. These events made it clear that, in order to achieve better flood forecasting and prevention, we need a country-wise map, at least approximate, of the soil water retention capacity.

Materials and methods

The information sources used comprised data base of soil physical characteristics and the graphical part of the data base of the Czech Land Evaluation System. The latter data base is fully digitised and comprises all agricultural lands over the entire territory of the Czech Republic (78 860 km2). Its resolution (the smallest mapped soil area) is 3 hectares. The two data bases were combined in order to create a map of the soil water retention capacity. This implied, among others, to process an enormous amount of data (on average about 60 data pieces per km2).

Metodology

For agricultural lands the Main Soil Units of the Czech Land Evaluation System were grouped into five categories according to their texture, their water content at pF 2.0 to 2.3 and their field water capacity. Five special subcategories were created for soils with a high content of skeleton. With regard to lack of analogous data on forest and non-agricultural soils the textural and hydrogeological characteristics of the underlying parent substratas were used to categorise forest lands in the same manner as the agricultural soils.

A typical value of the water retention capacity was determined to each category and subcategory, expressing to content of water in litres per square metre (or in millimetres of water) for the unified depth of soil profiles equal 1.0 m. The shallower or deeper profiles had to be neglected.

The computations were made in the ArcInfo GIS environment for a rectangular grid with 1 km mesh size. Each cell of the grid was assigned a typical soil water retention capacity value, corresponding to the prevailing soil category. In the boundary cells (e.g., those adjacent to the state border) the soil water retention capacity was determined as corresponding to the soil group which prevailed in the part of the cell for which the soil map was available.

Conclusions

The resulting digital map with one kilometre pixel size can only be used for the estimation of average water retention capacity of soils over large areas, e.g., over larger river basins. If used in this way, its accuracy is estimated to be ± 20 to 25 %. The main sources of uncertainty are the limited number of direct soil water retention data, a weak correlation between the water retention capacity and the soil texture, loose definitions of the soil categories in terms of their texture, and of course, spatial heterogeneity and complexity of the soil mosaic. The map is therefore only a small step forward in our effort to quantify the role of soils in the flood formation processes.

[1] Research Institute for Soil and Water Conservation, Zabovreska 250, 156 27 Prague 5 – Zbraslav, Czech Republic; Tel.: ++420257921640; Fax: ++420257921246; E-mail: pnovak@vumop.cz

Retention Water Capacity in Hydrologic Groups of Soil
(In relation to Czech Land Evaluation System)

Basic Soil Hydrological Group	Subgroups	Texture, skeleton content, infiltration, percolation	Main Soil Unit of Land Evaluation System	Retention Water Capacity l.m^{-2}
A	1	Sand, loamy sand, non skeletal, high infiltration and percolation	04, 17, 21, 31, 37, 38, 39, 40, 55	Low (60)
	1.1.	Dtto + higher skeleton content, shallow profiles, forest soils	dtto	Very low (35)
B	2	Sandy loam, low skeleton content, middle infiltration, middle percolation	05, 13, 18, 22, 23, 27, 29, 30, 32, 34, 36, 41, 48, 51	Lower middle (140)
	2.1.	Dtto but higher skeleton content, forest soils, shallow profiles	dtto	Lower middle (80)
	3	Loam, non - skeletal or low skeleton, middle infiltration, lower middle percolation	01, 02, 03, 08, 09, 10, 11, 12, 14, 15, 16, 26, 28, 33, 35, 42, 45, 46, 56	Very high (320)
	3.1.	Dtto but higher skeleton content, forest soils	dtto	High (210)
C	4	Clay loam, non – skeletal or low skeleton, lower middle infiltration and percolation	06, 19, 24, 25, 43, 44, 47, 50, 52, 58, 60, 64, 65, 75, 76, 77, 78	Higher middle (220)
	4.1.	Dtto but higher skeleton content, forest soils	dtto	Lower middle (130)
D	5	Clay, very fine clay, non - skeletal or low skeleton content, swelling soils, low infiltration, low and very low percolation	07, 20, 49, 53, 54, 57, 59, 61, 62, 63, 66, 67, 68, 69, 70, 71, 72, 73, 74	Middle (150)
	5.1.	Dtto but higher skeleton content, forest soils	dtto	Lower middle (90)

References

Feddes, R.A., 1980: Physics of Soil Moisture. Inst. for Land and Water Management Research, Wageningen, 116 pgs
Kent, K.M.: Hydrology Section 4 National Engineering Handbook. SCS Washington D.C., USDA 1171, 350 pgs
Land Evaluation System of Czech Republic. Graphical part, VUMOP Praha, 1985 – 2004
Novak,P. et all, 1998: Water Retention Ability of Soils of Upper Morava Basin. Research report, VUMOP Praha
Numerical data base of soil characteristics, VUMOP Praha, 1990 – 2004
Stakman, W., 1974: Soil Moisture Characteristics. Inst. for Soil and Water Management Research, Wageningen, 62 pgs

Olive grove soil conservation by addition of sewage sludge compost

Beltrán, E.M.[1] – Miralles de Imperial, R. – Porcel, M.A. – Beringola, M.L. – Martin, J.V. – Calvo, R. – Delgado, M.M.

Fields experiment were conducted during four years, between 1998 and 2002. To evaluate sewage sludge compost on soil-grove two adult olive orchards (Olea europaea L. cv. Cornicabra) were established in a clay loam soil in Seseña (Toledo, Spain) and in a sandy loam soil in Aranjuez (Madrid, Spain). Four treatments were set up, every experiment was replicated four times and two depths were studied (0-15 and 15-30 cm). The applied treatments were sewage sludge compost (SSC), 16.000 kg of sewage sludge compost.ha-1; sewage sludge compost plus urea (SSC+U), 0.5 kg of N as Urea/tree + 8.000 kg of sewage sludge compost.ha-1; urea (U), 1 kg of N as Urea /tree, and control (C).

All the treatments were placed on the soil between the rows of the trees and incorporated by means of harrowing in spring in 1998, 1999, 2000 and 2001.

Once a year, before spreading sewage sludge compost, soil samples were taken at depths of 0 to 15 cm and 15 to 30 cm between the rows of the trees. Samples were air-dried and crushed to pass a 2 mm sieve. Organic matter, total Kjeldhal nitrogen, electric conductivity, pH and phosphorus availability was determined.

Data were analysed by analysis of repeated measures based on the mixed model, with special parametric structure on the covariance matrices. The basic repeated measures study consists of completely randomised experimental design with data collected in a sequence of equally spaced points in time. Treatments have been assigned to experimental units, and data are collected at a sequence of time from each experimental unit, the experimental unit are often called subjects. In our case, the experimental unit or subject has been considered the interaction Depth*Repetition(Treatment) and the structure of the covariance matrix is AR(1) that specifies a first-order autoregressive structure. The multiple adjustment is for the p-values and confidence limits for the differences of LS-means by the Bonferroni test. The software used is the Procedure Mixed of SAS/STAT 8.2. In order to analyse the organic matter (OM) and nitrogen content, that are obtained in percentage, we must transform this two data as:

$$OMt = \sqrt{(OM + 0.5)}$$

$$Nt = \sqrt{(N + 0.5)}$$

Treatment versus Year on organic matter is shown in Figures 1 and 2 for Aranjuez and Seseña respectively. In Aranjuez there were no significant differences between treatments ($p=0.999$). The differences were found between the two depths ($p=0.0001$). Ranges from 0.80 to 0.2% of organic matter were obtained at 0-15 cm depth and ranges from 0.76 to 0.18% of organic matter at 15-30 cm depth. In Seseña the ranges were higher. At 0-15 cm depth ranges from 1.3-0.7% of organic matter and from 1.12 to 0.5% at 15-30 cm depth were found. In relation to years, were found significantly higher differences between the three first years and the last years ($p<0.05$). Due to degradation process of organic matter applied to the olive grove soil is slow (Cabezas, J.G., 2003) we have not observed significant differences between treatments with sewage sludge compost (SSC and SSC + U) and treatments without sewage sludge compost (C and U)

Figures 3 and 4 show Treatment versus Year on total nitrogen for Aranjuez and Seseña respectively. In Aranjuez only were found significant differences between the interaction "Control treatment-1999 year" and "Control treatment-2000 year" ($p<0.05$). In Seseña, at 0-15 cm depth, SSC treatments and Urea treatments were significantly different in the first three years, the nitrogen content was 13% higher in plots treated with SSC than in those treated with Urea. Miralles de Imperial (2003) in an essay in a greenhouse with three different types of sewage sludge on rooted cv. Cornicabra olive cuttings observed that the content of nitrogen in soil increased linearly in terms of rates. In Seseña, 2002 year was significantly different ($p<0.05$) from 1999-2000-2001 years. The interaction Treatment*Year was significant ($p<0.005$) too, it means that SSC + U provided more to the olive grove soil in 1999 and 2000, but in 2001 was the second treatment in providing more nitrogen content and in 2002 was the last one. This trend can be observed in the 0-30 cm depth.

Treatment versus Year on pH is shown in Figures 5 and 6. In Aranjuez significantly ($p<0.005$) higher ranges of pH were found in SSC treatment than in Control and Urea treatments, the increasing of pH was 2%. Miralles de Imperial (2002) in an emergence test in pots under greenhouse conditions with two types of sewage sludge compost found that the use of sewage sludge compost increases pH. We also found significant differences in every year ($p<0.005$). In Seseña, pH in plots treated with SSC + U were significantly ($p<0.005$) lower than in plots treated with Urea.

Figures 7 and 8 show Treatment versus Year on electric conductivity for Aranjuez and Seseña respectively. In Aranjuez between the three first years (1999-2001) were found no significant differences

[1] National Institute of Agricultural Research. Apdo. 8111. 28080 Madrid. Spain; Tel.: 00 34 91347 6736; Fax: 00 34 913572293; E-mail: beltran@inia.es

(p=0.999), the differences were found between this three years and the last one (p<0.005). The interaction Treatment*Year was significant (p<0.005) too. In Seseña although SSC and SSC + U treatments provided higher electric conductivity to the soils than Control and Urea treatments were no significant (0.235<p<0.495). This agree with Guidi et al (1982) that observed slight increasing on electric conductivity after application of sewage sludge compost.

Figure 9 shows that SSC treatments provided more phosphorus availability in Aranjuez soils at 0-15 cm depth during all the years. This treatment was significantly different from the others (p<0.05). Ranges from 10 mg.kg-1 in C plots to 40 mg.kg-1 in SSC plots were found. Between Control treatment and Urea treatment there were no significant differences (p=0.999). At 15-30 cm it can be observed that SSC treatment is significantly different (p<0.05) from the other ones. The ranges of phosphorus availability were lower than at 0-15 cm, from 5 mg.kg-1 in C plots to 25 mg.kg-1 in SSC plots.

In Seseña at 0-15 cm (Figure 10), there was no significant differences between SSC and SSC + U treatments (p=0.99). The significant differences appeared between this two treatments and the other ones (C and U treatments) with a p<0.05. Ranges from 8 mg.kg-1 in U plots to 50 mg.kg-1 in SSC plots were found.

At 15-30 cm the higher concentration of phosphorus was found when SSC + U treatment was applied.

The application of organic wastes to the soil improve the phosphorus availability in soils and their content increases as the rate of application increases. (Blázquez, R. et al, 1999; Burgos, P. et al, 2001).

Conclusions

We found no increase on organic matter after four years of application of sewage sludge compost to two olive grove soils. We attribute this behaviour to the slow fertilization of the sewage sludge compost that makes that would be too early to observe differences. In relation to nitrogen content we found that sewage sludge compost, only in Seseña, produced higher nitrogen soil content than the traditionally urea treatment. With respect to pH, the use of sewage sludge compost increased the pH of the soil with respect to urea and control plots in Aranjuez but in Seseña we found the inverse effect.

We found no differences between treatments with respect to the electric conductivity.

Sewage sludge compost applied as a Phosphorus fertilizer on a olive grove soils improve the Phosphorus availability for the olive tree at two depths.

References

Blázquez, R., Cuevas, G., López, R., Martínez, F. and Walter, I. 1999. Some chemical changes in a mediterranean soil following urban organic wastes application. 6th International Meeting on Soils with Mediterranean Type of Climate. Barcelona. Spain. 832-834.

Burgos, P., Madejón, E., Murillo J.M., Cabrera R. 2001. Agricultural use of three organic residues: effect on orange crop and on chemical properties of a soil of the comarca Costa de Huelva (SW, Spain). Proceedings of the International Conference ORBIT 2001 on Biological processing of waste: a product-oriented perspective. Ed. Orbit. Part 1. 115

Cabezas, J.G., Alonso, J., Yébenes, I., Vicente, M.A. and Lobo, M.C. 2003. Aplicación de lodos residuales para la restauración de la cubierta vegetal en suelos degradados. I Simposio Nacional sobre Control de la Erosión y Degradación del Suelo. Madrid. 279-282.

Guidi, G.; Pagliai, M.; and Giachetti, M., 1982. Modifications of some physical and chemical soil properties following sludge and compost applications. In: G. Catroux, P. L`Hermite & E. Suess (Eds.) “The influence of sewage sludge applications on physical and biological properties of soils”, pp. 122-130. Dordrasht, The Netherlands.

Miralles de Imperial, R., Beltrán, E.M., Porcel, M.A., Delgado, M.M., Beringola, M.L., Martín, J.V., Calvo, R. and Walter, I. 2002. Emergencia de seis cultivos tratados con lodo, fresco y compostado, de estaciones depuradoras. Revista Internacional de Contaminación Ambiental. N. 3. Vol. 18. 139-146.

Miralles de Imperial, R., Beltrán, E.M., Porcel, M.A., Beringola, M.L., Martín, J.V., Calvo, R. and Delgado, M.M. 2003. Disponibilidad de nutrientes por el aporte de tres tipos de lodo de estaciones depuradoras. Revista Internacional de Contaminación Ambiental. N. 3. Vol. 19.

Smith, R.S. 1996. Agricultural Recycling of Sewage Sludge and the Environment. CAB Intern. Wallington, UK. pp 382.

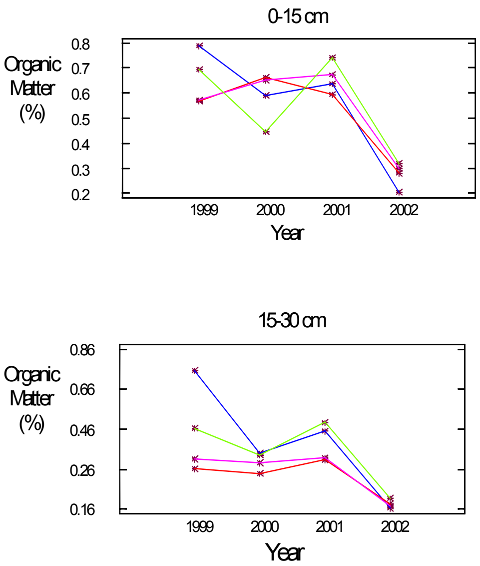


Figure 1. Organic matter (%) in Aranjuez at 0-15 cm y 15-30 cm depth.

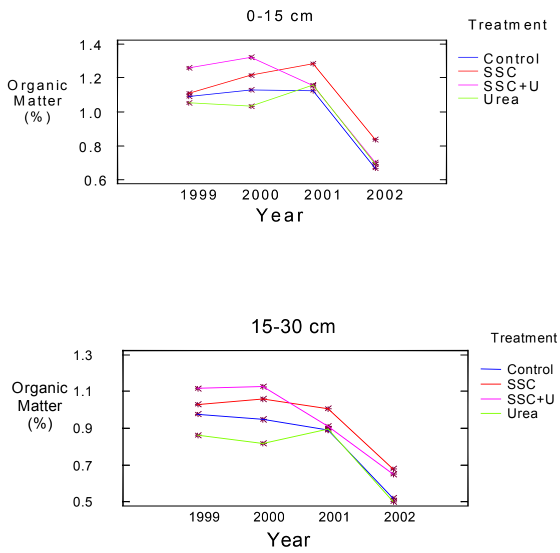


Figure 2. Organic matter (%) in Seseña at 0- 15 cm y 15-30 cm depth.

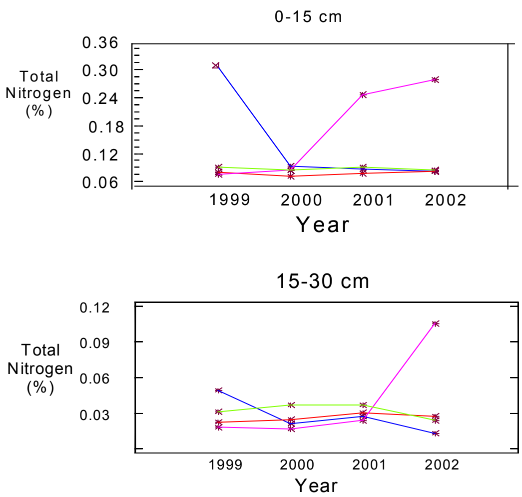


Figure 3. Total Nitrogen (%) in Aranjuez at 0-15 cm y 15-30 cm depth.

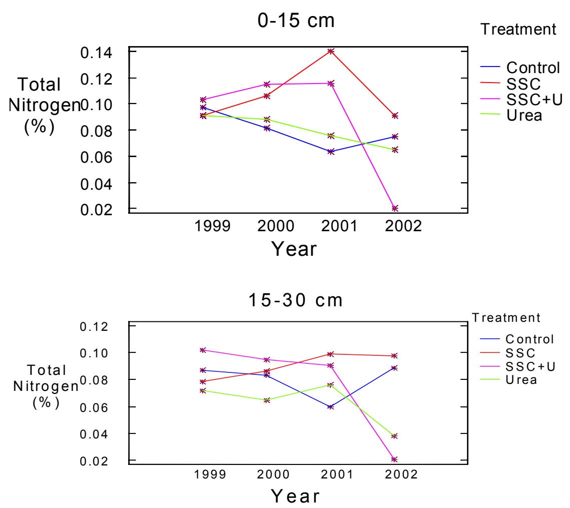
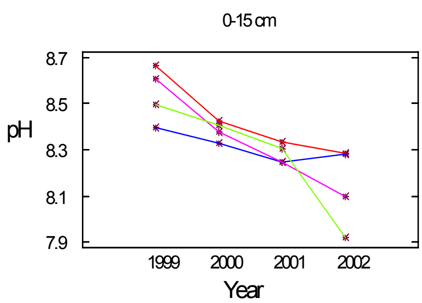
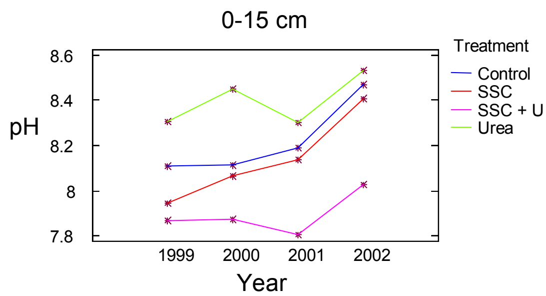


Figure 4. Total Nitrogen (%) in Aranjuez at 0-15 cm y 15-30 cm depth.





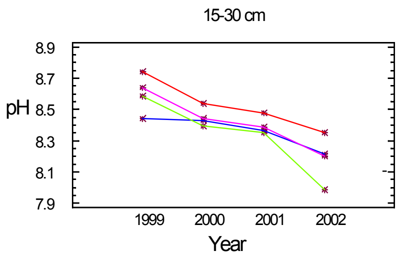


Figure 5. pH in Aranjuez at 0-15 cm and 15-30 cm depth.

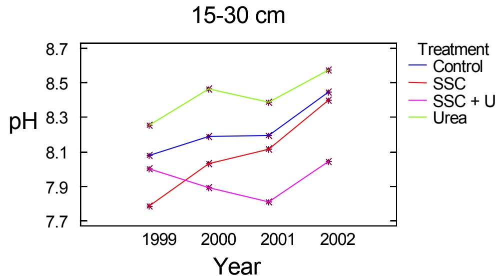


Figure 6. pH in Seseña at 0-15 cm and 15-30 cm depth.

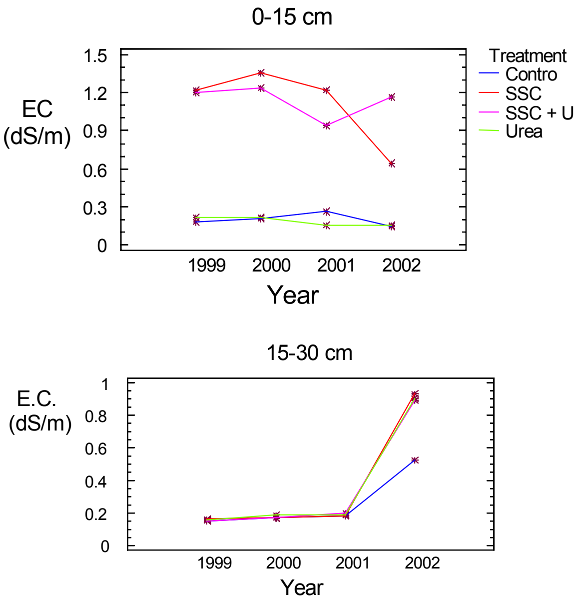


Figure 7. EC (dS/m) in Aranjuez at 0-15 cm and 15-30cm depth.

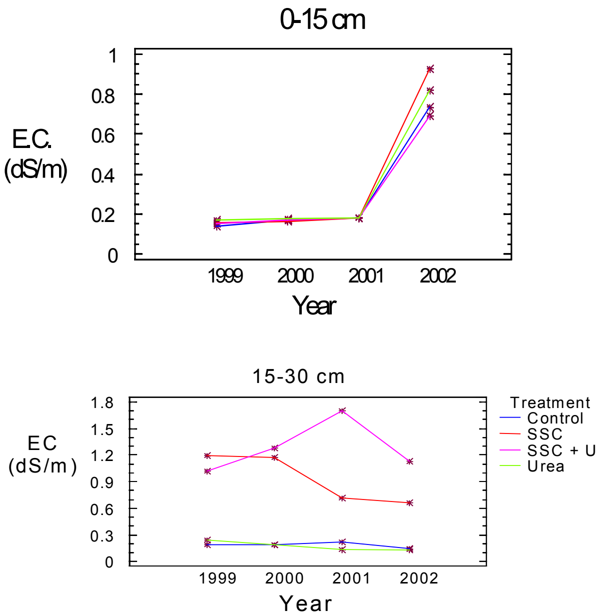


Figure 8. EC (dS/m) in Seseña at 0-15 cm and 15-30 cm depth

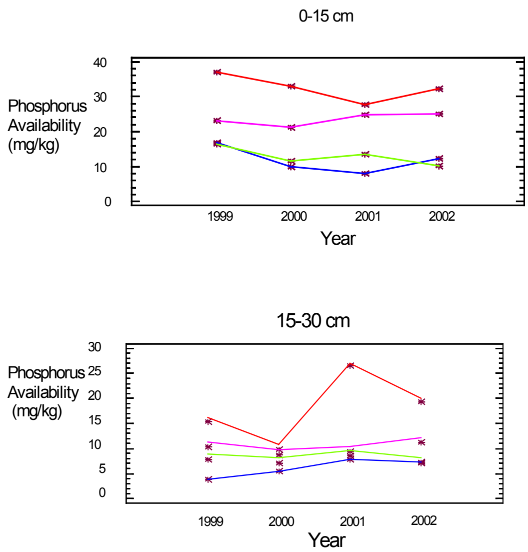


Figure 9. Phosphorus availability in Aranjuez at 0-15 cm and 15-30 cm depth.

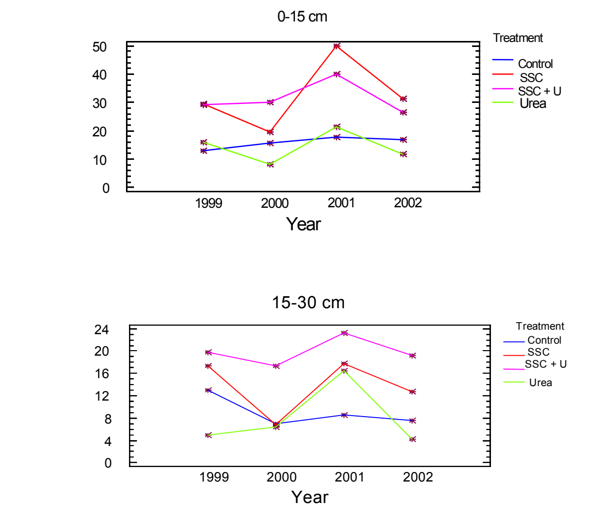


Figure 10. Phosphorus availability in Seseña at 0-15 cm and 15-30 cm depth

The premises to institution to guaranteeing of soil preservation in Pricernomorski basin.

Jigeu, G.[1] – Slonovski, V. – Lupu, M. – Jolondkovski, A. – Jigue, R.

For the countries Prichernomorskogo of the basin, having agrarian – an industrial economic direction, steady use of soil resources is the main priority of steady development. In these countries land resources are mainest of kinds of natural resources which provide production of food stuffs and also about 80 % of raw material for an industrial complex. At the same time generalization of the literary data and also data of own researches shows that a condition of this important natural resource is critical. In accordance with calculations for the last 100 years the soils of Moldova, Romania, Ukraine, Bulgaria, Russia and other countries have lost from 20 up to 40 % of humus's stocks. More than on 80 % of the area of region of soil are subject 2 – 3 and more processes of physical degradation (destruction of soil, over ramming of soil, crusty, etc.). Almost everywhere in irrigated territories the soils are expose to processes secondary waterlogging of soils and swamp formation, salinization, alcalinisation and slitization. In the majority of the countries of region the soils are characterized negative balance of nutrient substances. All palpable becomes deficiency of some physiologically important microelements (Zn, Mn) and on the contrary pressure of some elements – poljuantov (heavy metals) progressively grows. On the verge of an exhaustion stocks of phosphorus in ecosystems – at the further degradation of soil the problem of shortage of phosphorus to be pushed in the near future on the foreground and will take a place among the sharpest ecology problems.

In consequence of all marked inhabitants of the countries of region already collide with a number of heavy economic, ecological and social problems: the progressive and accelerated increase in frequency of droughts, sharp reduction and the accelerated deterioration of water stocks, degradation of a climate, low incomes, shortage of food stuffs, increase in number of the unemployed, became a reality processes of desertification, on the verge of accident a condition of Black sea, etc. For the sake of justice it is necessary to tell that all this occurs despite of efforts enclosed by the Governments of these countries directed on improvement nature - ecological and socially – economic spheres. At the same time today we state, that despite of human and material expenditures are not achieved some appreciable positive results. Frequently, in the justification of such condition of things refer to difficulties of transitional from the centralized planned form of economy to market. In this context we mark, that the feature of the modern stage for the majority of the countries Prichernomorskogo of basin is simultaneous change of the general paradigms of development and the form of the organization politico – legal and economic – economic communications, namely formation of new patterns of ownership and the organizations of manufacture. In the given situation it is necessary to take advantage of the moment, having provided transition to new forms economic and at new, higher technological level.

Thus to assume that it is possible to achieve the certain successes to the countries separately it is impossible that is why it is counted that creation of Regional Coordination Council on Steady Use of Soil's Resources of function is necessary assume:

- Elaboration of a uniform Regional policy of steady use of soil resources based on: a) a principle of pedocentrizma in functioning regional ecosystems. b) a principle of unity lito-morfo and pedogeneza in region in last ecological epoch and in a principle of anticipation.
- Elaboration of regional model of steady use of soil resources based on principles factor – process interpretation of processes of pedogenesis and functioning of a soil cover in modern conditions.
- Elaboration and demonstration of approaches (concepts) which can be reproduced in other conditions.
- Elaboration supporting briefly – average – long – and superurgent strategy of efficient control by soil resources. Thus steady use of soil resources is understood by us not as gradual curtailment of production and as:
  - structural reorganization of economy; rationalization of the territorial organization of regional systems of use of soil resources;
  - introduction new soil – and energosave technologies and also technologies of reproduction and land improvement of fertility of soil;
  - transition from extensive to an intensive agricultural production;
  - it is soil – ecological and it is soil – an economic substantiation of productive forces;
  - perfection of economic and legal mechanisms of management by soil resources and fertility of soil.

[1] Research and Production Centre of Agricultural Chemistry Service, Republic of Moldova

Remains of the medieval canal systems in the Carpathian Basin

Takács, K.[1] – Füleky, Gy.

Introduction

The Carpathian Basin, situated in the centre of the European continent, is surrounded by one of the closest rings of mountains in the world. The main arterial waterway in the centre of the basin is the River Danube, which collects the water from all the other waterways and transports it to the Black Sea. The climate of the Carpathian Basin represents a transition between the oceanic, continental and Mediterranean climate zones. Partly as a result of this, the distribution of rainfall in the region is rather uneven, and there are often long periods of drought in summer. Hungary is one of the countries where water regulation is a vital question both for agriculture and for everyday life. It is sufficient to mention that prior to the river regulation carried out in the 19th century, some 4 million hectares of land was subject to permanent or temporary inundation. The wide expanses of marshes and wetlands were the consequence both of the undrained or poorly drained plains within the basin and of the numerous rivers and streams flowing into the basin from the surrounding hills, the waters of which turned the area into a sea when they flooded. During the course of river regulation and marsh drainage, which lasted from the end of the 18th century to the beginning of the 20th, the longest dike system in Europe was constructed, in addition to which drains with a total length of several tens of thousands of kilometres were dug, chiefly for inland drainage purposes. This construction work started from scratch; there was no indication that any similar work had ever been carried out in Hungary prior to the 18th century and it was a long time before any data on this subject were discovered.

Materials and methods

During the first half of the 1990s the remains of ditches with an unusual structure were observed during archaeological field work in the Rábaköz region of Hungary (Northwest Hungary). The ditches were characterized by two or three parallel channels and it could be clearly seen that the earth removed to make the channels was piled up between them. The ditches were in various stages of decay and in general only short, apparently unconnected sections were found. By mapping the various trenches sections and examining them in more detail it became obvious that these were the remains of an originally interconnected ditch network. In the course of the years a ditch system covering the whole of the eastern, Tóköz area of the Rábaköz region was discovered.

As a result of archaeological excavations and geodesic surveys, a relatively accurate picture was formed of the internal structure and function of the trenches. The excavations confirmed the surface observations: almost without exception the ditches discovered up to now consist of two or three channels, with earth banks between them. It became obvious that, as suggested by the written sources, these two- or three-channelled earth-works were created to transport water, and were thus part of a canal system. Finds suitable for dating the canal system were also discovered, in the form of pottery fragments from the Árpád period.

Results

Naturally, the question arises of whether the remains of similar canal systems can be expected to be found elsewhere. Field surveys soon provided an answer to this question, as the remains of such two- or three-channelled ditches and the surface phenomena characteristic of them were found in various parts of the Kisalföld region, then along the Danube on the Hungarian plain and in the valleys of the Tisza and the Körös rivers. Special attention has been paid to the central part of the Kalocsai-Sárköz region and the north-eastern part of the Bodrogköz region, though excavations have not yet been carried out. Records from the Árpád period, which helped to date the canals, were found not only in the Rábaköz region, but also elsewhere. Since the remains of ditches with this characteristic structure were found in all the regions examined up to now, throughout the country from the western borders to the east, it can be concluded that they are to be found all over the Carpathian Basin on areas with similar geographic features.

As mentioned above, the ditches discovered up to now have all consisted of two or three separate channels, with the earth piled up between them to form embankments. This is the most characteristic feature of the canals, which can be considered as their basic structure. Consequently we may speak of two- or three-channelled canals. Nevertheless, substantial differences can be observed between the individual ditches, particularly as regards the shape and size of the channels and the embankments. The width of the canals ranges from 2–3 m to 25–30 m, with a depth of anything from 0.5 m to 4 m. In the case of three-channelled ditches the size and shape of the three channels always differs: in general the central channel is wider and deeper than the two side channels, though there are exceptions to this. The two-channelled structures may be symmetrical or

[1] Kultúrális Örökségvédelmi Hivatal, 1014 Budapest, Táncsics Mihály u. 1. E-mail: canal@primposta.hu

asymmetrical. The difference in size between the two channels is, on occasion, extreme. The canals thus exhibit great variability of form and size, and this variability can sometimes be observed even between the various sections of the same canals.

The beds of the canals were carefully dug with some as yet unknown tool to a special shape. Steps were often formed in one or both sides of the channel, while the bed of the wider canals was sometimes divided into two or three smaller channels. The function of the latter is as yet a mystery, but the steps were obviously designed to facilitate work on the canals, such as construction and cleaning. The beds of the canals had a clearly defined slope, which will be discussed in detail below.[2]

The distinctive structure of the ancient ditches obviously has a functional explanation. It will become clear from the following that the differences in size and shape can be attributed to the role played by the given canal section in the system as a whole.

The canals have survived in a great variety of forms and conditions. Some sections have remained in fairly good condition, while others have disappeared without trace; at most the different colour of the soil suggests that they once existed. In most cases the channels were buried by earth from the embankments. In many places the mixed soil of the embankments could be observed in the earth filling the channels. Ditches can be found in every stage of decay from completely destroyed to almost undamaged. Some of the most characteristic forms and surface phenomena will be presented here.

In many cases there are or have been roads alongside the site of the old canals. It is highly probable that the link between the road network and the canal network goes back to the time when the ditch system was still in use. It is quite natural that the roads should have followed the ditches. Numerous analogies can be found in this connection, including the fact that many modern roads also follow the course of the canals. In some cases roads (some of which still exist today) were built on the earth banks, which gradually became trampled down, filling up the channels on either side partially or completely. The widespread use of these banks as roads, which led to a rapid deterioration in the state of the canals, obviously started after the system had ceased to function. The embankments of the abandoned ditches will have proved especially suitable for transport purposes on low-lying, water-logged areas. Although the roads aggravated the decay of the canal system, they now serve as a useful marker of where to look for the drains.

Numerous examples can be found of the use of the medieval canals in the course of drainage in recent centuries. The trebled canals were chiefly used for this purpose. In such cases the central channel was generally cleared, and was broadened and deepened where necessary. The side channels, which were not required in the new system, were allowed to decay further, or were filled up completely with the earth removed from the central channel. As canal systems are very thin today, this modern use of the old canals only affects certain sections of a very small proportion of the original objects.

Some of the most clearly visible of the surface phenomena are the characteristic plant species which can frequently be found on the remains of the canals or on the sites they once occupied. These species include thorny bushes such as blackthorn, hawthorn, dogrose and spindleberry, and fruit-trees such as plum, sour cherry, sweet cherry, apple, etc. The relatively undamaged ditch sections are thickly covered with these plants, especially with thorn bushes, and this obviously made a great contribution to their survival. They are found sporadically in the neighbourhood of almost all the canal remains, so they can virtually be used as indicators. In some cases it would appear that the presence of these plant species is not accidental, but that they are the descendants of bushes planted on the embankments when the canal system was in use. The reason for this could have been that the roots and dense branches of these bushes protected the canals against erosion, damage by animals, etc. At the same time, the mixed, often moist soil of the embankments and the humid microclimate will have provided favourable conditions for the bushes. Archaeobotanic studies will be required to confirm this hypothesis.

Mention should first be made of the clear differences between the medieval canal systems and its modern counterparts. Distinctions can be made not only in the structure of the ditches (modern drains all have a single channel) but also in the density of the network. On the intensively excavated area in the Tóköz region (the square area indicated by thin lines on the remains of canals with a total length of 52 km have so far been discovered on an area of 22 km^2, while today the length of the draining canals on the same area is only 9 km. It should be noted in passing that even these short ditches follow the course of their medieval predecessors, which were cleared out and, in places, widened and deepened. Nor should it be forgotten that even on this intensively excavated area only a small proportion of the smaller two-channelled ditches which made up the larger part of the medieval system have been excavated to date, so the original network must have been far denser than that depicted on the map. The differences between the medieval and modern canals in both structure and number obviously reflect functional differences.

[2] Szent István University, Gödöllő

The central components of the medieval system were the trebled canals, which served a number of water management purposes. The central channel was enclosed by earth banks on both sides and was thus able to transport water above ground level. The height of the water column between the banks ranged from 2 to 4 metres, depending on the local conditions. So far the level of some 24 kilometres of three-channelled canals has been determined and it can be seen that in general the banked-up channels do not have a uniform slope; with slight fluctuations the bottom of the banked up channels was roughly horizontal. The fluctuation did not amount to more than a few decimetres over the whole length of the canals. The level of the bottom of the central channel appears to have been kept within a very close range (between 110 and 111.5 m above sea level throughout the Tóköz region. This meant that the water was able to flow in either direction in these banked-up channels depending on the current water level of the rivers.

It should be mentioned here that the canals which branch off the main rivers, the Rábca and the Rába, are almost without exception three-channelled. It is thus clear that when the water level in the rivers rose, the central, banked-up channels of the canal system served to draw water from the river, if necessary at a level higher than the surrounding fields, and to distribute it in some way to the other canals. The water could be kept between the banks up to a certain level, but at various points it could be led off, in some cases into fishponds, which could be regarded from the hydrological point of view as storage lakes. In addition, when the water in the central channel was high enough it could be allowed to flow on to selected areas (for irrigation purposes). If the water level in the system dropped, the water flowed the other way, in which case these same three-channelled canals collected water from the network and led it back into the rivers. Since the bottom of all the canals investigated so far was lower than the lowest point of the surrounding areas, they allowed the whole area to be completely drained.

The side channels of the trebled canals were of especial importance in the drainage of surplus water. They not only served to raise the embankments to the necessary height, but also collected the water seeping through the banks and were utilised during irrigation and drainage. The side channels have been connected to the central channel by means of culverts. This has been confirmed by the discovery of openings in the embankments, the only explanation for which is that they once contained tubular structures of some easily decaying material, obviously wood. It seems likely that these were hollowed-out tree-trunks which could be opened and closed.

It has been found that in some places the banks of the three-channelled canals contained culverts placed at a fairly high level at frequent intervals. These will have allowed the rising water to flow into the side channels and from there on to the surrounding areas. There were also other culverts, however, placed at a lower level, which must have served to drain the water in the side channels into the central channel. The side channels all sloped to a certain point, and it was at this point that these drainage culverts were found.

The two-channelled ditches primarily differed from the three-channelled ones that they were not able to transport water at a level higher than that of the surrounding areas and in that they only contained water at certain periods in certain places, while the central channels of the trebled canals were likely to have contained water at almost all times. The most characteristic features of doubled canals were that they were situated at various heights and had various slopes, which will not be discussed in detail here. Judging by their characteristics (slope of the channel, structure, network density, etc.) their purpose appears to have been the distribution of the water transported by the banked-up channels to the irrigated areas and the collection and drainage of water from these same areas into the three-channelled canals.

The two-channelled ditches were small: the distance between the middle of the canal beds was very uniform, ranging between 2.9 and 3.7 metres. Reconstructions based on sectional drawings show that the embankments were all roughly of the same height, rising around 80–90 cm above the surrounding areas.

The beds of the two-channelled ditches slope evenly towards the trebled canal, dropping about 30–40 cm from the starting-point to the point where the canals meet (5–10 cm per 100 metres).

References

Andrásfalvy B.: A Sárköz és a környező Duna menti területek ősi ártéri gazdálkodása és vízhasználatai a szabályozás előtt (Vízügyi Történeti Füzetek 6.) /=Ancient flood-plain farming and water utilisation in the Sárköz region and neighbouring areas along the Danube before the river regulation (Hydrology Historical Pamphlets 6.)/ Budapest, 1973

Bogdánfy Ö.: Az Alföld hidrologiája. Vízimunkálatok az Alföldön /= Hydrology of the Great Hungarian Plain. Water management measures on the Great Hungarian Plain/ Debrecen, 1924

Dávid L.: A kettős célú csatornák működésének néhány kérdése /=Questions connected with the operation of the dual-purpose canals/ Vízügyi Közlöny (1970) 3. szám 126-131.

Glick, Th. F.: Irrigation and Society in Medieval Valencia. Cambridge, 1970

Glaser L.: Az Alföld régi vízrajza és a települések /=Ancient hydrography of the Great Hungarian Plain and the settlements/ Földrajzi Közlemények (1939) 297-307.

Györffy Gy.: Az Árpád-kori Magyarország történeti földrajza I-IV. /=Historical geography of Hungary in the Árpád Period/ Budapest, 1963-1998

Györffy Gy. – Zólyomi B.: A Kárpát-medence és Etelköz képe egy évezred előtt. In.: Honfoglalás és régészet. Szerk.:Kovács L. (Honfoglalásról sok szemmel I.) /=The Carpathian Basin and the Etelköz area a thousand years ago. In: The conquest of Hungary and archaeology (Different views of the Hungarian conquest.)/ Budapest, 1994. 13-37.

Haraszti E.: Az állat és a legelõ (Második, átdolgozott kiadás) /=Animals and pastures. (Second, revised edition)/ Budapest, 1977

Ihrig D. (szerk.): A magyar vízszabályozás története /=History of water management in Hungary/ Budapest, 1973

Károlyi Zs.: Vízhasznosítás, vízépítés és vízgazdálkodás története Magyarországon /=History of water utilisation, hydraulic engineering and water management in Hungary/ Budapest, 1960

Kolossváry Ö.: Alföldünk öntözése /=Irrigation on the Great Hungarian Plain/ Budapest, 1899

Kovács G.(szerk): Az öntözés kézikönyve /=Irrigation manual/ Budapest, 1968

Paládi-Kovács A.: A magyar parasztság rétgazdálkodása /=Meadow management by Hungarian peasants/ Budapest, 1979

Somogyi S.: Az Alföld földrajzi képe a honfoglalás és a magyar középkor időszakában. Észak-és Kelet-Magyarországi Földrajzi Évkönyv I. /=Geography of the Great Hungarian Plain during the Hungarian Conquest and the Middle Ages/ Miskolc-Nyíregyháza, 1994. 61-75.

Szabó L.: Néprajzi párhuzam Árpád-kori falvaink árkainak rendeltetéséhez /=Ethnographical parallels in the role of ditches in medieval Hungarian villages/ Archaeológiai Értesítő 102. (1975) 84-87.

Szalai Gy. (szerk.): Az öntözés gyakorlati kézikönyve /=Practical irrigation manual/ Budapest, 1989

Takács K.: Árpád-kori csatornarendszerek kutatása a Rábaközben és a Kárpát-medence egyéb területein I-II. /=Research on medieval canal systems in the Rábaköz region and in other parts of the Carpathian Basin/ Korall I. (2000) 1. szám 27-62., Korall II. (2001) 1-2. szám 297-314.

Takács K.: Árpád-kori csatornarendszerek kutatásáról. In.: Táj és történelem. Tanulmányok a történeti ökológia világából /=Research on medieval canal systems. In: Countryside and history. Studies on historical ecology/ Szerk.: R. Várkonyi Ágnes, Budapest, 2000. 78-106

Takács K.: Árpád-kori csatornarendszerek kutatásának eredményei /=Results of research on medieval canal systems/ Vízügyi Közlemények 83. (2001) 2. füzet 266-288.

Flood Control as a part of Integrated River Management in Hungary

Szlávik, L.[1] – Deseő, É.

Water demand is globally increasing, while the availability and quality of water resources are decreasing due to growth of domestic, industrial and agricultural water uses. The climate change, the extreme meteorological situations have caused temporary decrease of resources and the growth of the frequency of the flood events as well. There is a consensus that the integrated planning and management of water resources plays important role. The decisional process must be participatory, in order to reach decisions shared by the widest group of interested parties. Hungary has been prepared for the EU accession with the legal harmonisation of both the environmental and water related issues.

The new Water Framework Directive (WFD) aims the integrated approach of the future water management, rivers need to be managed by river basin – according to the natural geographical and hydrological unit- with the consideration of the environment and nature protection and with the involvement of the population, the active participation of the public in the decision making process and the intensive information of the local stakeholders. In Hungary - due to our country's geo-morphological situation – the river regulation has been developed long time ago. The fundamental cause of the high flood hazard is the situation of the overwhelmingly plain country in the deepest part of the Carpathian Basin, so that the flood waves which arrive from the surrounding Carpathian and Alpine mountain catchments tend to superimpose each other and often create emergency situations. Main purpose of the integrated river basin management is to ensure that the planning and implementation of water management harmonise with the requirement of ecological systems. The River Raba of western Hungary was investigated by a pilot integrated water management plan with the aim to improve the ecological status of the river and the whole river basin. Further objective of the project is the development of the country-side, nature conservation and environmental protection. Based on the experiment gained from this pilot project integrated river management plans have been considered for other major Hungarian rivers. This program is also supported by river related information system.

Following several serious flood events in the recent past it has been recognized in Hungary that a paradigm shift has to be made in coping with floods and this has to be in line with the objectives of the EU WFD. The "Update of the Vásárhelyi Plan", as the long-term programme is called aims to provide flood safety in the Tisza river basin applying a combination of traditional and non-traditional methods, together with a rural development scheme through an integrated way. The programme is set to start in 2004 in compliance with EU regulations including the Common Agricultural Policy. The paper describes the second largest water resources management programme in the history of the country.

The Update of the Vásárhelyi Plan is more than a simple flood control programme. It is also aimed at the development of the country-side, at nature conservation and environmental protection and also at the modernisation of agricultural practices. It is the reactivation of the floodplain, with regulated water outlets.

Analysing the above suggestions a proposal has been worked out for the necessary interventions and their potential impacts have been studied. To convey the flood without damage the most appropriate solution is the development of a system of storage-spillage. Based on this concept the optimal development policy for the Tisza-valley flood protection system is the combination of different technical alternatives providing also an opportunity for the rehabilitation of the Tisza River and the neighbouring landscape. It has been concluded that the involvement of stakeholders is key in the successful implementation.

During the 1998 to 2001 period four extraordinary flood waves have passed down the River Tisza. The total costs of flood fighting, emergency measures and reconstruction have amounted to some USD 570 million. Both public awareness of the hazard potential and the demand for a higher level of safety have grown in the wake thereof. The government had approved of the conceptual plan of enhancing flood safety in the Tisza Valley and obliged the competent ministries to elaborate detailed plans for Stage I of the development program. The development proposal comprises a complex program, which covers beyond the creation of a higher level of flood safety, the improvement of the living standards of the rural- and urban population in the region, the formulation and introduction of new types of agro-ecological land use in the area of the emergency flood retention reservoirs and the modernisation of the infrastructure in the communities along the River Tisza. In Stage I, which covers the years 2004 to 2007, the proposed flood safety enhancement measures include the restoration of the flow conveying capacity of the flood bed, the conservation oriented revitalisation thereof along the Upper Tisza, as well as along that between Szolnok town and the southern national border. Work will also be started on the creation of emergency retention reservoirs, of which six are contemplated at strategic sites (*Fig. 1.*). Agreement has been reached on the principles according to which a) the reservoir sites are selected and their area secured, b) the compensation to the farmers is awarded when they make their fields temporarily available for the purpose of

[1] Eötvös József College, 6500 Baja, Bajcsy 14. Hungary. Tel.: 36 30 655 6994; E-mail: szlavik@hu.inter.net

flood storage, and c) the methods of subsequent farming are decided upon. The costs of the first four years have been estimated at USD 620 million, one-half thereof devoted to flood control measures, the other to rural development, agro-ecological farming and infrastructure modernisation projects. Of this total USD 310 million have been earmarked for flood control projects. EU support is expected to cover approximately one-fourth of the total costs of the program. Progress towards program implementation has been achieved according to schedule. Preparatory activities so far have included surveys on the potential reservoir sites for ecological and archaeological values. The findings have revealed no obstacles to further designing work. The Strategic Environmental Assessment has been completed according to EU standards, the rural- and regional development opportunities related to the program have been explored together with the demands for intensifying economy and improving the infrastructure. Complying with EU requirements, the preparatory phase of the planning process was an open, transparent one, at public hearings with large audiences all potential stakeholders were given opportunity to voice their opinion. Over one-hundred village meetings and eighty other consultations have been organised. Among the tasks set for the year 2004 attention is called to the environmental impact assessments, to the preparation of the permit drawings, to the procurement of official permits for the structures designed, to the preparation of the detailed rural and regional development programs and to the selection of contractors by an open tendering procedure. Work on the first reservoirs and on clearing the flood bed has been scheduled to start in autumn, 2004. Continuous and outstanding care has been devoted to providing detailed information to the communities concerned and to obtaining public approval to the implementation of the program.

Figure 1. Emergency retention reservoirs

Soil and phosphorus loss differences between two study catchments on the watershed of Lake Balaton

Sisák, I.[1] – Máté, F. – Szűcs, P.

The soil erosion has special importance on the rolling watershed of the Lake Balaton, Hungary, since the sediment rich in organic matter and nutrients can accelerate eutrophication of the lake.
A nationally unique erosion monitoring network was established on the watershed of Lake Balaton in 2003. Three monitoring stations were constructed and equipped with automatic flow, rainfall and relative humidity meters and automatic samplers on three charcteristic catchments (2-7 km^2), one on each subwatershed of the lake. The three study catchments are Tagyon (in the northern subwatershed, steep slopes, forest in the upper segment and vineyards in the lower segment of the catchment), Nagyhorváti (in the western subwatershed, moderate slopes, deep, not eroded soils, dominantly arable land) and Somogybabod (in the southern subwatershed, forest in the upper segment, arable land in the lower segment of the catchment, relatively steep slopes, highly eroded soils on sandy loess).

Preliminary result from Tagyon and Nagyhorváti are presented in this paper. 94 soil samples from Tagyon and 74 samples from Nagyhorváti were collected from the upper layer of soils (vineyards and arable land). Routine soil-P test (ammonium-lactate soluble P) and an environmental soil P test were performed with the samples. The environmental soil P test is practically a wet sieving procedure (25 g soil, sieve of 125 µm mesh size, gentle horizontal shaker). After 5 minutes shaking the remainder of soil is washed from the sieve to a dish, it is dried, weighed and the percentage of fraction passed the sieve was calculated (data are not shown). The suspension is topped up to 2000 ml and is shaken up (10 upside down turn) and deposited for 100 and seconds and 24 hours. 25 ml samples are taken from 5 cm below surface, and filtered to determine the suspended sediment content larger than 0.45 µm by drying the filtered material at 105 ºC (SS). Molybdenium reactive P (MRP) is determined from the filtered sample. 10 ml sample is also taken at the same time as the 25 ml and it is used to determine total P (TP) content after sulfuric acid and hydrogen-peroxide digestion. SS MRP and TP were determined on one set of samples from runoff events on both study catchments.

			Tagyon	Nagyhorváti
	No. of soil samples		94	74
soil	Amm.-lactate sol. P_2O_5	$mg.kg^{-1}$	681	174
environmental soil P test	SS_{100sec}	$mg.l^{-1}$	1247	1417
	SS_{24hrs}	$mg.l^{-1}$	25.7	45.1
	MRP_{100sec}	$mg.l^{-1}$	0.23	0.10
	MRP_{24hrs}	$mg.l^{-1}$	0.27	0.11
	TP_{100sec}	$mg.l^{-1}$	1.84	1.33
	TP_{24hrs}	$mg.l^{-1}$	0.43	0.33
	No. of runoff samples		24	24
runoff samples	SS	$mg.l^{-1}$	319	297
	MRP	$mg.l^{-1}$	0.51	0.37
	TP	$mg.l^{-1}$	1.36	1.13

SS in environmental test is somewhat higher at Nagyhorváti but P signals are higher at Tagyon as a consequence of high P status of soils. The consecutive runoff samples have had relatively uniform SS, TP and MRP content throughout the sampling in Nagyhorváti but in Tagyon MRP was uniform in the initial phase of runoff event and increased drastically in the later, high-runoff-phase of the event. The phenomenon is in accordance with the high available P content of the soil.

The environmental soil P test is suitable to detect differences between potential P loss from different watersheds but the combined use of MRP and TP and incorporation of other (topographic, soil cover etc.) data should be investigated further.

This work was carried out with support of the DESPRAL (EVK1-CT-1999-00007) and 3/024/2001 NKFP projects.

[1] University of Veszprém, Georgikon Faculty for Agriculture, Department of Soil Science and Agrochemistry, Deák F. St. 16, H-8360 Keszthely, Hungary. Tel.: 36-83 312-330; E-mail: talajtan@georgikon.hu

Mechanical properties of a soil treated with brackish water

Spugnoli, P.[1] – Melani, E.M.

The paper reports the results of a study aimed to analyze the changes in mechanical behaviour of an agricultural soil at two different levels of sodicity, one very light (SAR 1,44), the other medium (SAR 4,34) simulating the effects of using slightly brackish water. It is well know that an increasing clay dispersion, caused by greater SAR, apart of other negative effects, also results in a higher mechanical strength of soil and aggregates (Barzegar et al. 1994b). However, mechanical strength alone gives poor information regarding stress-strain relationships and their repercussion on soil tillage and traffic problems. To relate soil volumetric change in response to external loads, the approach of critical state soil mechanics has been used. To this purpose, compression and direct shear tests have been carried out which, together with the measure of samples height variation during shear, allow the assessing of the main critical state mechanics parameters (Kirby, 1991), as well as Coulomb soil strength. The tested soil is a Haploxeralf Clay-silty Loam with illite and caolinite clay minerals, organic matter 33,9 g/kg. The two brackish water treatments produced the following two sodicity traits:

a: SAR 1,44; ESP 1,64; EC 1,45dSm^{-1}; **b**: SAR 4,34; ESP 4,83; EC 0,92dSm^{-1}.

Stability tests of these soils did not show any significant differences (Cavazza et al, 2002). The samples for soil mechanics tests were taken from two pies (diameter 380mm) of dry soil (weight 900g) composed by aggregates between 0,5 and 2 mm, slightly consolidated, wetted by spraying distilled water up to "field capacity", then dried at a moisture of 0,18g/g and subsequently allowed to equilibrate for 24h in sealed plastic containers. Thus five samples from each pie were prepared by cylindrical core sampler.

The results are that: as far as Coulomb law is concerned, soil **b** has a cohesion (143,48KPa) and an internal friction coefficient (0,279) higher than soil **a** (93,75KPa; 0,241, respectively), therefore the soil with higher SAR need more energy to be worked. In the framework of the critical state theory, the higher strength of soil **b** results in a lower compaction vulnerability but in a more deviatoric stress state needed to resume its initial macro porosity, i.e. to expand up to the precompaction specific volume. This later possibility doesn't mean that the agronomic soil structure functionality could be restored.

References

Barzegar, A.R., J.M. , Oades, P., Rengasamy, L., Giles, 1994b. Effects of sodicity and salinity on disaggregation and tensile strength of an Alfisol under different cropping systems. Soil & Tillage Research, 32: 329-345.

Kirby J. M., 1991. Strenght and deformation of agricultural soil: measurement and practical significance. Soil use and Management. Vol. 7, Nr. 4: 223-229.

Cavazza, L., A., Patruno, E., Cirillo, 2002. Soil traits and structure stability in artificially sodicated soil. Ital. J. Agron., 6, 1, 15-25.

[1] DIAF, Università di Firenze, P.le Cascine, 15. 50144 Firenze. Italia, Tel.: 0039 0553288318; Fax: 0039 0553288316; E-mail: paolo.spugnoli@unifi.it.

Influence of the thickness and grain-size of tephra mulch on soil water evaporation

Díaz, F. – Jiménez, C.C.[1] – Tejedor, M.

On the island of Lanzarote (Canary Islands, Spain), under extremely arid conditions which include annual rainfall of below 150 mm, a dryland farming system has evolved based on the use of volcanic mulch. The present paper examines the influence of two parameters of the mulch - thickness and grain size - on soil water evaporation. A laboratory experiment was conducted using columns with the following characteristics: interior diameter of 8.4 cm; exterior diameter of 9.0 cm; 30 cm in height. A Haplocambid soil with an bulk apparent of 1.1 g cm^{-3} was placed in each column. The mulch used consisted of basaltic pyroclasts of medium grain-size, with thicknesses of 2, 5 an-cm. The procedure used was as follows: the soils were saturated by capillary ascension for two days; they were then freely drained for two days. Each column was weighed and the soils were then covered with the different types of mulch, with some left uncovered as controls (3 replications of each). The columns were placed randomly on a round table such that all the columns were exposed to the same radiation. The energy required for evaporation was supplied by a 1500 W lamp placed at a height of 1.2 m above the central axis of the table. The evaporation rate for three columns with water which were included in the experiment also was taken as the potential evaporation and was more or less constant, varying between 9.1 and 11.5 mm day^{-1}, with an average of 10 mm day^{-1}, in keeping with an arid climate. Water loss in the columns was obtained by daily weighing during 31 consecutive days. The experiment was conducted in a closed room in which the temperature and relative humidity were monitored: the temperature remained at around 35 ± 2ºC and the relative humidity at 45-50%.

The accumulated evaporation in the mulched soils, irrespective of the thickness and grain size of the mulch, was significantly lower than in the bare soil. At the end of the experiment the water content at all depths of the mulched soils was higher than in the bare soils. In the covered soils the water distribution in the profile was markedly uniform, whereas in the bare soils there was a sudden increase at around 15 cm, as of which point the distribution was homogenous also. This circumstance is explained by the natural mulch effect exerted by the dry surface layer formed.

The reduction in accumulated evaporation was proportional to the mulch thickness: 10-cm of mulch (92 % reduction), 5-cm (83 % reduction) and 2-cm (52 % reduction). The 10 and 5-cm layers of mulch provide sufficient soil insulation, unlike the 2-cm thickness which is ineffective as a barrier preventing loss through evaporation. Field experiments have shown a much greater difference between the 10 cm and 5 cm layers, in favour of the former. With respect to grain-size, our experiment revealed a link between particle size and dispersion, through the effect on pore size, and losses through evaporation. The relationship between accumulated evaporation and the median particle diameter (D_{50}) was direct, but inverse in the case of the degree of dispersion. Of the three grain-sizes used in the experiment, the fine grain was found to be the most effective and the coarse grain the least effective.

[1] Dept. Edafología y Geología. Universidad La Laguna, Tenerife, Spain. Tel: 34 922 318629; Fax: 34 922 318311; E-mail: cacojime@ull.es

Soil Conservation in Romania - problems, research, control

Dumitru, E.[1] – Canarache, A.

Main problems of soil conservation in Romania refer to water erosion (47% of country total agricultural land), drought (48%), temporary waterlogging (26%, mostly surface-water ponding), subsoil compaction (of natural origin, 14% of cropland), topsoil man-made compaction (40% of cropland), crusting risk (16% of cropland), reduced humus storage (48%), reduced available nitrogen (55%) and phosphorus (44%), acidity (23%). Less frequent, but with serious problems of future expansion, are related to man-made pollution (surface mining, oil and industrial waste, airborne waste (8%), wind erosion (3%), salinity and sodicity (5%), alkalinity (2%), presence of coarse fragments (2%).

Research on various soil conservation problems started in this country during the 30', and it was much increased since the 50' of last century.

A first kind of research has been devoted to finding out extent and to localise soil degradation processes, mainly on cropland. Existence since the beginning of last century of soil maps at small scale, and preparation during the last 50 years of large scale (1:10,000) maps made possible identification of areas affected by all degradation processes, as well as drawing of derived maps on erosion, salinity, water excess, compaction, etc. A database and a geographical information system is in its final stage for small scale maps, and it will make possible further processing of existing data. The soil quality monitoring system, in use in the last decade, is detailing such data, based on a network of almost 1,000 soil profiles set-up according a regular pattern throughout the country.

The next area of research has been related to soil degradation processes, causes, relationships to various natural environment and to cropping pattern, to their effects on soil quality, environment, crop yields, farming economic results. Significant results were obtained in this area of research concerning water and wind erosion, drought, compaction, acidity, available nutrients, pollution, and salinity. For several of these processes, statistical processing of data and simulation modelling are in advanced stage of progress.

Research on technical solutions to prevent, mitigate and / or rehabilitate soil degradation has been quite intensive. Adequate techniques for water and wind erosion control, efficient use of irrigation water in correlation with soil moisture storage, dry-farming cropping on non-irrigated land, land shaping for control of surface ponding, deep ripping for remediation of subsoil-compacted soils, prevention of topsoil compaction under specific climatic conditions of this country, application of fertilisers and liming according to soil testing, melioration of saline soils especially in rice fields, etc. Most of these procedures are of high quality from the technical point of view, but often not enough related to economical profits.

Most of soil conservation problems in this country are related to increase in population and in agricultural land, mainly leading to deforestation, during the last two centuries. The period of centralised, state and collective farming, agriculture before 1989 may be characterised, from the point of view of soil conservation, by transforming in cropland many areas not suitable to such use, by a large extent of engineering projects, including irrigation, many of them non-economical and technically incomplete, by larger but still insufficient use of fertilisers and liming, by low interest for prevention of pollution, by better land planning related to erosion control, especially in Eastern Romania. Since 1989, return of land to original owners under conditions of an extremely large percentage of rural population and of very low capital funding of the new farmers proved to be detrimental for soil conservation, at least on a short-time range. Such problems refer especially to sloping land, where the return of land act stated that old location, unfortunately mostly up-down slopes, should be restored. Increase in farm size and in economical status of these farms, build-up of family farms similar to the ones active in other parts of the world, should certainly deal with these questions.

Present legislation concerning soil conservation is acceptable. There are specific regulations concerning establishment of a soil restoration fund, reafforestation of degraded land, pollution control, soil quality monitoring, soil survey, establishment of irrigation water-users associations and state-supported low prices of water for these associations, financial support for liming and other techniques, a. o. State budget funding of these actions is provided, even if the present financial status of the country is able to cover only a relatively low part of such needs. Government agencies are active in soil survey, soil testing and soil quality monitoring, as well as in engineering practices. A couple of years ago a Government agency has been founded for extension, with local teams in each county and in many villages. At present, discussions are going on for harmonisation of regulations with the European Union acquis, and efforts are made to adjust provision of the acquis to local natural and social-economical conditions.

[1] Research Institute for Soil Science and Agrochemistry, Bucharest, Romania. Tel.: +40 21 2241791; Fax: +40 21 2225979; E-mail: elisa@icpa.ro

Missing items for the developing European Soil Protection Strategy

Michéli, E.[1] – Szegi, T. – Montanarella, L.

Introduction

Only a small fraction of the European population is currently living in rural areas and having a direct contact with soils. That is one of the reasons that most European citizens do not know enough about soils. The most common perception is usually that soils are a good dumping site for all kind of wastes and that soils can be quite useful as surfaces for building houses and infrastructure. In recent years it has been emphasised even in political circles in Europe that soils perform a number of functions, that is, they offer a range of different utilization options that depend on their natural characteristics, some of which can be influenced by humans.

Soil Functions

It has been suggested that soils have a regulation function, a habitat function, a utilization or production function, and a cultural function. The function of regulation refers to mediating fluxes of energy, water and external additions, and habitat means being home to the richness of the world's biodiversity. A function of production refers mainly to the support of plants and animals, and culturally soils serve as a primary source of values as well as a final resting place. Details of these functions have been appropriately described by several groups (GCACC,1995; Karlen et al, 1997). From an economic point of view every area of land embodies a production function with soil characteristics representing the production factors and soil functions representing the output. The different soil functions form a complex network of relationships with each other and with the specific characteristics of the soils. In some instances conflicting relations exist whereby use of a soil for one function excludes or restricts other use options. In some cases there may be complementary relations of the functions.

Soil degradation restricts the functions of soils.

Based on the recognition that "'Soil degradation restricts the functions of soils" it became obvious that there is need need for a coherent approach to soil protection on the political agenda in Europe. In the Community's 6th Environment Action Programme (6th EAP) therefore soil protection is one of the thematic strategies to be developed.

The EU soil protection strategy builds upon the recognition that severe degradation processes threaten the important functions of soils. The major threats identified so far are:

soil erosion
decline in organic matter content
loss of soil biodiversity
soil contamination
salinization
soil compaction
soil sealing
and major hydro-geological risks (flood and landslides).

The estimated areas affected by major soil threats in Europe are given in Table 1.

Below a brief summary is given on the land degradation processes:

Soil erosion

Soil erosion by water is a widespread problem throughout Europe. A report for the Council of Europe, using revised GLASOD data (Oldeman *et al.*, 1991; Van Lynden, 1995), provides an overview of the extent of soil degradation in Europe. 114.5 M ha (52.3%) of the total area is affected by erosion. The most dominant effect is the loss of topsoil. (Fournier, 1972).The main causes of soil erosion are still inappropriate agricultural practices, deforestation, overgrazing and construction activities (Yassoglou *et al.*, 1998).

Decline in organic matter

Closely linked to the process of soil erosion is the extensive decline in organic matter content that can be observed in Europe.

[1] Szent Istvan University, Gödöllő, Hungary, Páter Károly utca 1. 2100 Tel: +36 28 410-200, E-mail: micheli@fau.gau.hu

Soil organic matter is extremely important in all soil processes. It is essentially derived from residual plant and animal material, synthesised by microbes and decomposed under the influence of temperature, moisture and ambient soil conditions.

Agronomists consider soils with less than 1.7% organic matter to be in pre-desertification stage. Effective measures to revert this trend exist: reduced tillage, zero tillage, conservation agriculture, cover crops, application of manure, compost and sewage sludge. Land use changes like conversion to grassland and reforestation can have a very positive effect on soil organic matter content.

Loss of soil biodiversity

The decline of organic matter is closely linked to the loss of soil biodiversity. Soils are a major habitat for plants and animals. Millions of organisms can be present in just one teaspoon of soil. Fungi, bacteria, nematodes, earthworms and higher animals form a complex food web that is still only partially known and understood. Many species still are waiting to be correctly identified and described. The increasing use of agro-chemicals and the rapid decline in organic matter content are threatening the diversity of organisms in soils. Only little is known on the impact of genetically modified crops on the gene pool in soils. Root residues from these new GMO's could affect the soil biodiversity. There is still a lot to be investigated in this respect.

Recognising that soils contain as much biodiversity as the above ground habitats requires to take steps towards protecting this precious resource from further degradation. This was also recognised by the Conference of Parties (COP) to the Convention on Biological Diversity (CBD) at its 6th meeting in Nairobi April 2002 that decided (COP decision VI/5, paragraph 13) "…to establish an International Initiative for the Conservation and Sustainable Use of Soil Biodiversity as a cross-cutting initiative within the programme of work on agricultural biodiversity, and invites the Food and Agriculture Organization of the United Nations, and other relevant organizations, to facilitate and coordinate this initiative".

Soil contamination

One of the main threats to soil biodiversity and soil health in general is contamination both by diffuse and local pollution. Diffuse pollution is generally associated with atmospheric deposition, certain farming practices and inadequate waste and wastewater recycling and treatment. Atmospheric deposition is due to emissions from industry, traffic and agriculture.

Salinization

Salinization is the accumulation in soils of soluble salts of sodium, magnesium, and calcium to the extent that soil fertility is severely reduced. In dry land areas of Europe potentially affected by desertification (arid, semiarid and dry sub humid) the most affected zones are located in Hungary, Romania, Spain, Italy, Albania, and Greece, according to several authors (EEA, 1998).

Physical degradation

The most common form of soil physical degradation is soil compaction. Soil compaction occurs when soil is subject to mechanical pressure through the use of heavy machinery or overgrazing, especially in wet soil conditions. In sensitive areas, walking tourism and skiing also contribute to the problem. Compaction reduces the pore space between soil particles and the soil partially or fully loses its absorptive capacity. Compaction of deeper soil layers is very difficult to reverse. It has been estimated that nearly 4% of soil throughout Europe suffers from compaction , but no precise data are available.

According to a recent study (Jones et al., 2001, 2003), more than a third of the soils in Europe are highly susceptible to compaction in the subsurface layers or horizons. Compaction of surface soil can, at least temporarily, be alleviated by mechanical loosening but in the subsurface horizons this is often difficult and expensive. Therefore any management system that is likely to increase subsoil compaction is not truly sustainable.

Soil sealing

Much more serious then soil compaction is the threat to soil functions by covering of soil for housing, roads or other land developments, known as soil sealing. When land is sealed, the area for soil to carry out its functions including the absorption of rainwater for infiltration and filtering is reduced. The sealing of land leads to the direct run-off of precipitation into rivers (EEA, 2001) which, in turn, enhances the risk of flooding at the regional level. In addition sealed areas may have a great impact on surrounding soils by changing water flow patterns and by increasing the fragmentation of biodiversity. Soil sealing is almost irreversible.

Floods and Landslides

Floods and landslides are mainly natural hazards intimately related to soil and land management. Floods and mass movements of soil cause erosion, pollution with sediments and loss of soil resources with major impacts for human activities and human lives, damage to buildings and infrastructures, and loss of agricultural land. Floods and landslides are not a threat to soils in the same manner as the threats already listed. However, floods can, in some cases, result in part from soil not performing its role of controlling the water cycle due to compaction or sealing. They may also be favoured by erosion often caused by deforestation or by abandonment of land.

Table 1. Estimated areas affected by major soil threats in Europe

Threat[1]	Area affected[2] (million hectare)	Percentage of total European land area
Pesticides	180	19
Nitrates and phosphates	170	18
Water erosion	115	12
Acidification	85	9
Wind erosion	42	4
Soil Compaction	33	4
Salinisation	3.8	0.4
Organic matter loss	3.2	0.3

[1.] Different threats can affect the same land area so that numbers cannot be added up.
[2.] Area covers all land uses. *Source*: EEA (1995a, p.152)

The development of the European Soil Thematic Strategy

For development of the European Soil Thematic Strategy special mandates were given five *Working Groups on* 1. Contamination , 2. Organic matter *and biodiversity* , 3. Erosion, *salinisation, compaction, floods and landslides,* 4. Research *and sealing and 5.* Monitoring (consisting of representatives from member and accession countries). An Advisory Forum was also established to guide the soil policy development process, to co-ordinate and oversee the work of the different Working Groups, to monitor the implementation of the work-plan, to give guidance on key issues and assess and evaluate the output from the various working groups.

The missing items

Protection of unique formations

Soils are often preserving cultural heritage and anthropologists generally protect those. However soils are often preserving unique formations that have not so strong connection to the primary soil functions and no body is in charge to protect them. Those formations might be natural soils from ancient climatic periods, or result of complex unusual soil forming processes. An example is given in Figure 1. Others might soils of lands were special ancient or traditional ways of cultivations were performed, or just sites for important in research or education interests. Without protection those formation may disappear. Therefore we suggest that the protection of such site should have place in the developing strategy.

Suggestion for the establishment of a European Soil Conservation Service

The implementation of the EU soil protection policy and related directives and programs need harmonized information, harmonized concepts and methods and an operative network. At the moment there is no defined plan for a coordination body in the implementation. We believe that there is a need for the establishment of a European Soil Conservation Service

The mission of the ESCS would be to provide coordination to the effort to conserve and improve soils and other natural resources in Europe. The vision of such organization is a harmonized soil survey and soil protection in Europe.

The suggested function of a potential ESCS:

- Provide bridge between EU political decisions and practical execution of soil survey and protection programs on national and regional levels.
- Provide harmonized methodology for soil survey, data collection and problem evaluation.
- Provide coordination of the development for conservation programs and practices and technical guidance to them (through training programs, published guidelines and brochures).
- Provide bridge between scientific results and practices.

The suggested structure of a potential ESCS:

Nested structure

ESCS Center → National Centers → regional offices (stations)

Figure 1. Example for a unique formation to be protected. The Atkár periglacial paleosol. Paleosols are soils of past geologic periods. In their morphology and properties these soils preserve important information of the paleo environment in which they formed. The Atkár periglacial soil is a unique formation resulting from the changing environment of the Pleistocene period.

References

COMMUNICATION FROM THE COMMISSION TO THE COUNCIL, THE EUROPEAN PARLIAMENT, THE ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS "Towards a Thematic Strategy for Soil Protection", COM(2002) 179 final, Brussels, 16.4.2002.

EEA, Europe's Environment: The Dobris Assessment, Chapter 7. Soil, 27pp. European Environment Agency, 1995.

EEA, Down to Earth: soil degradation and sustainable development in Europe. Environmental Issues Series, Number 16, 32pp. European Environment Agency, 2000.

Fournier, Soil Conservation - Nature and Environment No 5, Council of Europe, Strasbourg, 1972.

German Advisory Committee on Global Change (GACGC). 1995. World in transition: the threat to soils. 1994 annual report. Economia Verlag, Bonn.

Karlen, D. L., M. J. Mausbach, J. W. Doran, R. G. Cline, R. F. Harris, and G. E. Schuman. 1997. Soil quality: a concept, definition, and framework for evaluation. Soil Sci. Am. J. 61: 4-10.

Gentile, A.R., Towards the development of a system of policy relevant indicators on soil. European Soil Forum, Berlin, 1999.

Jones, R.J.A., Spoor, G. and Thomasson, A.J. (2000). Assessing the vulnerability of subsoils in Europe to compaction. In: J. Arvidsson, J.J.H. Van den Akker and R.Horn (Eds.), Proceedings of 3rd Workshop of the Concerted Action 'Experiences with the impact of subsoil compaction on soil, crop growth and environment and ways to prevent subsoil compaction', 14-16th June 2000, Uppsala, Sweden p.160-172.

Jones, R.J.A., Spoor, G. and Thomasson, A.J. (2003). Assessing the vulnerability of subsoils in Europe to compaction: A preliminary analysis. [Soil & Tillage Research, 0, 000-000. In press].

Oldeman, L.R., Hakkeling, R.T.A. and Sombroek, W.G., World Map of the Status of Human-Induced Soil Degradation, with Explanatory Note (second revised edition) - ISRIC, Wageningen; UNEP, Nairobi, 1991.

World Atlas of Desertification. Edward Arnold, London, United Nations Environment Programme, 1992.

Yassoglou, N., Montanarella, L., Govers, G., Van Lynden, G., Jones, R.J.A., Zdruli, P., Kirkby, M., Giordano, A., Le Bissonnais, Y., Daroussin, J. & King, D. Soil Erosion in Europe. European Soil Bureau, 1998.

Zdruli, P,. Jones, R., Montanarella L (1999). Organic Matter in the Soils of Southern Europe. DGXI.E3 Brussels.

Rainfall and mineral fertilization interactions on crops yield

Márton, L.[1]

Abstract

The effect of rainfall quantity, distribution and N, P, K, Ca, Mg fertilization on the yield of rye, potato, winter wheat, triticale were evaluated in the 42 years of a long-term mineral fertilization experiment [soil (acidic, sandy, brown forest) x fertilization (N, P, K, Ca, Mg) x rainfall (quantity, distribution) x crop (rye, potato, winter wheat, triticale)] set up in 1962 in a fragile agro-ecological circumstances in Nyírlugos-Nyírség region of Eastern Hungary. The soil had the following agrochemical characteristics: pH (H_2O) 5.9, pH (KCl) 4.7, hydrolytic acidity 8.4, hy_1 0.3, humus 0.7%, total N 34 mg kg^{-1}, ammonlactate (AL) soluble-P_2O_5 43 mg kg^{-1}, AL-K_2O 60 mg kg^{-1} in the plowed layer. From 1962 to 1980 the experiment consisted of 2x16x4x4=512 plots and from 1980 of 32x4=128 plots in split-split-plot and factorial random block designs. The gross plot size was 10x5=50 m^2. The average fertiliser rates in kg ha^{-1} $year^{-1}$ were nitrogen 45, phosphorus 24 (P_2O_5), potassium 40 (K_2O), magnesium 7.5 (MgO) until 1980 and nitrogen 75, phosphorus 90 (P_2O_5), potassium 90 (K_2O), magnesium 140 ($MgCO_3$) after 1980. The main results and conclusions were as follows: 1. During the vegetation period the relationships between rainfall quantity, NPKCaMg nutrition and yield could be characterised primarily by quadratic correlations (rye „R":0=0.9900***, N=0.8400***, NP=0.8400***, NK=0.9100***, NPK=0.8500***, NPKMg=0.6500***, potato:0=0.9800***, N=0.9500***, NP=0.9600***, NK=0.9500***, NPK=0.9800***, NPKMg=0.9600***, winter wheat:0=0.5949***, N=0.5734***, NP=0.7635***, NK=0.5357***, NPK=0.6710***, NPKMg=0.7055***, triticale:0=0.3455***, N=0.2779+, NP=0.4722***, NK=0.3738***, NPK=0.6311***, NPKCa=0.6673***, NPKMg=0.6734***, NPKCaMg=0.6232***). 2. Maximum yields rye: 4.0 t ha^{-1}, potato: 21.0 t ha^{-1}, winter wheat: 3.4 t ha^{-1}, triticale: 5.0-6.0 t ha^{-1} were recorded when the natural rainfall amounted to 430-500, 280-330, 449-495 and 550-600 mm. At values above and below this figures there were a cosiderable reduction in the yield. According to our scientific results we can state that the yield of crops were strongly influenced (quadratic correlation) by N, P, K, Ca, Mg fertilization x rainfall quantity and distribution interctions.

Key words: rainfall, crops, nutrient supply, yield

Introduction

Agricultural production has a well estabished relationship to climate change (Berényi 1944., Szász 1981., Adams et al. 1990., Harnos 1993., Barrow et al. 2000., Downing et al. 2000., Bocz 2001). There is, therefore, growing concern about the potentially wide ranging impacts that climate change would have on these key as the nature and extent of anticipated changes have become more evident. It also includes changes in land use and in plant production and their management. These changes are unprecedented in terms of both their rate and their spatial extent. Changes in land use (agrotechnics, soil cultivation-, fertility-, quality-, protection-, etc.) and in plant production (plant nutrition-, rotation-, protection-, etc.) are currently the main manifestations (Stefanovits 1966., Győrffy and Sváb 1993., Várallyay 1984., Kováts et al. 1985., Lásztity 1991., Kádár 1992., Kádár and Szemes 1994., Németh 1996). As an interdisciplinary problem it is necessary to study such a complex matter (Láng 1973., 2003).

Generally among natural catastrophes, droughts and floods cause the greatest problems in field crop production (Gyuricza and Birkás 2000). The droughts and the floods that were experienced in Hungary in the early 1980s have drawn renewed attention to the analyses of these problems (Rácz 1999).

Rye (*Secale cereale* L.), potato (*Solanum tuberosum* L.), winter wheat (*Triticum aestivum* L.) and triticale are demanding indicator crops to climate factors and soil nutrient status.

New research on climate change-soil-plant systems are focused on crops yield. This paper reports the raifall change x soil x mineral fertilization x plant interactions on crops yield in a long term field experiment in Hungary.

Materials and Methods

The effect of climatic anomalies primarily the quantity and distribution of rainfall and mineral fetrilization (N, P, K, Ca, Mg) on rye, potato, winter wheat and triticale yields were examined from 1962 to 2001 in a long term mineral fertilization field experiment set up on an acidic, sandy, brown forest soil with alternating thin layers of clay substance in Nyírlugos, North-East Hungary.

[1] Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, H-1022 Budapest, Herman O. u. 15. Tel/Fax: 00-36-1-3558491; E-mail: marton@rissac.hu

The soil had the following agrochemical characteristics: pH (H_2O) 5.2-6.5, pH (KCl) 4.4-4.9, hydrolytic acidity 5.9-10.8, hy_1 0.2-0.4, humus 0.4-0.9%, total N 20.6-48.0 mg kg^{-1}, ammonlactate (AL) soluble-P_2O_5 20-66 mg kg^{-1}, AL-K_2O 20-100 mg kg^{-1} in the plowed layer.

From 1962 to 1980 the experiment consisted of 2 x 16 x 4 = 128 treatments in 4 replications, giving a total of 512 plots and from 1980 of 32 x 4 = 128 plots in split-split-plot and factorial random block designs. The gross plot size was 10 x 5 = 50 m^2. The fertilizer rates and combinations applied are shown in 1. table.

The nitrogen as 28% calcium ammonium nitrate was applied in two equal splits in autumn and spring, while the P, K, Ca and Mg fertilizers were applied prior to ploughing in autumn in the form of 18% superphosphate, 60% potassium chloride, 95% limstone powder and 18% dolomite powder. In autumn 1997 the P, K, Ca and Mg fertilizers were applied for four years in advance. Rinfall datas were estimated by hungarian traditional and crop-specific ecological standards. Experimental data bases were analysed by MANOVA and regression analysis (SPSS).

Table 1. Fertilizer rates and combinations applied (Nyírlugos, 1962-2001)

Fertilizer rates (kg ha^{-1} $year^{-1}$) from 1962 to 1980							
Control (no fertilization)							
Rate	Rye	Wheat	Potato	Rate	Rye	Wheat	Potato
N_1	30	30	50	P_2O_5	48	48	48
N_2	60	60	100	K_2O	80	80	150
N_3	90	90	150	MgO	15	15	30

N, P, K, Mg combinations		
Control (no fertilization)		
N_1	N_2	N_3
N_1P	N_2P	N_3P
N_1K	N_2K	N_3K
N_1PK	N_2PK	N_3PK
N_1PKMg	N_2PKMg	N_3PKMg

Fertilizer rates (kg ha^{-1} $year^{-1}$) from 1980					
Level	N	P_2O_5	K_2O	$CaCO_3$	$MgCO_3$
Control	0	0	0	0	0
1	50	60	60	250	140
2	100	120	120	500	280
3	150	180	180	1000	-

N, P, K, Ca, Mg combinations		
Control (no fertilization)		
N_1	N_2	N_3
N_1P	N_2P	N_3P
N_1K	N_2K	N_3K
N_1PK	N_2PK	N_3PK
N_1PKCa	N_2PKCa	N_3PKCa
N_1PKMg	N_2PKMg	N_3PKMg
$N_1PKCaMg$	$N_2PKCaMg$	$N_3PKCaMg$

Results and Discussion

Rye results between 1962 and 1972

On the basis of traditional (Harnos 1993) and rye specific rainfall deficiency values (Márton 2002a) the years could be divided into average (1966), dry (1964, 1968, 1972) and wet (1970) years. Without fertilization the weather anomalies (drought, abundant rainfall) did not cause significant yield differences (average year: 1.63 t ha^{-1}, dry year: 1.51 t ha^{-1}, wet year: 1.47 t ha^{-1}). In the case of poor (30 kg ha^{-1}) N supplies the yields ranged between 2.35 and 2.77 t ha^{-1}. In the average year the yield was more than 1.0 t ha^{-1} higher than on the control plot, while dry and wet years led to yield reductions of 26 and 23%, respectively. With a moderate rate of N fertiliser (60 kg ha^{-1}) the yields were almost twice those in the control. The damaging effect of drought was reduced from 26% with poor N supplies to 15%. Excessive rainfall reduced the yields by 29%. At an N rate of 90 kg ha^{-1} the yields were greater than 3.5 t ha^{-1} in the average year, while this was reduced by 20% on average in the dry years and by 48% in the wet year. In general close quadratic correlations could be demonstrated between the rainfall quantity during the vegetation period and the yield, depending on the 0 (R=0.9900***), N

(R=0.8400***), NP (R=0.8400***), NK (R=0.9100***), NPK (R=0.8500***), NPKMg (R=0.6500***) rate. The best yields of around 4.0 t ha^{-1} were recorded when the natural rainfall amounted to 430-500 mm. Rainfall quantities in excess of 500 mm caused severe yield reductions.

Potato results between 1962 and 1979

The years were distinguished as dry (1973), wet (1965) or average (1963, 1967, 1969, 1971, 1975, 1977, 1979) on the basis of „general" (Harnos 1993) and potato specific (Márton 2002b) rainfall deficiency limits. The year effects in the experiments were determined chiefly by the rainfall quantities in the winter half years, followed by the months prior to seeding, the vegetation periods, the summer half years and the harvesting months. Without fertilization the yield was reduced by 2.0-2.8 t ha^{-1} in the dry (1973) and wet (1965) years compared with the average years. At low nutrient rates (N, NP, NK, NPK and NPKMg combinations involving 50 kg ha^{-1} N) the yield was greater than in the control plots, especially in the dry year (8.0 t ha^{-1}), when averaged over the fertilization treatments. In the average and wet years this value was 5.8 and 4.4 t ha^{-1}, respectively. Compared to the average years, the yield increase was around 67% in the dry year, while the yield in the wet year was similar to than in the average years. At medium nutrient rates (N, NP, NK, NPK and NPKMg combinations involving 100 kg ha^{-1} N) the maximum yields were produced in the NPK and NPKMg treatments. The year effects were more uniform due to the better nutrient status. In the average years the yield increasing effect of fertilization was over 7.0 t ha^{-1}. In the dry year this figure approached 10.0 t ha^{-1}, while in the wet year it dropped to 7.6 t ha^{-1}. At high nutrient rates (N, NP, NK, NPK and NPKMg combinations involving 150 kg ha^{-1} N) the yield rose to over 16.0 t ha^{-1} when averaged over all the fertilizer treatments, which was 100% greater than that of the control plots. The yield reducing effect of wet and dry years was not observed at this nutrient supply level, confirming the ability of fertilization to compensate for poor weather conditions. The yield increased by 3% in the dry year and 12% in the wet year compared with the average. The positive effect of the wet year was almost 24% greater than that of the medium nutrient level. Close quadratic correlations were observed between the rainfall during the vegetation period and the yield, depending on the nitrogen rates (0:R=0.9800***, N:R=0.9500***) and on the NP (R=0.9600***), NK (R=0.9500***), NPK (R=0.9800***) and NPKMg (R=0.9600***) combinations. Yields close to the maximum (21.0 t ha^{-1}) were achieved in the 280-330 mm range. Rainfall amounting to over 400 mm caused a substantial reduction in yield.

Winter wheat results between 1973 and 1990

On the basis of „general" (Harnos 1993) and winter wheat specific rainfall deficiency values (Márton 2002c) the years could be classified as average (1978, 1982, 1989), dry (1974), droughty (1976, 1990) and wet (1980). In average years the yield of the control plots became stabilised at the 1.6 t ha^{-1} level. In the fertilized treatments the highest yield (3.7 t ha^{-1}) was more than one and a half times the lowest yield (2.3 t ha^{-1}). N, NP and NK fertilization resulted in an increase of around 1.0 t ha^{-1} in the main yield compared with the control. The wheat yields could only be enhanced economically by full treatment with NPK or NPKMg. Without fertilization the yield in the dry year (1.7 t ha^{-1}) was similar to that in the average year (1.6 t ha^{-1}). The extent of loss was 12% in the N, NP and NK treatments and 10% in the NPK and NPKMg treatments. In the case of drought the grain yield of the control plots was approx. 30% lower than in the average year. The loss in the one sided N and deficient NP and NK combinations was 41%, and this was aggravated by a further 7% by the NPK and NPKMg rates (48%). In the wet year the yield declined even more than in the case of drought. The unfertilized plots yielded over 80% less than in the average years. In the case of the unfavourable nutrition (N, NP, NK) the decrease in the harvested main yield was 64%, while the negative effect was slightly less (63%) in the NPK and NPKMg treatments. The relationships between rainfall during the vegetation period, N, P, K and Mg fertilization and yield were characterised by second degree correlations depending on the level of nutrition (0:R=0.5949***, N:R=0.5734***, NP:R=0.7635***, NK:R=0.5357***, NPK:R=0.6710***, NPKMg:R=0.7055***). The garin yield per mm in the case of optimum rainfall supplies ranged from 3.7 to 7.2 kg ha^{-1}, depending on the fertilizer rate (0:3.7, N:4.6, NP:6.1, NK:4.8, NPK:6.2, NPKMg:7.2, treatment mean:5.4 kg ha^{-1}). The natural rainfall was utilised better in the fertilized plots than in the untreated control (N:24, NP:65, NK:28, NPK:67, NPKMg:95, treatment mean 46%). Supplementary magnesium fertilization led to a 17% (1.0 kg ha^{-1} mm^{-1}) increase in yield compared to the NPK treatment. Maximum yields (3.4 t ha^{-1}) were recorded when the natural rainfall amounted to 449-495 mm.

Triticale results between 1990 and 2001

On the basis of „general" (Harnos 1993) and specific rainfall suplly values (Márton 2002d) the years were characterised as average (1991, 1995, 2000), dry (1993), droughty (1992, 1994, 1996), wet (1997, 1998, 2001) and very wet (1999). The year effects in the experiments were determined chiefly by the rainfall quantities in the winter half year, the summer half year and the month prior to sowing, and by the frequency of consecutive critical months during the vegetation period and the experimental year. In average years the yield of the unfertilised control plots was low (1.4 t ha^{-1}). In the fertiliser treatments the maximum yield (4.0 t ha^{-1}) was more than twice the lowest yield (1.9 t ha^{-1}). N, NP and NK fertilization resulted on average in a 1.0 t ha^{-1} yield increment compared to the control plots. The triticale yield could only be incresaed economically by the full NPK treatment (3.3 t ha^{-1}) or by combinations including calcium and magnesium (NPKCa, NPKMg, NPKCaMg) (3.9 t ha^{-1}). In dry and droughty weather the yield of the control areas was 14% and 36% less, respectively, than in average years. The application of N alone or of NP and NK treatments led to yield losses of 45 and 24%, respectively, while that of NPK, NPKCa, NPKMg or NPKCaMg caused a further 22% drop in both types of years. In the wet years the yield decreased by 14% in the unfertilized plots, remained unchanged in the case of N, NP or NK nutrition, and increased by 31% in the NPK, NPKCa, NPKMg and NPKCaMg treatments. In the very wet year the yields were similar to those in the average year. The relationships between rainfall quantity during the vegetation period, NPKCaMg nutrition and yield could be characterised primarily by quadratic correlations (R: Control=0.3455***, N=0.2779+, NP=0.4722***, NK=0.3738***, NPK=0.6311***, NPKCa=0.6673***, NPKMg=0.6734***, NPKCaMg=0.6232***). Maximum yields in the region of 5.0-6.0 t ha^{-1} were achieved in the rainfall range of 550-600 mm, at around 580 mm. At values above and below this figure there was a cosiderable reduction in the grain yield.

Acknowledgement

This researches were supported by Hungarian Academy of Sciences, H-Budapest

References

Adams R. M., Rosenzweig C., Peart R. M., Ritchie J. T., McCarl B. A., Glyer J. D., Curry R. B., Boote K. J., Allen L. H. (1990): Global climate change and U.S. agriculture. *Nature.* 345, 219-224.

Barrow E. M., Hulme M., Semenov M. A., Brooks R. J. (2000): Climate change scenarios. In: Climate Change, Climatic Variability and Agriculture in Europe (Ed's. T. E. Downing., P. A. Harrison., R. E. Butterfield., K. G. Londsdale). European Commision. Brussel.

Berényi D. (1944): Relationship between potato yield and weather. *Alföldi Magvető.* Debrecen.

Bocz E. (2001): Water supply reduction in Hungary. In*: Water supply and irrigation forecast.* (eds Lunczer S). XXX. 3. AUD. Debrecen.

Downing T. E., P. A. Harrison., R. E. Butterfield., K. G. Lonsdale. (2000): Climate Change, Climatic Variability and Agriculture in Europe. University of Oxford. Oxford.

Győrffy B., Sváb J. (1993): Farm scale drought analysis in 1983. In: Drought 1983 (eds Baráth Csné., Győrffy B., Harnos Zs) UVF. Budapest. 47-106.

Gyuricza Cs., Birkás M. (2000): Effect of extremes of rainfall supplies on certain crop production factors in maize grown on brown forest soil. *Plant Production.* 49, 691-706.

Harnos Zs. (1993): Time scale weather and weather-yield analysis. In: Drought 1983 (eds. Baráth Cs.-né., Győrffy B., Harnos Zs). UVF. Budapest.

Kádár I. (1992): Principles and methods in plant nutrition. RISSAC-HAS. Akarint.Budapest.

Kádár I., Szemes I. (1994): 30 years of long term experiment Nyírlugos. RISSAC-HAS. Budapest.

Kováts A., Márton L., Szabó L. (1985): Analysis of the relations between humus and pH on the ground of results of soil investigations on farm-scale plots. *Plant Production.* 34, 507-512.

Láng I. (1973): Long-term fertilisation experiments on sandy soils. Thesis of the Academy. Budapest.

Láng I. (2003): Plan for researches of global climate changes. *The village.* 18, 85-89.

Lásztity B. (1991): Water supply of barley and fertilisation. *Agrochemistry and Soil Science.* 40, 97-108.

Márton L. (2002a): Climate fluctuations and the effect of N fertiliser on the yield of rye (*Secale cereale* L.). *Plant Production*. 51, 199-210.

Márton L. (2002b): Analysis of year effect in a long-term fertilisation experiment in Nyírlugos (North East Hungary). Effect of rainfall and nutrient supplies on the yield of potato (*Solanum tuberosum* L.). *Plant Production.* 51, 71-87.

Márton L. (2002c): Relationships between rainfall, nutrient supplies and the yield of winter wheat (*Triticum aestivum* L.). *Plant Production.* 51, 529-542.

Márton L. (2002d): Effect of rainfall and nutrient supplies on the yield of triticale in long-term experiments. *Plant Production*. 51, 687-701.

Németh T. (1996): Organic matter content and N cycling in our soils. RISSAC-HAS. Budapest.

Rácz L. (1999): Climate History of Hungary Since 16th Century: Past, Present and future. Discussion paper (Serial editor. Z. Gál) Center for Regional Studies of the Hungarian Academy of Sciences, Pécs. 160 p.

Stefanovits P. 1966. Hungarian sandy soil characterisation. In: Plant production on sandy soil. (eds Antal J) 9-22. Agricultural Press. Budapest.

Szász G. (1981): Bases of the weather and yield modelling systems. *Weather.* 85, 334-345.

Várallyay Gy. (1984): Water manage problems of the hungarian sandy soils. Agrochemistry and soil Science. 33, 159-170.

Comparison of tillage and water erosion rates on a loess slope: a case study from south-eastern Poland

Rejman, J.[1]

Abstract

Soil translocation due to shallow and deep mouldboard plow was studied on silt loam developed from loess. Tillage operations were performed in up- and down-slope direction on 7-12% slopes. During shallow plow, 34 kg m^{-1} of soil was displaced down-slope on an average distance of 25.8 cm and during deep plow, 46 kg m-1 of soil was displaced with an average distance of 13.5 cm. These results were compared with water erosion rates evaluated with a system of runoff plots of different length (bare plots). Water erosion rates established on particular measurement periods was 290.7 kg m^{-1} with average effective distance of 5.7 m.

Introduction

In agricultural use of hilly regions, soil is moved during tillage operations and by erosion processes. Once, soil translocation due to tillage took place each year with a stable rate, water erosion rates depends on precipitation and plant cover characteristics. In conventional agriculture system, that is prevailing in Poland, the amount of tillage operations depends on crop type. Usually, 3 mouldboard ploughs are performed with spring crops (deep – performed in autumn, medium – before sowing and shallow - after harvest) and 2 with winter crops (medium and shallow). First studies on soil translocation due to tillage in Poland started in the 50-ties (Bac, 1950; Martini, 1953; Czyżyk, 1955; Jankowski, 1959). Research were concentrated on suitability of different ploughs to mountain areas and covered soil translocation measured under different tillage direction (along and across slope and under 45^0). All implements were performed with a one blade plough (using both horse and tractor). After 1960, the studies were suddenly stopped. With introducing more powerful tractors into agriculture, interest in soil translocation due to tillage have started in many countries (Lindstrom et al., 1992; Govers et al., 1994, Govers et al., 1999). One of the arising question becomes which process, water or tillage dominates in present agriculture of hilly areas. Difficulties with comparison of both processes are connected with differences in methodology. Whilst in tillage experiments, soil mass and distance of displacement is determined, in water erosion studies conducted with standard runoff plots only mass per unit area can be derived as it is in the USLE model (Wischmeier and Smith, 1978). Hypothetically, water erosion rates could be transformed to soil mass and distance of displacement equal to plot length. However, in such a case, distance of displacement is assumed to be constant and independent on input energy of rain and runoff (both being highly variable in reality). The basis of comparison of these two processes could be studies with system of runoff plots of different length (Rejman and Usowicz, 2002). Analyzing data from these plots, both soil mass and effective distance of soil transport (soil translocation) can be determined.

The aim of the study was to establish (i) rate of soil translocation by tillage (under typical contemporary farming conditions) and (ii) compare the results with water erosion rates from system of plots of different length.

Methods

Experimental site and soil

Tillage and erosion experiments were conducted on a loess slope of small catchment located in the Lublin Uplands (SE Poland), ($51^0$20'N; $22^0$46'E). Numbered small catchments in the area are characterized by rolled landscape with short slopes 50-100m long and height change of 5-10m. The upper soil layer (0-20 cm) was characterized by 1% of coarse sand (1-0.1 mm), 19% of fine sand (0.1-0.05 mm), 46% of coarse silt (0.05-0.02 mm), 23% of fine silt (0.02-0.002 mm), 11% of clay (<0.002 mm), 1.8% of organic matter, and pH_{KCl} - 5.3.

Tillage experiments

Tillage operations consisted of shallow and deep mouldboard plows and were conducted with a 38 KW tractor and a mouldboard plough with 3 blades (of total working width of 0.8-0.9m). Shallow plow was performed on depth of 10 cm at 7% slope (14 August 2003) and deep plow - on the depth of 24 cm at 10-12% slope (4 November 2003). Shallow plow was made directly after wheat harvest to stop evaporation, and deep plow after sugar beet harvest. Tractor speed was recorded by measuring the time needed to pass 20 m, and was 8.0 (in up-slope direction) and 9.6 km h^{-1} (down-slope) at shallow plow, and 6.3 (up-slope) and 8.0 km h^{-1} (down-slope) at deep plow. Before shallow plow, soil moisture content was 11.9% (g/g) and bulk density - 1.32 Mg m^{-3}, and before deep plow - 16.6% and 1.42 Mg m^{-3}. After tillage, bulk density decreased to 0.92 and 1.09 Mg m^{-3} for shallow and deep plow, respectively.

[1] Institute of Agrophysics, Polish Academy of Sciences, Str. Doswiadczalna 4, Lublin 20-290, Poland; Telephone: (48) 81 7445061; fax: (48) 81 7445067; E-mail: rejman@demeter.ipan.lublin.pl

Soil translocation was evaluated on the basis of displacement of numbered and painted on different color aluminium cubes (tracers) with an edge-length of 15 mm. Aluminium tracers were placed both in up- and down-slope tillage directions in 6 lines perpendicular to slope and tillage. Cubes were inserted into holes drilled in soil on depth of 0, 5, 10, 15 and 24 cm. First line consisted of 55 tracers placed in 11 columns (with intervals of 10 cm), second line of 35 tracers in 7 columns (15 cm), and third line of 30 tracers in 6 columns (20 cm). Distance between lines of tracers was 3 m. After tillage, the plough layer was carefully excavated and tracers positions was recorded. Displacement distance was evaluated in horizontal plane perpendicular to initial line of tracers' columns. Recovery rate was high. Usually, from 120 tracers only 2 were lost in one pass. No correction was made for lost tracers. Apart of displacement characteristics, diffusion coefficient *k* was calculated according to Govers et al. (1994):

$$k = -D \rho_b B$$

where:
D - depth of tillage operation, m
ρ_b – soil bulk density, kg m^{-3}
B – coefficient, m

Water erosion experiments

Runoff plots of different length (20, 10, 5 and 2.5 m) and the same width (3 m) were located on 12% slope and maintained under continuous bare soil conditions. At the plot outlet, containers to measure runoff and soil loss were installed. After each period of rainfall, runoff volume was measured and samples were taken to determine soil loss. Measurements were carried in the years 1998-2000 and contained periods from April to November (23 measurement periods in total). Total rainfall amount responsible for runoff events was 763.2 mm and its erosivity (EI_{30}) 3194.5 MJ mm ha^{-1} h^{-1}. Details of water erosion experiments contain the paper (Rejman and Usowicz, 2002).

Results

Soil translocation due to tillage

Average values of soil translocation are presented in Table 1. Generally, distance of soil translocation was larger for shallow in comparison to deep plow. In almost all replications, average soil translocation down-slope was larger than up-slope. Maximum values of displacement reached 218 cm (down-slope direction) and 105 cm (up-slope direction) for shallow plow, and 184 cm (down-slope) and 115 cm (up-slope) for deep plow. During shallow tillage, down-slope translocation was larger in comparison to deep plow by 25.8 cm, and during deep tillage – by 13.5 cm.

Table 1. Average values of soil translocation (cm) under mouldboard tillage.

Replications	Shallow plow		Deep plow	
	Up-slope	Down-slope	Up-slope	Down-slope
1	16.2	59.0	27.6	37.2
2	45.0	41.2	26.0	33.9
3	27.6	66.2	17.2*	40.0
Average	29.6	55.4	23.6	37.1
Standard deviation	14.5	12.9	5.6	3.0
Coefficient of variation, %	49.0	23.2	23.7	8.2

*10% slope

Profiles of soil translocation and net down-slope translocation are presented in Figures 1 and 2. Generally, tracers initially placed closer to the soil surface were displaced on longer distances. The only exception are tracers placed at the soil surface at deep plow performed in up-slope direction. During shallow plow, net down-slope translocation was on average 40, 30 and 6 cm for tracers placed on depth of 0, 5 and 10 cm. During deep plough, net down-slope translocation was on average 21, 3, 11, 19 and 7 cm for tracers placed on depth of 0, 5, 10, 15 and 24 cm.

On the basis of average value of net down-slope translocation, plow depth and bulk density before tillage, amount of displaced soil was calculated. For shallow plow, 34 kg m^{-1} of soil was moved down-slope on an average distance of 25.8 cm, and for deep plow - 46 kg m^{-1} of soil was moved down-slope on an average distance of 13.5 cm. Calculated values of diffusion coefficient *k* were presented in Table 2.

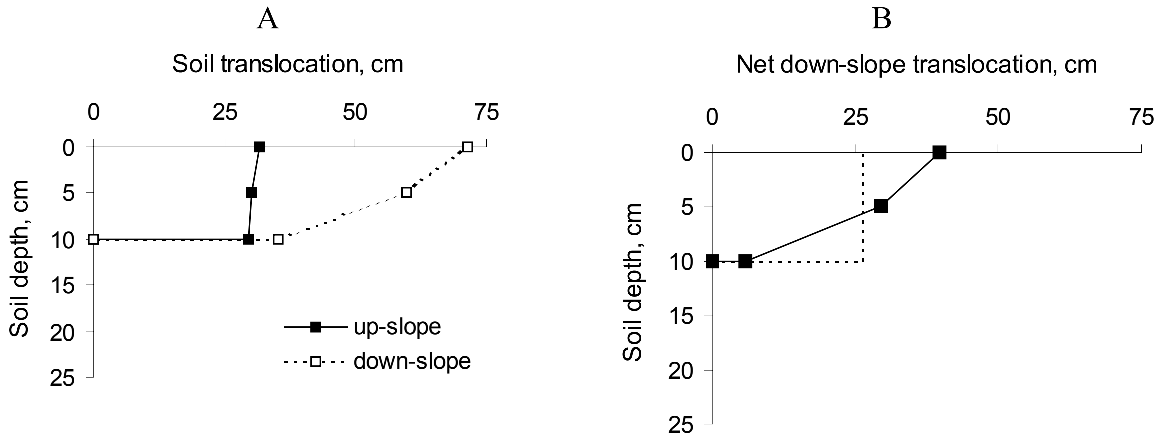


Figure 1. Profiles of soil translocation (A) and net down-slope translocation (B) during shallow plough

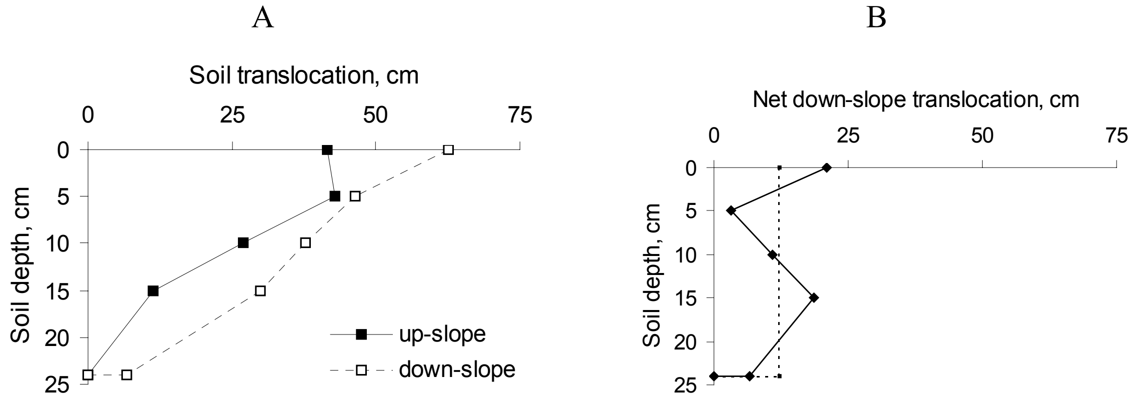


Figure 2. Profiles of soil translocation (A) and net down-slope translocation (B) during deep plough

Table 2. Comparison of some diffusion coefficient (*k*) values derived from the experiment and from literature for mouldboard plow performed along slope (*D* – plow depth; *B* – coefficient).

Source	Soil	Slope, %	Tillage speed, km h^{-1}		*B*,	*D*,	*k*,
			Up-slope	Down-slope	m	m	kg m^{-1}
This study	Silt loam	7	8.00	9.60	-1.85	0.10	243.9
This study	Silt loam	10-12	6.30	8.00	-0.56	0.24	190.8
Czyżyk, 1955*	Sandy loam	14-26	2.9-4.0		-0.44	0.18	118.8
Martini, 1953*	Loam	16-27	5.76		-0.43	0.18	116.1
Martini, 1953*	Loam	16-27	1.44		-0.14	0.18	37.8
Govers et al., 1994	Silt loam	3-22	4.50		-0.62	0.28	260.4

* - assuming bulk density of 1500 kg m^{-3}, plough with 1 blade

Soil translocation due to erosion

Total and soil loss per unit area are presented in Table 3. The largest soil loss per unit area for the whole period of measurements was found on plot 5 m long. Average soil loss contribution area (ratio of soil loss from longer plots to maximum soil loss per unit area) was 27.22 m^2 and average effective distance of soil transport – 9.0 m. In contrast to average values, in particular measurement periods, maximum soil loss per unit area were found on different plots (3-times on a plot 10 m long, 8-times on a plot 5 m long, and 12-times on a plot 2.5 m long). Calculated on the basis of particular measurement periods, average annual soil loss was 51 kg m^{-2} and average effective distance of 5.7 m. It means that at the effective transport distance of 5.7 m and at width of 1 m, annually 290.7 kg of soil was moved under bare soil conditions.

Table 3. Total soil loss and soil loss per unit area, Bogucin, 1998-2000.

Parameter	Plot size, m^2			
	60 (length: 20 m)	30 (length: 10 m)	15 (length: 5 m)	7.5 (length: 2.5 m)
Total soil loss, kg $plot^{-1}$	715.50	595.94	361.29	152.18
Unit soil loss, kg m^{-2}	11.93	19.87	24.09	20.29
Soil loss contributing area, m^{-2}	29.70	24.74	-	-
Effective distance of soil transport, m	9.90	8.25		

Summary

Presented results pointed that during plow operations performed along slope, quite large soil amounts are displaced over short distances. Totally during shallow and deep plow (usually applied in winter cereal cultivation) 80 kg m^{-1} was displaced. For cultivation system of spring cereals, these amounts are larger due to additional plow performed on middle depth. Studies showed that tillage erosion rates were lower than water erosion rates (290.1 kg m^{-1}). However, the latter were established under the most favorable conditions for the process (bare plots). Under canopy cover, water erosion rates are much lower. Previously conducted experiments on plots of 20 m length showed that soil loss under winter wheat and spring barley were 17-20%, and under maize 33% of the amounts found on bare plots (Rejman, 1997). At present, these values are verified in the system of plots of different length.

Acknowledgements

The research for this paper was carried out in the frame of research project no. 6 P06S 003 21 founded by the State Committee of Research (Poland). Additional funding, provided by the EC under no. QLAM-2001-00428 is also gratefully acknowledged.

References

Bac, S. 1950. Studies of soil translocation on slopes (in Polish). Roczniki Nauk Rolniczych, 66-C-2.

Czyżyk, W. 1955. Soil translocation during plowing on slope (in Polish). Roczniki Nauk Rolniczych, 71-F-1, 73-86.

Govers, G. 1999. Tillage and translocation: emergence of a new paradigm in soil erosion research. Soil and Tillage Research, 51, 167-174.

Govers, G. , Vandaele, K., Desmet, P, Poesen, J., Bunte, K. 1994. The role of tillage in soil redistribution on hillslopes. European Journal of Soil Science, 45, 469-478.

Govers, G., Lobb, D.A., Quine, T.A. (Eds). 1999. Tillage erosion and tillage translocation. Soil and Tillage Research, 51, 1-356.

Jankowski, A. 1959. Plowing on slopes from a counter erosion point of view (in Polish). Roczniki Nauk Rolniczych, 73-F-4, 679-714.

Martini, Z. 1953. Studies on soil movement during plowing of slopes (in Polish). Roczniki Nauk Rolniczych, 71-F-1, 57-72.

Rejman, J. 1997. Runoff and soil loss under conventional tillage for cereal production in SE Poland. Bibliotheca Fragmenta Agronomica, 2B/97, 559-562.

Rejman, J., Usowicz, B. 2002. Evaluation of soil-loss contribution areas on loess soils in southeast Poland, Earth Surface Processes and Landforms, 27(13), 1415-1423.

Wischmeier, W.H., Smith, D.D. 1978. Predicting rainfall erosion losses – a guide to conservation planning, Agricultural Handbook No. 537, U.S. Department of Agriculture, Washington, D.C.

Soil conservation by ridge tillage of Maize

László, P.[1] – Gyuricza, Cs. – Liebhard, P. – Rosner, J.

Abstract

Conservation tillage is generally accepted as the most successful technology currently available for reducing runoff and soil loss. Ridge tillage is one of the cultivation systems in which the plant (generally maize, soy beans, sometimes sugar beet) is grown in ridges raised above the soil surface. This soil-protective technique has long history in North America and many countries of Africa, but which has only been studied in experiments for the most part in Europe. Within the framework of cooperation between the Szent István University and the Vienna University of Agricultural Sciences, soil cultivation experiment in corn (*Zea mays L.*) monoculture was set up for the first time in Austria near Pyhra (Lower-Austria) in 1996.

A study was conducted to evaluate the effects of ridge tillage (RT) in comparison with fall-mouldboard-plow (CT) and no-tillage (NT) on penetration resistance (PR), soil bulk density (BD) and porosity (P) of sandy loam soil (Typic Agriudoll). It is also important to evaluate the technology from the viewpoint of soil conservation and to adapt it to the condition system of eco-farming. Analysis were made at each treatments and different part of ridge (at top of the ridge, side of the ridge and interrow) in 1998, 2000 and 2002. The average PR an BD values were greatest in the no-tillage plot 3.42 MPa and 1.56 g·cm^{-3}, respectively. After six years ridge tillage resulted in lower penetration resistance and bulk density values in the upper 20 cm than conventional and no-tillage. Ridge tillage appears capable of reducing compaction in this soil. These results show that adverse soil physical condition (increased BD and PR) development was justified when using no-tillage in this region.

Key words: ridge tillage, corn, penetration resistance, bulk density, porosity

Introduction

Conservation tillage, which involves maintenance of crop residues on the soil surface, effectively controls soil erosion (Harrold and Edwards, 1974; Langdale et al., 1979) and enhances soil water conservation (Buchele et al., 1955; Mielke et al., 1986; Unger, 1984). According to Agricultural Research Service (1981) conservation tillage means any tillage and planting system that leaves at least 30 % of the soil surface covered by residue after planting. Conservation tillage techniques include minimum tillage, mulch tillage, ridge tillage, and no-till. However, adaptation of conservation tillage for corn (*Zea mays L.*) production on poorly drained soils is limited because it often results in yields lower than for corn grown under conventional tillage (Dick and Van Doren, 1985; Griffith et al., 1973). Ridge tillage is a bed and spacing formation, created with the aim of soil protection and cultivation, where the drill is 12-20 or 22 cm above the spacing most of the time during the year (Stone et al., 1989; Lal, 1990; Birkás et al., 1998). The method has been known for centuries in the United States and certain countries of Africa and belongs to the soil conservation systems (Lal, 1990; Vyn et al., 1990). The method had no precedence in the Hungarian literature, and the same is true for the whole Central European region. The first publication in this topic was written by Birkás et al. (1998), which shows the results of soil condition analysis and yield in the ridge tillage trial set in Gödöllő, 1995.

In Austria about 2.3 million ha is affected by water erosion, 380,000 ha are considered moderately to highly erosive. The yearly loss of soil is estimated to be 8 million tons. Radke (1982) concluded that ridge tillage could help control erosion by leaving crop residues on the surface. Buhler (1995), Clements et al. (1996), Gail et al. (1996), and Klein et al. (1996) emphasize the low weed coverage, especially in the spacing, while on the ridges the threat of weeds increases because of the quicker warming of the soil and the better loosening. Ridge tillage method shows favourable results from the economic aspect as compared with the conventional ploughing systems. When analysing ridge tillage all authors (Benjamin et al., 1990; Vyn et al., 1990; McInnes et al., 1991; Stonehouse, 1997) take the basis that the main objective is not the increase of the yield but the conservation of the soil, and therefore this method is recommended mostly on sloping, protection requiring fields, where this way higher yield can also be guaranteed.

Materials and methods

The experiment was established in Pyhra (St. Pölten) located at about 80 km west of Vienna (Lower Austria) on a < 0.1 % slope in the fall of 1996. This region is located on the foothills of the Alps 325 m above the see level. The landscape is characterised by gentle to fairly steep slopes. The average long term annual rainfall amount is 725 mm (1901-1990), and the mean annual temperature is 8.8 ^{o}C. The soil was classified as sandy loam Typic Agriudoll (USDA SCS, 1992). The average soil texture analysis of this soil is 34 % sand, 46

[1] Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences (RISSAC), Budapest, Hungary. Tel: +36-1-225-3201; E-mail: laszlo@rissac.hu

% silt, and 20 % clay in the surface horizon (0-20 cm depth) and an average organic carbon content of about 1.3 %.

The study was conducted at the experimental field of the Pyhra Agricultural School on small plots where corn (*Raissa*) was grown in monoculture. The experimental design was an one factor, strip arranged small plot trial. Plot size was 9 m wide and 50 m long (450 m^2). In the experiment three tillage systems were compared, no-tillage (a_1), conventional tillage with fall mouldboard ploughing (to 15 cm) (a_2) and ridge tillage (a_3). The number of replications (r) is 4, and treatments were randomised on the area.

At the beginning soil was prepared in case of no-tillage in one procession together with the sowing and consisted only of the loosening of the seedbed. In case of conventional tillage the autumn medium deep ploughing (20-25 cm) and the smoothing were carried out in one procession. Ridge tillage consist of planting on existing ridges and rebuilding the ridge during cultivation. The autumn soil preparing in case of ridge tillage was the same in the year 1996 as in case of the conventional tillage, and in spring ridges were formed. A potato ridge-filling cultivator was used to form the initial 18-20 cm high ridges with spacing of 70 cm and to cultivate and rebuild ridges. In June the ridges were readjusted with the machine that also served as mechanical weed killing. In 1997 and 1998 there was no autumn base tillage, and next year ridges were formed before sowing and after sowing in June. From 1999 on autumn ploughing was carried out also in ridge tillage treatment because of the invasion of weeds.

All treatments were planted at the same seeding rate and depth as early as soil and weather conditions permitted. Fertilizer was applied equally to all treatments. The evaluation of the physical characteristics of the soil was carried out according to the results of penetration resistance, bulk density, moisture content (measured with electronic penetration probe from Szarvas), and porosity (calculated from the pF chart). Penetration resistance and bulk density values were used for statistical analysis at depth of 10, 20, 30, 40, 50 cm and 5-10 cm and 15-20 cm, respectively. Effect of treatments was analysed by using one-way ANOVA.

Results and discussion

Penetration resistance

The penetration resistance values and statistical features in the upper 50 cm layer of the soil are presented in Table 1. Two years after the setting of the experiment (1998) no statistically supported difference was shown in the uppermost layer. In the 10-20 cm depth PR exceeded 1.4 MPa only in the no-tillage and the interrow area of the ridge tillage, but according to the soil conditions and moisture content even this value is not harmfully compacted. During the analysis carried out in 2000 the lack of soil tillage was mostly evident in the uppermost soil layers (0-10 and 10-20 cm) in no-tillage. The highest penetration resistance was measured in no-tillage which exceeded the critical value of 2.5 MPa, while under 20 cm the penetration resistance was 2.5-3.5 MPa at all plots. In the sixth year of the experiment (2002) the soil resistance values equalized in the upper soil layer and did not exceed 2.00 MPa in either treatments. No compacted plow layer was evident, but it is interesting that penetration resistance does not increase in a statistically significant degree in no-till, compared to ploughing treatment.

Table 1. Effect of soil cultivation systems on the penetration resistance [MPa]

Soil depth (m)	Soil cultivation systems				
	No-tillage	Conventional tillage	Ridge		
			Top	Side	Interrow
October 1998					
0.00-0.10	1.37a	0.98a	0.90a	1.13a	1.13a
0.10-0.20	1.46b	1.13a	1.13a	1.03a	1.83c
0.20-0.30	1.51a	1.53a	1.47a	1.86a	2.17a
0.30-0.40	1.63a	1.59a	2.27b	2.06b	1.70a
0.40-0.50	1.60a	1.55a	2.11a	1.87a	1.65a
August 2000					
0.00-0.10	3.42c	1.10a	1.50a	1.57ab	1.97b
0.10-0.20	2.50b	1.12a	2.50b	2.25b	2.10b
0.20-0.30	2.62a	2.50a	2.50a	2.50a	2.77a
0.30-0.40	2.60a	2.27a	2.62a	2.67a	3.10a
0.40-0.50	2.65a	2.07a	2.60a	2.67a	3.35a
May 2002					
0.00-0.10	1.87a	1.45a	1.45a	1.25a	1.45a
0.10-0.20	1.92bc	1.52ab	1.37a	1.90bc	2.30c
0.20-0.30	1.57a	2.25a	2.47a	2.20a	2.30a
0.30-0.40	1.22a	2.40c	2.00bc	1.62ab	1.55ab
0.40-0.50	1.27a	1.90b	1.47a	1.35a	1.35a

Soil moisture content (mass % average of 0-50 cm): 1998: 20.4 %; 2000: 18.3 %; 2002: 15.6 %.

Bulk density and pore size distribution

Bulk density and porosity gives information on the cultivability, air and compactness condition and the potentially absorbable moisture content of the soil. The highest bulk density was measured in no-tillage in the second year of the experiment (1998), but comparing this with ploughing and ridge tillage the difference is not significant (Table 2). The same is true for the ratio of different size pores. In the fourth year of the experiment (2000) this tendency changed, and in no-tillage bulk density increased in 5-10 cm depths because of the lack of tillage, while in case of ploughing and ridge tillage it decreased by 0,1-0,2 $g \cdot cm^{-3}$ compared to the measurements taken two years before (1998). The distribution of pore size also changed. The proportion of macropores decreased in no-tillage, so the increase of bulk density and the lack of tillage resulted in the decrease of the macropores ratio.

In the sixth year of the experiment (2002) bulk density was even the greatest in no-tillage, but it was almost the same in conventional tillage also, the difference of 0,06 $g \cdot cm^{-3}$ was not significant. The ratio of macropores was still different: a difference of 3.2 % was measured between no-tillage and ridge tillage.

Table 2. Effect of soil cultivation systems on the soil bulk density and the pore size distribution

	Bulk density ($g \cdot cm^{-3}$)		Macropores (%)		Mezopores (%)		Micropores (%)	
1998	0.05-0.10 m	0.15-0.20 m	0.05-0.10 m	0.15-0.20 m	0.05-0.10 m	0.15-0.20 m	0.05-0.10 m	0.15-0.20 m
No-tillage	1,51a	1,54a	20,4a	20,1a	20,7a	20,6a	3,9a	3,7a
Ploughing	1,47a	1,51a	21,3a	20,3a	20,5a	20,0a	3,6a	3,3a
Ridge tillage	1,37a	1,44a	22,8a	20,9a	20,5a	20,7a	4,0a	3,6a
2000								
No-tillage	1,53b	1,49b	18,5a	20,1a	20,1a	21,1a	4,3a	4,1a
Ploughing	1,26a	1,38a	25,4b	24,0b	21,1a	21,0a	4,1a	3,8a
Ridge tillage	1,30a	1,52b	24,9b	20,0a	22,2a	20,4a	4,2a	3,8a
2002								
No-tillage	1,55b	1,56a	19,0a	18,3a	20,1a	19,9a	3,8a	4,0a
Ploughing	1,49ab	1,51a	20,6b	21,2b	20,7a	21,1b	3,6a	3,8a
Ridge tillage	1,41a	1,50a	22,2c	19,6ab	20,8a	20,4a	3,8a	3,9a

Conclusions

In Austria a lot of land is tilled on steep slopes. Many of these soils are highly erodible, and intense spring and summer rainfalls are not unusual. As a consequence erosion can be severe. Most of the damage from erosion occurs during infrequent high intensity storms. Agricultural land use and crop production must anticipate and protect soil from such events, therefore conservation tillage is needed. Ridge tillage as other conservation tillage systems maintains a ground cover with less soil disturbance than traditional cultivation, thereby reducing runoff, soil loss and energy use while maintaining crop yields and quality.

Within the framework of cooperation between the Szent István University and the Vienna University of Agricultural Sciences, soil cultivation experiment in corn (*Zea mays L.*) monoculture was set up for the first time in Austria near Pyhra (Lower-Austria) in 1996. Treatments were conventional tillage (CT) with ploughing, no-tillage with residues left standing (NT) and ridge tillage (RT). This study determined the effects of tillage treatments on penetration resistance (PR), soil bulk density (BD) and porosity (P). The ridge tillage system was capable as soil conservation method on sandy loam soil in this regions. Adverse soil physical conditions that limit soil water infiltration, root growth, and crop yield could develop when using a no-tillage system.

References

Agricultural Research Service (1981): Report of the Soil Erosion-Soil Productivity Research Planning Workshop, Fayette, Indiana. U.S. Dept. Agr., Washington, D.C.

Benjamin, J. G., Baylock, A. D., Brown, H. J., Cruse, R. M. (1990): Ridge tillage effects on simulated water and heat transport. *Soil Till. Res.*, **18**, 167-180.

Birkás, M., Gyuricza, Cs., Percze, A., Szalai, T. (1998): Kísérletek a kukorica bakhátas termesztésével barna erdőtalajon. *Növénytermelés*, **47**, 559-571.

Buchele, W. F., Collins, E. V., Lovely, W. G. (1955): Ridge farming for soil and water control. *Agric. Eng.*, 36, 324-329.

Buhler, D. D. (1995): Influence of tillage systems on weed population dynamics and management in corn and soybean in the central US. *Crop Sci.*, **35**, 1247-1258.

Clements, D. R., Benoit, D.L., et al. (1996): Tillage effects on weed seed return and seedbank composition. *Weed Sci.,* **44**, 314-322.

Dick, W. A., Van Doren, D. M. (1985): Continuous tillage and rotation effects on corn, soybeans, and oat yields. Agron. J., **77**, 459-465.
Ehlers, W., Köpke, U., Hesse, F., Böhm, W. (1983): Penetration resistance and root growth of oats in tilled and untilled loess soil. *Soil Till. Res*., **3**, 261-275.
Gail, A. W., Wilson, R. G., Mahnken, G. W., Hanson, G. E. (1996): Influence of weed control on weed population in ridge-till Corn (Zea mays). *Weed Sci.,* **4**,. 903-910.
Griffith, D. R., Mannering, J. V., Galloway, H. M., Parsons, S.D., Richey, C.B. (1973): Effect of eight tillage-planting systems on soil temperature, percent stand, plant growth, and yield of corn on five Indiana soils. *Agron. J.*, **65**, 321-326.
Harrold, L. L., Edwards, W. M. (1974): No-tillage system reduces erosion from contiuous corn watersheds. *Trans. Am. Soc. Agric. Eng.*, 17, 414-416.
Hayes, W. A. (1982): Minimum tillage farming. No-till Farmer Inc. Brookfield, Wisc.
Klein, R. N., Gail, A. W., Wilson, R.G. (1996): Ridge-till, an integrated weed management system. *Weed Sci*., **44**, 417-422.
Lal, R. (1990): Ridge tillage. *Soil Till. Res*., **18**, 107-111.
Langdale G. W., Barnett, A. P., Leonard, R. A., Fleming, W. G. (1979): Reduction of soil erosion by the no-till system in the Southern Piedmont. *Trans. Am. Soc. Agric. Eng.*, **22**, 82-86, 92.
Liebig, M. A., Jones, A. J., Mielke, L. N., Doran, J. W. (1993): Controlled wheel traffic effects on soil properties in ridge tillage. *Soil Sci. Soc. Am. J*., **57**, 1061-1066.
McInnes, K. J., Heilmann, J. L., Gesch, R.W. (1991): Momentum roughness and zero-plane displacement of ridge-furrow tilled soil. *Agricultural and Forest Meteorology*, **55**, 167-179.
Radke, J. K. (1982): Managing early season soil temperatures in the northern corn belt using configured soil surfaces and mulches. *Soil Sci. Soc. Am. J*., **46**,1067-1071.
Stone, J. A., Vyn, T. J., Martin H. D., Groenevelt, P. H. (1989): Ridge-tillage and early-season soil moisture and temperature on a poorly drained soil. *Can. J. Soil Sci.*, **69**, 181-186.
Stonehouse, D. P. (1997): Socio-economics of alternative tillage systems. *Soil Till. Res*., **43**, 109-130.
Sváb J. (1981): Biometriai módszerek a kutatásban. *Mezőgazdasági Kiadó*, Budapest.
Unger, P. W. (1984): Tillage and residue effects on wheat, sorghum, and sunflower grown rotation. *Soil Sci. Soc. Am. J.*, **48**, 885-891.
Unger, P. W. (1995): Organic matter and water-stable aggregate distribution in ridge-tilled surface soil. *Soil Sci. Soc. Am. J.*, **59**, 1141-1145.
Unger, P. W. (1996): Soil bulk density, penetration resistance, and hydraulic conductivity under controlled traffic conditions. *Soil Till. Res*., **37**, 67-75
Vyn, T. J., Stone, J. A., Raimbault, B. A. (1990): Corn development and crop yield response to ridge-plant systems on a poorly drained soil in southwestern Ontario. *Soil Till. Res*., **18**, 207-217.
Weersink, A., Walker, M., Swanton, C., Shaw, J. E. (1992): Costs of conventional and conservation tillage systems. J. Soil and Water Cons., 47, 328-334.

The effect of some conventional and soil conserving tillage systems on soil hydraulic properties and soil water regime of a loamy Mollisol

Farkas, Cs.[1] – Várallyay, Gy. – Tóth, E.

Introduction

In Hungary soil compaction – that might as well be caused by conventional soil tillage systems - is one of the main soil degradation phenomena. Long-term tillage, applied yearly at the same depth can result in formation of a compacted layer in the subsoil. Soil compaction has a harmful influence on water-, air- and heat regime of soil as well as on microbiological activity and root development (Soane and Ouwerkerk 1994), and consequently, on crop growth. Several investigations were carried out to study the effect of different conventional and so-called soil- and moisture-conserving tillage systems on soil bulk density, total porosity, penetration resistance and other soil physical characteristics as well as soil water balance (Linstrom et al. 1984, Negi et al. 1981). Nevertheless, studies comparing one-time measurements on the effect of soil tillage on soil properties may obtain contradictory results probably because the effects of tillage are time-dependent (Zhai et al., 1990) and the response of different soils to a certain mechanical disturbance can be different.

In Hungary the amount of precipitation during the vegetation period is less than the potential evapotranspiration. Thus, the retention of water in soils has great importance to ensure water supply for crops during dry periods. The effect of different tillage systems on soil water retention curve (pF-curve), however, is not yet well examined.

This paper studies the effect of six tillage system on soil water regime and on seasonal variability of soil water retention characteristics of a Mollisol developed on loam at the beginning of the vegetation period.

Materials and methods

A long-term field experiment of six tillage treatments was established in the fall of 2002 in Hatvan, 60 km from Budapest, on the experimental field of the Szent István University, Hungary (Birkás and Gyuricza, 2004). Tillage treatments include ploughing (P: 22-25cm), disking (D: 16-20cm), loosening and disking (L: 35-40cm, D: 16-20cm), strip tillage (S: 12-15cm), cultivator (C: 12-15cm), and minimum tillage (direct drilling, NT). Treatments were replicated 3 times on 13m x 200m plots. During the growing season of 2003 all the treatments were tested at optimal level of nutrient supply. The soil was tilled in October 2002. Fertilisation treatments were knifed prior to planting. Corn was planted in April 2002 and harvested in September 2003.

From each treatment, undisturbed soil cores of 100 cm3 volume were collected 6 times during the vegetation period of 2003 from 4 soil layers (0-5 cm, 5-10 cm, 15-20 cm and 45-50 cm) in 3 replicates. Soil water retention characteristics were measured at pressure heads represented by the pF values of 0.0, 0.4, 1.0, 1.5, 2.0, 2.3, 2.7, 3.4 and 4.2 according to Várallyay (1973). Soil water content and soil texture were determined as well. Bulk density was calculated from dry soil weights (105Co, 48h) and the volume of undisturbed samples.

In each tillage treatment, 3T-System type capacitive probes were installed up to 80 cm depth with 10 cm increment to ensure continuous measurement of soil temperature and soil water content. Measurements were performed four times a day from 13 May until September 11, 2003. Daily average values were used for the evaluation.

Differences in soil physical properties attributed to tillage treatment were analysed by ANOVA. The F statistics was used to separate significant differences in response parameters due to tillage. Significance is indicated at $P<0.05$.

[1] Research Institute for Soil Science and Agricultural Chemistry of HAS, 1022 Budapest, Herman Ottó u. 15. Tel.: +361 2243652, E-mail: csilla@rissac.hu

Results and discussion

Figure 1. shows soil water retention curves, measured on 10th April and 30th June. Each point represents an average of the 3 replicates.

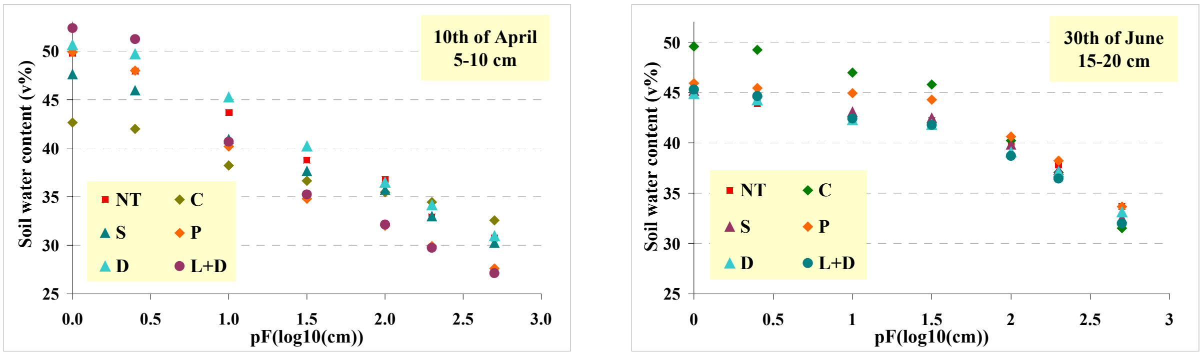


Figure 1. Soil water retention curves, measured in different treatments

At the beginning of the growing season soil water retention curves measured in the tilled layer (0-5, 5-10 and 15-20 cm) were significantly different in the low suction range (pF<1.5). The measured saturated water contents (□s) were significantly larger (50-53 v%) in the P, D, NT and LD treatments than in the S and C (47 and 43 v%, respectively). Soil water retention curves of the 15-20 cm layer, measured in April, were similar to the ones of the topsoil, but the differences between them were less expressed. These differences disappeared by the end of June, when the saturated water contents varied between 44 and 46 v%. The C treatment with □s=49 v% was the only exception. No significant differences between the soil water retention curves of the 45-50 cm soil layer were found.

Strong seasonal variability of soil water retention curves was detected (Figure 2.)

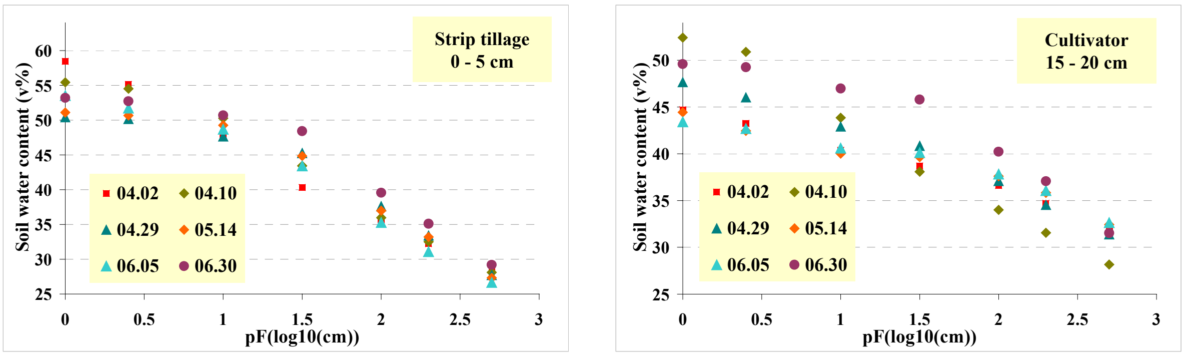


Figure 2. Seasonal variability of the soil water retention curves

Soil water content dynamics and soil water content profiles, measured in different tillage treatments are presented in Figures 3 and 4, respectively. Valuable differences up to 15 v% were measured. Differences between the soil water contents were bigger in the tilled layer compared to the non-tilled one. The very dry topsoil (0-10 cm) in the ploughing treatment prevented the evaporation from the deeper (60-70 cm) soil layers.

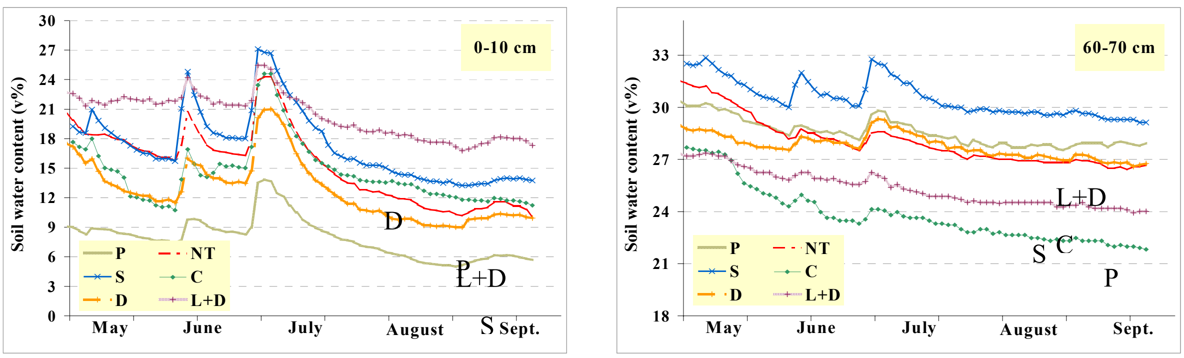


Figure 3. Soil water content dynamics, measured in different treatments

Conclusions

The effect of six tillage treatments on the soil water retention curves and soil water content dynamics was studied. The effect of tillage systems on the soil water retention curves of the tilled soil layer was valuable in the low suction range. Soil water retention curves of different treatments, measured under the tilled layer (45-50 cm), did not differ significantly. Strong seasonal variability of soil water retention curves was found.

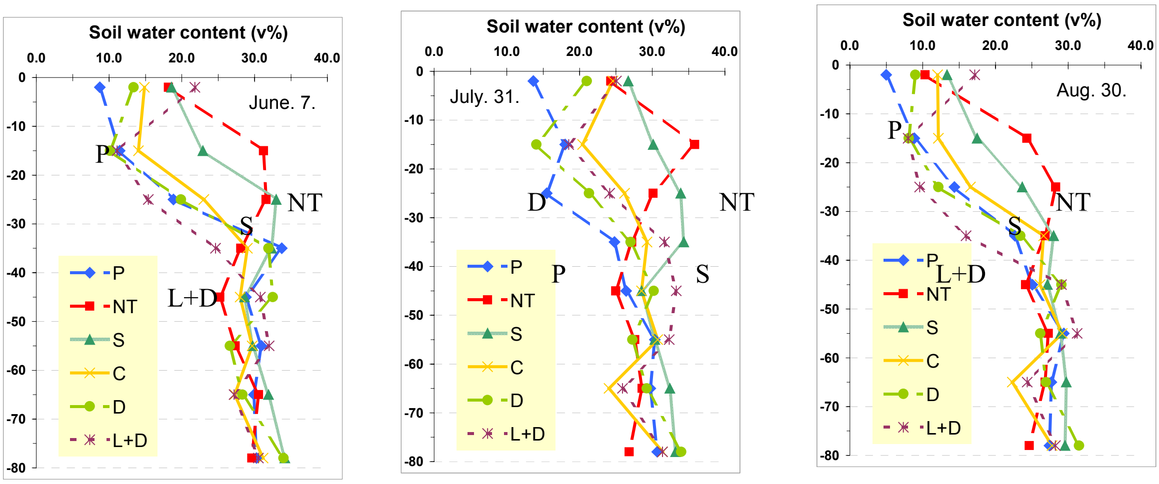


Figure 4. Soil water content profiles, measured in different treatments

Significant differences – up to 15 v% - between the soil water contents were measured in the tilled layer. In the topsoil, the biggest soil water content values were detected in the L+D and S treatments. Regarding the subsoil - 50-80 cm -, the biggest soil water content values were observed in the P, S, D, and NT treatments.

Although no differences between the soil physical properties and water retention curves were found below the tilled layer (45-50 cm), the soil water content dynamics of the subsoil differed significantly. Thus, the soil water regime reflected the indirect effect of tillage treatments on the soil water balance.

Acknowledgement

This paper presents results of research programs supported by the Hungarian National Research Foundation (OTKA, Grant No. T 042996) and Hungarian Ministry of Education (OM 3B-0057/2002).

References

Birkás and Gyuricza, 2004: Agroökoszisztéma elemek kölcsönhatásának vizsgálata művelési kísérletben. Agro21 füzetek, in press

Lindstrom M.J., Vorhees W.B. and Onstod C.A.: 1984. Tillage system and residue cover effects on infiltration in northwestern corn belt soil. J. Soil Water Conserv. 39:64-68.

Negi S.C., Raghavan G.S.V. and Taylor F.: 1981. Hydraulic characteristics of conventional and zero-tillage field plots. Soil Till. Res. 2:281-292.

Soane, B.D. and Ouwerkerk, C. van: 1994. Soil compaction problems in world agriculture. In: Soil compaction in crop production. Elsevier Sci. pp. 1-21.

Várallyay, Gy.; 1973. A new apparatus for the determination of soil moisture potential in the low suction range. Agrokémia és Talajtan, 22:1-22.

Zhai R., Kachanoski R.G. and Voroney R.P.; 1990. Tillage effects on the Spatial and Temporal Variations of Soil Water. Soil Sci. Soc. Am. J., 54:186-192.

The SOWAP Project in Hungary – Measuring the environmental consequences of conventional and conservation tillage

Bádonyi, K.[1] - Madarász, B.[2]

Introduction

Arable cropping systems are based on intensive mechanical cultivation of the soil to ensure a good seedbed quality and to provide effective weed control. On arable lands intensive soil management can lead to severe soil erosion, water pollution from transported sediments, reduced biodiversity and less carbon sequestration. In Hungary soil erosion is the most severe among these. More than one-third of the agricultural land (about 2,3 million hectares), nearly a quarter of the total area of Hungary is affected by soil erosion. 8,5 % strongly, 13,6 % moderately and 13,2 % are weakly eroded (Stefanovits, Várallyay, 1992).

Conservation tillage is practised on 45 million ha worldwide, mainly in North and South America, South Africa and Australia. In Europe its area is increasing for the sake of reducing production costs, preventing soil erosion and retain soil moisture (Holland, 2004). In Hungary the applied tillage systems can be characterised as a fight against extreme climatic and economic situations (Birkás et al., 2004). Soil preserving tillage systems used in Hungary nowadays are not the unmitigated conservation tillage systems practiced elsewhere in Europe. The applicability of such new soil management methods is currently being tested (Birkás et al., 1989).

The environmental benefits of conservation tillage are reviewed, but detailed information on problems of land degradation – particularly soil erosion and soil degradation – on arable land, and information on the viability of conservation oriented arable land use systems is sparse from European studies. To fill this gap the SOWAP (Soil and Surface Water Protection Using Conservation Tillage in Northern and Central Europe) project was launched under the EU Life-Environment Programme.

The SOWAP project started in the UK, Belgium and Hungary in August 2003, in cooperation with Syngenta UK/HU, Väderstad UK/HU, Cranfield University, Harper Adams University, Royal Society for the Protection of the Birds, The Ponds Conservation Trust, University of Leuven and several other national organisations. This project aims at a complex comparison between different tillage regimes in order to find and demonstrate better ways of managing the land. Study sites have been designated and between 2003-2006 we test conventional and conservation tillage (minimum and no tillage) and compare their impacts on soil erosion, soil structure, soil biological activity, ecosystems and on economics. As soil is particularly valuable in Hungary – 48,5 % of the country is under arable cultivation – we are working on the development of a better site-specific agronomy, which reduces the risk of soil erosion and provides a better environment for soil micro-organisms, earthworms and birds. The economic viability of the two different tillage systems will also be assessed: costs, extra expenses, working hours will be recorded. This will enable us to demonstrate the economic advantages, disadvatages, which is one of the most important key aspects for farmers.

Study sites

In Hungary two sites were selected near Lake Balaton, in the vicinity of Keszthely. Our priority was to choose private enterprises, because sustainable land use, which does not exploit resources, can be realised better in private property regime, than in common property regime. Thus we chose a small 2 ha farm at *Szentgyörgyvár* for the plot scale experiment, erosion study (*Figure 1*). The farm is on a dissected, rolling sandy loess–fine sand plain, at the boundary of the humid and dry continental climate types. The average annual precipitation is 700 mm. The soil type is luvisol. The plots were designated on an even 9-10 % slope gradient.

For the farm scale demonstration, ecology survey we chose a 107 ha farm at *Dióskál (Figure 1)*. The farm is situated in a hilly, sandy loess–fine sand area. The climate is temperate cool and humid with an average annual precipitation of 700-750 mm. The soil type is luvisol, at some points strongly eroded luvisol and cambisol.

[1–2] Department for Physical Geography, Geographical Research Institute, Hungarian Academy of Sciences; Budaörsi út 45, Budapest 1112, Hungary. Tel./Fax: +36-1-3092686; E-mail: bad8379@helka.iif.hu

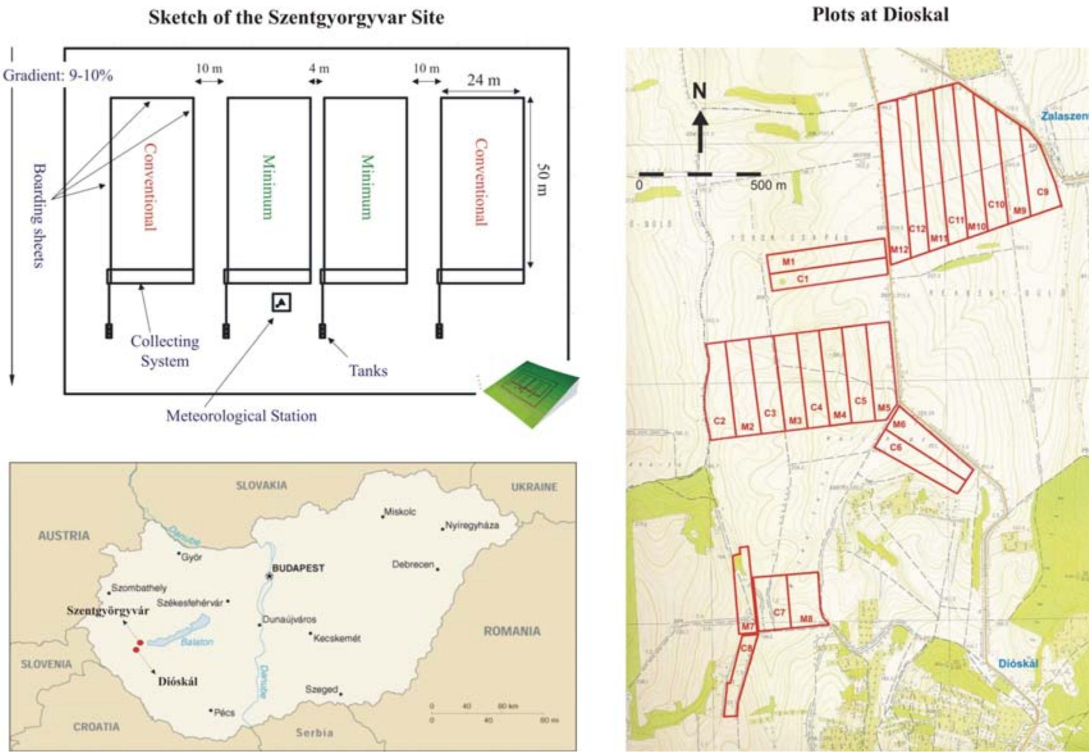


Figure 1. Location of study sites

Sampling and measurement

For the erosion survey we have constructed 4 plots at *Szentgyörgyvár* (2 conventionally tilled, 2 minimum tilled), each 50 x 24 m in size. These plots are big enough to measure runoff on field scale and to use the same machinery as on the farmer's fields. The plots were arranged the following way: conventional-minimum-minimum-conventional tillage plots follow each other to eliminate impacts of soil property inhomogenities. To collect runoff a special dual channel collecting system was created. With the help of this we can measure the smallest and the biggest amount of runoff. The size of the bigger channel was determined according to the 1 % probability rainfall. To every channel 3-3 tanks of 1 m^3 each are connected. A weather station was installed at the site, which is capable of monitoring air temperature, soil temperature, rainfall, relative humidity, wind speed, wind direction, solar energy. The plots will be used to generate high resolution data of the environmental impacts of the different tillage systems, using environmental indicators, including physical, chemical and biological soil properties, soil loss and runoff. Besides the *Dióskál* plots, the same ecological surveys, except the ornithological, are carried out.

For the terrestrial ecology survey we marked out 24 plots at *Dióskál* (12 conventionally tilled, 12 minimum tilled, each between 3-5 ha in size, in total 107 ha). They make up 5 separate blocks. *Dióskál 1* includes the plots C1-C8, M1-M8, *Dióskál 2* the C9-C12, M9-M12. The ecology experiment includes the survey of weeds, soil micro-organisms, birds and earthworms-insects-seeds as important food sources for birds. Location, timing and frequency of each terrestrial ecological survey is summarised in *Table 1*.

At both sites crop rotation, weed/pest control and tillage regime for the conservation plots are planned for the project duration. On the conventional plots the farmer does everything as he always has been doing traditionally: he uses the same varieties, herbicides, pesticides, fungicides, fertilisers, machinery as before. On the SOWAP plots these were determined by the participants and experts of the project. At *Szentgyörgyvár* the crop rotation is as follows: wheat – sunflower – maize, at *Dióskál 1*(C1-C8, M1-M8): wheat – winter oil seed rape – maize, at *Dióskál 2* (C9-C12, M9-M12): maize – winter oil seed rape – wheat. This crop rotation represents the typical rotation of the region, and includes the four most frequently produced crops of Hungary.

Table 1. Summary of the terrestrial ecological survey of the SOWAP Project in Hungary, 2003-2006

	Soil erosion plots	**Ecological survey sites**
Birds	—	Whole year/1x a week
Insects	March, May, July (3x a year) 12 samples/ plot surrounding	March, May, July (3x a year) 12 samples/plot
Earthworms	October, March (2x a year) 9 samples/plot surrounding	October, March (2x a year) 9 samples/plot
Seeds	October, March (2x a year) 9 samples/plot surrounding	October, March (2x a year) 9 samples/plot
Soil micro-organisms	October, March (2x a year) 9 samples/plot surrounding	October, March (2x a year) 9 samples/plot
Weeds	—	Whole year/1x a month

Bird data are collected from all plots. Census of winter and summer birds follows standard methods used for counting birds on UK farmlands. Each plot is censused 3 times a month. The plots are surveyed along transects across the plot, 20 m apart from each other, in order to flush all birds from the ground/vegetation in each plot. Census routes are reversed between visits. Double counting is minimised by the observer: birds, which are flushed to other plots or to other parts of the plot being censused are ignored if seen again. Censuses are commenced at least one hour after sunrise and are completed by at least one hour before sunset, and are not conducted in periods of heavy rains, strong winds or poor visibility. Once a month vegetation and ground cover estimates are made. Within each plot vegetation and ground cover variables are recorded at ten randomly selected 1 m quadrates. The recorded data are as follows: percentage of ground cover by trash from previous crop, percentage of bare ground, percentage cover by current crop, percentage cover by weeds, crop height, crop development stage.

Results

We expect that from environmental, ecological and economical point of view conservation-oriented land use practice has benefits compared with conventional land use practice. We would like to prove that with conservation tillage we can protect our soil resources and promote biodiversity. From our preliminary results we can show that there are significant differences between the two differently managed plot types regarding the studied topics.

The two main driving factors of bird population dynamics in Europe are the provision of seed supplies during winter and invertebrate food for the chicks. Thus the availability of seeds on soil surface of the conservation tillage plots is essential and determines the number of foraging birds. At the beginning of the recording period (November 2003 – February 2004) we could observe a significant difference between the bird numbers. While on the minimum tilled plots at *Dióskál 1* 743 birds were recorded, on the conventionally tilled plots only 131 (*Figure 2*). At *Dióskál 2* on the minimum tilled plots 297 birds were observed, on the conventionally tilled plots only 18 (*Figure 3*). Skylark (Alauda arvensis), Goldfinch (Carduelis carduelis), Yellowhammer (Emberiza citrinella), Greenfinch (Carduelis chloris), Tree Sparrow (Passer montanus) preferred only the minimum tilled plots, because there they could find food (seeds, volunteer crop) and shelter of weeds. Buzzard (Buteo buteo) and Hen Harrier (Circus cyaneus) were also observed only on the minimum tilled plots, because the routes of rodents were not disturbed with ploughing. Grayleg Goose (Anser anser) and Bean Goose (Anser fabalis) did not show any preference, as they feed on the crop.

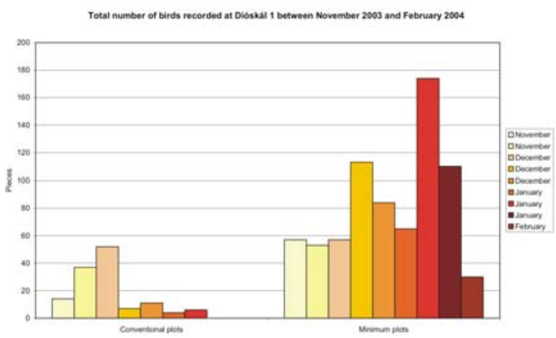


Figure 2. Preliminary results of bird recording at Dióskál 1

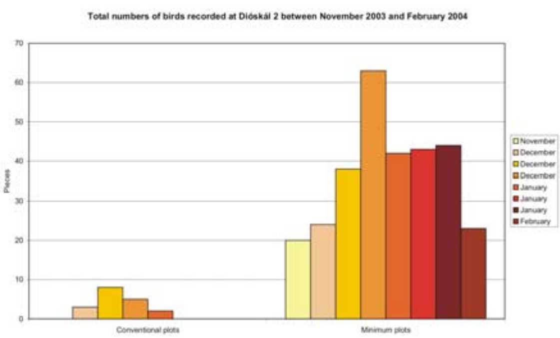


Figure 3. Preliminary results of bird recording at Dióskál 2

By the end of December 2003, construction of the erosion plots at Szentgyörgyvár was finished. In early January the meteorological station and the tank sensors were installed. During the first 3 months we tested the system: it worked well although with some teething troubles. In the middle of January the station measured the first rainfall event. Despite the small amount of rainfall, there was appreciable runoff due to the frozen soil. In March we could observe ponding on the bare surface of the conventional plots, which is due to raindrop erosion and siltation. Whereas on the minimum plots ponding did not happen, because the surface was covered with trash of the previous crop. This trash cover prevented raindrop erosion, thus siltation could not occur, moreover maize stems diverted water below the surface. Regular measurements started at the end of April. This short period is not enough to draw any conclusion, nevertheless these preliminary results are promising in respect of the conservation tillage (better soil structure, soil water management, less soil loss).

References

Birkás, M.–Antal, J. – Dorogi, I. 1989. Conventional and Reduced Tillage in Hungary – A Review. – Soil and Tillage Research, 13, pp. 233-252.

Birkás, M.–Jolánkai, M.–Gyuricza, C.–Percze, A. 2004. Tillage Effects on Compaction, Earthworms and Other Soil Quality Indicators in Hungary. – Soil and Tillage Research, article in press

Holland, J. M. 2004. The Environmental Consequences of Adopting Conservation Tillage in Europe: Reviewing the Evidence. – Agriculture, Ecosystems and Environment, article in press

Stefanovits, P.–Várallyay, Gy. 1992. State and Management of Soil Erosion in Hungary. – Soil Erosion and Remediation Workshop, US - Central and Eastern European Agro-Environmental Program, Budapest, April 27-May 1 1992, Proceedings, RISSAC, Budapest, pp. 79-95. Cit. – In: Kertész, Á. 2001. Land Degradation in Hungary.

Tillage Erosion

Akande, O.O.[1]

In the report got in 1976 by the general Accounting office (GAO) said the United State had spent 15% billion on soil and water conservation in the previous 40 years and still had a sever erosion problem.

That's like saying you got car fixed last year, but now its not running right. Though the statement may be true but they are not particularly instructive. They don't tell us what is wrong, or even if anything is wrong at all. These are the type of criticism and thinking that must be overcome if conservation programs are to get the national priority necessary to protect land and water resources and keep them productive for us to get a good practice on soil conservation in a new European Union.

What is soil conservation? It is the act of protect or prevent the soil for been damage or degradation.

The Crops Productivity

The production of crops involves several activities and operations and the aim of the farmer are:

- To control the factors necessary for the health growth of crop plants.
- To conserve and maintain the fertility of the soil.

Mulching for example reduce the loss of moisture from the soil by evaporation. It also reduces excess heat in the soil. The application of manure and following are practices used to replace nutrients removed from the soil by growing crops but apart from weed, pests and diseases the soil degradation cal also affect the Agricultural productivity.

Soil Erosion Measurement at Different scales

Soil constituents are made up of a mixture of broken particles of rock, organic mater, living things, soil water and air. The soil particles are group into three main types:

- Sandy
- Loamy
- Clayey

This soil particles are grouped into 3 main types depends on relative amount of the particles in each.

Erosion and drought

When we clear or burn the land and till it, we destroy the plants that protect the soil, the soil therefore become exposed and loose and may be carried away by running water.

Drought

Occurs when there is not enough rainfall to provide moisture in the soil for the plants to use. The plant will began to dry up and wilt and will die if there is not water applied to the soil.

The problem of drought is severing during the dry season gardening. A good farmer must be sure of his source of water when choosing s site. Water can be obtained from wells, rivers, stream or dams by the method called irrigation.

Preventions

- Making the beds cross stops.
- Building crossbars at interval between beds known as tie beds.
- Mulching the beds. This reduces the force of raindrops
- Adding enough comport or farmyard manure will form humus and bind the soil particles together.
- Practicing crop rotation
- Leaving some grass strips between plots to reduce the speed of run off water.

An experiment conducted in year 2003

Title: Studies in Tillage and Fertilizer interactions in a degraded Alfisol

Objectives: 1. To identify appropriate tillage in high input farming system niches.
2. To assess effective root growth in tillage/fertilizer studies.

Brief Methodology: Four tillage systems (TS): Plough + Harrow, chisel, chisel harrow
Three NPK (15-15-15) rates: 0,40 and 80kg/ha as subplots.

[1] Federal College of Agriculture, IAR & T, PMB 5029, Moor-Plantation, Ibadan, Oyo State, Nigeria. E-mail: fedcolag@yahoo.com

Design: split plot in RCBD, 3 replications
Site: I.A.R& T, Ibadan (pH -5,8; TN - 0.46 g/kg; Av;P -5.0mg/kg)
Test crop: Maize variety SIN 9449 -SR, planted 75cm x 25cm

Results

Root Length: Ploughing+Harming system had the longest root in both years. Significant increase in root length occurred only at 40kg NPK/ha, (Table 1).

Grain Yield: Yield significantly increase with increasing fertilizer rates in plough harrow and chisel tillage system, while in plough and chisel harrow tillage system, grain yield were stable at 40kg NPK/ha.

Conclusion: Ploughing alone plus early planting to capture nutrient lush and application of a sub optional amount of NPK (40KH/HA) was adequate for almost 2 tons per Hectare of maize production.

Advantage of soil conservation

- This will enable efficient use and management of land and water resources for agricultural productivity.
- It provide land and water used Management.
- It develops low cost and efficient technology for control and monitoring erosion and land degradation.
- It will provide advisory service to farmers, agricultural institutions and industries through soil survey, land evaluation, soil testing, laboratory analysis of soil, plant fertilizer, rock and water for appropriate management practice.
- It will develop efficient and effective engineering techniques to solve irrigation, land clearing and tillage problem.

Erosion sensitivity of the soils in Hungary
– experiments based on wind tunnel experiences –

Lóki, J.[1]

Wind erosion causes serious problems in various parts of the Earth. The surface forming activity of the wind is characteristic primarily in the desert areas, but it may be observed on the dry cultivated lands with harder soils and lacking vegetation. Wind erosion deteriorates the structure of the soil and causes damages in the vegetation. The dust and chemicals getting into the air cause respiratory diseases. The impacts of wind erosion may be felt on the soils of Hungary as well.

The erodibility of the soils with varying textures collected from different points of the country has been studied in the wind tunnel of the University of Debrecen. The characteristic features of the soil samples were determined (granular size, $CaCO_3$, humus content, pH value). The critical starting velocity of the soils and the wind profile function above the soils were determined during the wind tunnel experiences. The amount of the sediment transported from the air-dry soils was measured at four speeds. The results of the repeated experiments were processed on computer. The functions of the erodibility of the soils and their formulas were defined by fitting an exponential trend line over the measured results.

The data of the wind erosion experiments were processed in a wind erosion information system. A digital map was drawn on the basis of the AGROTOPO database and the values of the measured starting speeds. It shows the wind speeds at which wind erosion starts on certain unprotected dry soil surfaces in Hungary.

The soils with differing textures were listed into five categories on the basis of the amount of the soil transported at different wind speeds (very high, high, mediocre, weak, less or no endangerment). Using the created database, a digital potential wind erosion map of Hungary was drawn applying the GIS method. It may be concluded from the map that 17.1% of the area of Hungary is very highly endangered and 9.4% of it is highly endangered. The ratio of the areas where the level of endangerment is mediocre is 43.3%. The proportion of the weakly and non-endangered areas is a little more than 30%.

[1] Department of Physical Geography and Geoinformatics, University of Debrecen, Hungary. 4010 Debrecen, Egyetem tér 1. Tel.: 36-52 512900/2113; Fax: 36- 52 512945, E-mail: jloki@delfin.klte.hu

Water stable aggregates in an amended soil affected by simulated processes of soil degradation

Ingelmo, F.[1] – Albiach, M.R. – Canet, R. – Gamón, S.

Abstract

Under dry Mediterranean climate, water erosion and wildfire cause a continuous degradation of the soil structure. These effects, normally, were avoided with the organic amendment of the soil surface. To model these relationships, indexes of water stable aggregates of a forest soil classified as Rendzic Leptosol have been investigated in representative soil samples of Zarra (Valencia, Spain).

Under laboratory controlled conditions, soil samples amended with three doses of composted sludges (0, 5 and 10 %) were subjected to three levels of energy of the simulated action of water erosion (E0, E1 and E2; respectively 0, 100 and 600 J/ml) and at two levels of heat–induced intensity (F0: 25 ºC and F1: 500 º C of maximum temperature on the soil) in a randomised completed block experimental design. For the successive highest level of simulated degradation processes (i.e.- the combination E2 F1), the relative water stable aggregates index (WSAI) decreased in both the treatments by 82 % (without organic amendment) and 50 % with the highest dose. The initial level of organic matter was directly related to the dose of the amendment and that affected the proportion of macroaggregates / microaggregates in the soil.

Introduction

Under dry Mediterranean climate, continuous degradation of soil structure is caused by water erosion and wildfires because of the removal or destruction of the organic matter of the soil surface. These effects, normally, were avoided with the organic amendment of the soil surface, which ameliorates their main physical properties and the water infiltration (Albiach et al., 1999; Ingelmo & Ibáñez, 1998). Changes in water-stable aggregation have generally been correlated with changes in the total organic matter (OM) and in particular OM fractions (Angers & Giroux, 1996).

The water erosion process breaks the main structural units in macroaggregates, microaggregates and primary particles. Fire is a major factor controlling forest landscapes in Southern Europe, especially in the Mediterranean basin and so it is considered a major environmental problem. Different intensity of heating means different level of combustion of organic matter, and that may negatively alter the soil structure (Gimeno-García et al., 2000).

In this paper we examine through laboratory test the water stable aggregates index (WSAI) in representative soil samples of a coarse-textured forest soil amended with three rates of composted sludges and subjected to simulated actions of soil water erosion and soil heating.

Materials and methods

In a randomised complete block experimental design with four replicates, the air-dried fine soil (< 2mm) was amended with three rates of composted sludges (0, 5 and 10% w/w) and were successively subjected under controlled conditions of laboratory to three energy levels of simulated water-erosion (E0, E1 and E2, corresponding to 0, 100 and 600 $J.cm^{-3}$, respectively) and at two levels of heat–induced intensity (F0: 25 ºC and F1: 500 º C of maximum temperature on the soil. Details of the experimental procedure and the main physical, chemical and physicochemical characteristic of the original soil and the organic amendment, and the organic matter content in the bulk soil samples and in macroaggregates and microaggregateswas showed in Ingelmo et al. (2003). The WSAI was calculated as:

WSAI (%) = $(M - S). 100/((M * m) - S)$

Where, M and m are the macroaggregates and microaggregates content in the soil sample, and S is the coarse sand content in the soil sample.

Results and discussion

Table 1 shows the general decrease with the water erosion of the water stable aggregates index. The amendment of this soil with composted sludges significantly increased this index for uneroded and eroded soil samples. When increases the water erosion energy from 0 to 100 $J.cm^{-3}$ it can be see that an abrupt decay of this index was produced. This decrease was more gradual when the energy of water erosion increased from 100 to 600 $J.cm^{-3}$. As pointed by Roscoe et al.(2000), the energy input to separate organic matter from soil (i.e. by water erosion) depends of the water stability of the aggregates and has to be sufficiently large to disrupt macroaggregates into microaggregates and primary particles. An explanation of this facts is that the unamended

[1] Departamento de Degradación y Conservación de Suelos. Centro de Investigaciones sobre Desertificación-CIDE (CSIC-UVEG-GV). Tel.: 34-96 1220540; Fax: 34 96 1270967; E-mail: florencio.ingelmo@uv.es

soil has a coarse texture and concentrates their SOM mainly around the fine sand particles and into the microaggregates with low water structural stability, whereas the composted sludges may have particulate organic matter (POM) and other organic fractions such as microbial biomass that can increase the water stability of the amended soil.

Table 1. Mean values of the water stable aggregates index (WSAI) (%), for each rate of composted sludges and for each treatment. Values in the same column followed by the same letter are not significantly different at the 95 % level of probability.

Dose of sludges	Treatments					
	E0F0	E1F0	E2F0	E0F1	E1F1	E2F1
0	73.2 a	47.8 a	23.8 a	69.6 a	45.6 a	13.2 a
5	79.9 b	56.6 b	30.1 b	74.1 a	53.3 a	22.6 b
10	91.2 c	59.6 c	38.0 c	83.8 b	63.0 b	36.9 c

The heating of soil provoked the combustion of the SOM in the bulk soil and that means a new decrease in the water stable aggregates index by reference to the control without heating. Kemper et al. (1987) indicates an increase in water-stable aggregation because of carbonates precipitation, dehydration of organic compounds and hardening of clay particles thus affecting the soil cohesion.

Conclusion

The amendment of this coarse-textured soil with composted sludges at the rates of 5 and 10 % (w/w) diminished the breakdown of macroaggregates into microaggregates but their organic matter decreased more slowly than in the unamended soil.

For the successive highest level of simulated degradation processes (i.e.- the combination E2 F1), the relative water stable aggregates index (rate of variation referenced to the index of water stable aggregates in the control E0F0) decreased in both the treatments by 82 % (without organic amendment) and 50 % with the highest dose.

References

Albiach, R., Canet, R., Pomares, F. and Ingelmo, F. Structure, organic components and biological activity in citrus soils under organic and conventional management. Agrochimica,XLIII (5-6), pp. 235-241, 1999.

Angers, D. A. & Giroux, M. Recently deposited organic matter in soil water-stable aggregates. Soil Science Society of American Journal, 60, pp. 1547-1551, 1996.

Gimeno-García, E., Andreu, V. &Rubio, J.L. Changes in organic matter, nitrogen, phosphorus and cations in soil as a result of fire and water erosion in a Mediterranean landscape. European Journal of Soil Science, 51, pp. 201-210, 2000.

Ingelmo, F and Ibáñez, A. Runoff and infiltration in soils amended with sludge under dry Mediterranean climate. Ecosystems and Sustainable Development: 1 Advances in Ecological Sciences, ed. J. L. Usó, C.A. Brebbia & H. Power, Computational Mechanics Publications, Southampton, pp. 511-520, 1998.

Ingelmo, F., Albiach, R. & Gamón, S. Organic matter of a soil amended with composted sludges and affected by simulated processes of soil degradation.. Ecosystems and Sustainable Development IV. Advances in Ecological Sciences, 19 ed. E. Tiezzi, C.A. Brebbia &J. L. Usó, WIT Press, Southampton, vol., 2 pp.971-980, 2003. Kemper, W. D., Rosenau, R. C. & Dexter, A. R. Cohesion development in disrupted soils affected by clay, organic matter content and temperature. Soil Science Society of American Journal,51, pp. 860-867, 1987.

Roscoe, R., Buurman, P and Velthorst, E. J. Disruption of soil aggregates by varied amounts of ultrasonic energy in fractionation of organic matter of a clay latol: carbon, nitrogen and δ^{13} C distribution in particle – size fractions. European Journal of Soil Science, 51, pp 445 – 454, 2000.

About effect lupine (*Lupinus luteus*) root system on the properties of compacted soils

Kuht, J.[1] – Reintam, E. – Nugis, E. – Edesi, L.

Abstract

The impact of deep-rooted plants roots on compacted soil properties, especially on compacted subsoil, was investigated on many years in Estonian Agricultural University. The aim of the investigation is to find instead of mechanical subsoil loosening the suitable and less energy demanded methods for Estonian conditions to lose the subsoil compaction. The experiments with different natural and cultural plants were made on Estonian Agricultural University at Eerika, near Tartu (58º23´N, 26º44´E). The data were collected from research field with different levels of soil compaction (10 levels) on sandy loam *Fragi-Stagnic Luvisol* (WRB) soil. The soil was compacted by heavy tractor by multiple tyre-to-tyre passing. In this work the impact of lupines, as the plant with especially deep taproot, on properties on soil with thickened subsoil was investigated. To evaluate the changes in soil physical properties the bulk density and cone resistance of soil were measured. The mass of roots in different soil layers was also investigated. The results of investigation showed the positive effect of lupines growing on compacted soils. The negative correlation between dry biomass of lupines roots and soil bulk density was detected. The same trend was also observed with biomass of lupines roots. The root systems of lupines were able to penetrate the compacted subsoil in all investigated soil compaction variants.

Key words. Lupine, roots, soil properties, soil compaction

Introduction

In 1989–1994, a group of Estonian researchers developed and conducted a field trial to study the impact of deep and exuberant rooted plants on the properties of compacted soil. Although the crops used in the field trial (Galega orientalis L., Brassica napus L. and Trifolium pratense L. (coll.) did not eliminate all the deformations of excessively compacted soils, the results achieved were still promising (Kuht and Lopp, 1997).

The study on different types of soils (Dystric-Gleyc Podzoluvisol, Eutric Podzoluvisol, Calcaric Regosol, etc.) in Estonia showed that the average penetration resistance of soil in the fields with Canadian thistle (Cirsium arvense L.) was 10–35% lower in epipedon and 15–25% lower in subsoil compared to grain fields, depending on the tillage of the soil (Kuht and Reintam, 1998). The results of the field trials with Canadian thistle plants that had been planted to areas of different degree of compaction confirmed the capability of the thistle root system to improve the properties of compacted soils. In the area planted with Canadian thistle, the penetration resistance (with 20% water content in soil) declined considerably in all compaction variants compared to areas where only barley was grown (Kuht and Reintam, 2001).

The mechanical methods used to eliminate compacted soil layers are expensive and energy consuming.

One good alternative might be to use plants with vigorous roots to modify the compacted subsoil (Dexter, 1991). One of the best species for that is lupine.

Yellow lupine (Lupinus luteus) is a major lupine in the Baltic countries. It has been introduced and is cultivated in northern Europe, South Africa, Australia, and the southern U.S. Bitter lupines are typically used for green manure alone, whereas alkaloid-free varieties are also used for forage and silage. Yellow and blue lupines are mentioned as good honey plants. A.J. Duke (1981) described Lupinus luteus as a hairy annual 25-80 cm tall, the stems hairy, leaflets 40-60 mm long and 8-12 mm wide. Yellow lupine tolerates strongly to mildly acid infertile soils. In its native range, it grows on acid sandy loams. White and Robson (1989) stated that lupines suffer iron deficiency when grown on calcareous soils, much more so than does field pea. Duke (1981) indicated that yellow lupine roots could accumulate 147-160 kg N ha-1.

Gardner et al. (1982) found that lupine could acquire P through acidification of the rhizosphere and subsequent absorption. The former two nutrients were probably mobilized of by exudates from the lupine roots, and then taken up by the closely associated wheat roots.

The aim of the investigation is to find instead of mechanical subsoil loosening the suitable and less energy demanded methods for Estonian conditions to lose the subsoil compaction.

Materials and methods

The data were collected from research field with different levels of soil compaction on sandy loam Fragi-Stagnic Luvisol (WRB) soil. The soil was compacted by heavy tractor by multiple tyre-to-tyre passing. By heavy tractor (with loader; total weight 4.9 Mg) soil compaction was done before showing time in spring 2001, 2002 and 2003. For all that traffic applied uniformly to cover the entire experimental plots: 1 time, 3 times and 6 times. In this work the growing of lupine, as the plant with especially deep taproot, on soil with thickened topsoil

[1] Estonian Agricultural University, 64 Kreutzwaldi St., 51014 Tartu, Estonia; Tel.: +372-31-35-32; Fax: +372-31-35-39; E-mail: jkuht@eau.ee

and subsoil was investigated. The mass of roots in different soil layers was also investigated. The results were compared with barley on similar area. Seeds of yellow lupine with density 47 seeds per m–2 were sown by hand on different level of soil compaction in 2003. Lupine shoot mass was taken from the 1 m2 plots in four replications, from which the dry mass was measured. Lupine root samples were taken with 703.4 cm3 steel cylinders in 4 replications in 15 cm layers up to 60 cm

Results and discussion

The results of experiment showed that on the dense soil the shoot mass of yellow lupine decreased proportionally with compaction times (Figure 1). In result of three and six times compaction the phytomass of lupine decreased 8.7% and 14.9% (from 9.1 Mg ha-1 up to 7.9 Mg ha-1), respectively, compared to the control variant (without special compaction). Duke (1981) summarized biomass production for yellow lupine: 5–7.5 Mg ha-1, with root biomass ranging from 3–8.7 Mg ha-1. Decrease of lupine shoot yield was obviously connected more with worse soil water and air conditions than with developing of root system. Because there was no significant differences between roots dry mass and compaction times in 0–60 cm soil layer. This indicates that the investigated levels of soil bulk density did not inhibit the developing roots of yellow lupine.

Bennie (1996) noticed that the relative decrease in root elongation rate with increasing soil penetration resistance was the same for most plant species. However some researcher are determined more than 20 plant species, among them lupine, that are able satisfactory to develop their root system in dense and strength (penetration resistance 4200 kPa) soil (Materachera et al., 1991). The plants with thick roots can better spread their roots to the deep soil layers than plants with thin roots (Whitely and Dexter, 1984). The experiments with lupine were shown the better ability of soil water movement in deep soil layers after lupine growth (Materachera et al., 1993).

Lupines are strongly and deeply tap rooted. The roots of yellow lupine can penetrate to a depth of 2 m in dernopodzolic sandy loam soils of Russia, with a root biomass yield of yellow lupine of from 3–8.7 Mg ha-1 (Duke, 1981). Hartmann and Aldag (1989) compared white lupine with Vicia faba bean. The lupine developed a deeper root system than did the bean. In the soil stratum of from 60–90 cm depth, lupine root mass was 6 times higher that of bean. Overall root mass was 125 g m-2 for stands of lupine 86 g m-2 for bean.

As can see from the figure 2, the compaction effect on soil bulk density was mostly in the upper, 0–30 cm, layer of the soil. Loosening effect of yellow lupine was detected in the upper layer of soil on 3- and 6-times compacted variants, but there was some effect also in 45–60 cm soil layer, compared to the barley field. The certain increase of soil bulk density was detected on the noncompacted area by lupine growing. It can explain with compacting effect by growing of lupine thick taproots. This effect is mostly on loose soil. The percentage of roots grown into existing pores and channels increases in deeper and stronger layers (Goss, 1991) where they can be the only possible pathways for root growth. The preferential root growth into macropores will lead to increasing critical limits of soil compactness (Etana et al., 1999; Håkansson and Lipiec, 2000). Rosolem observed an increase in soybean root diameter when the soil resistance to penetration was >1.2 MPa and increase in the diameter of corn roots when the resistance to penetration was >1.4 MPa. Thus, the effect of soil compaction on root diameter depends largely on the level of penetration resistance (Rosolem et al., 2002).

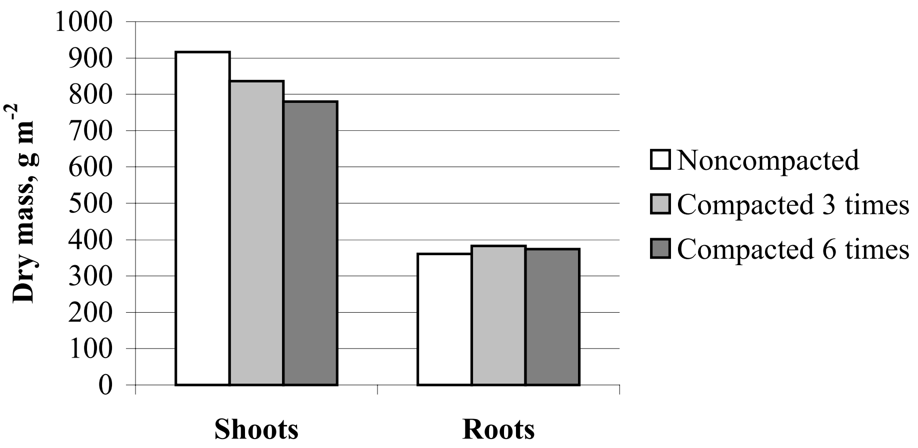


Figure 1. Dry mass of lupine shoots (g m-2) and roots in 0–60 cm soil layer (g m-2) on different levels of soil compaction. (LSD95 – for shoots 43; for roots 24)

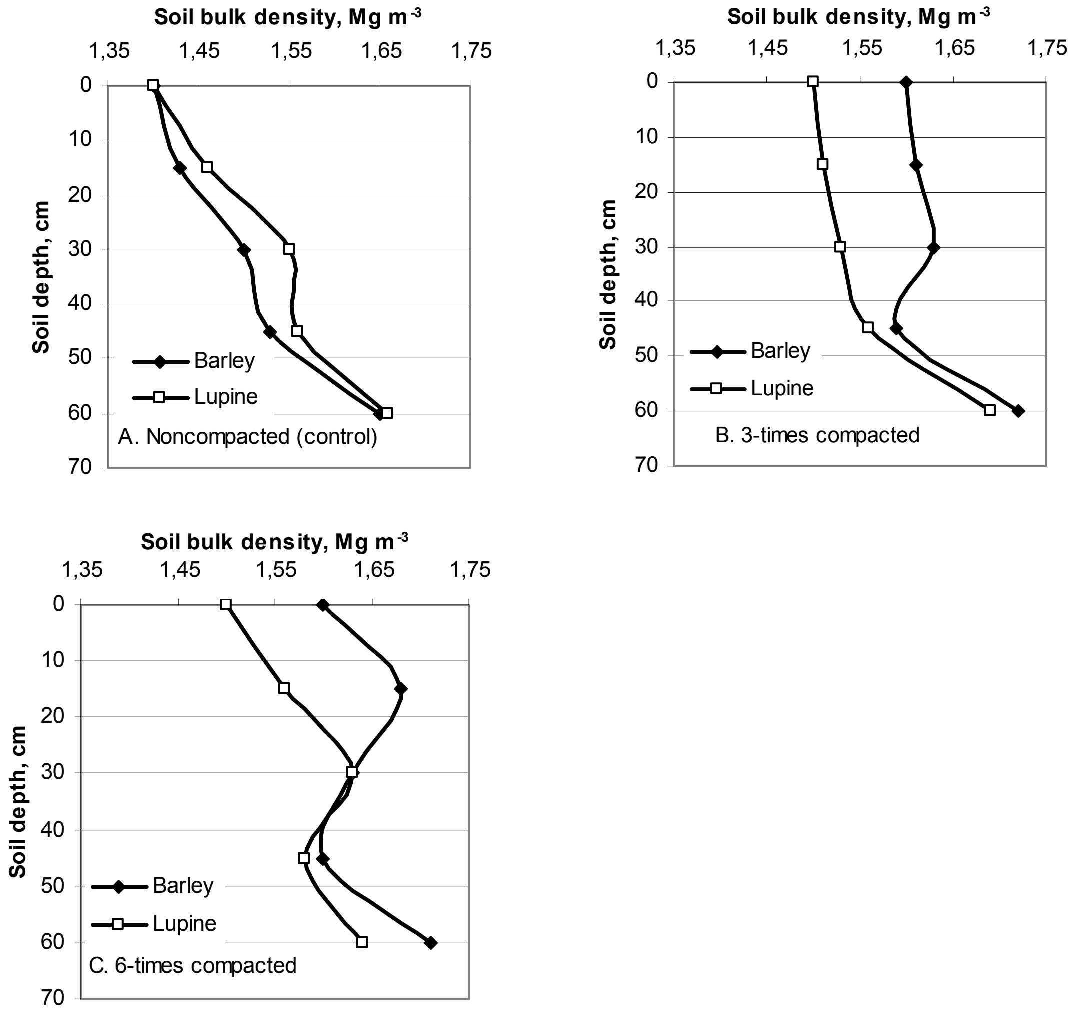


Figure 2. Changes in soil bulk density on different rates of compaction (A; B; C) in lupine (Lupinus luteus) and spring barley (Hordeum vulgare) fields

In the dense soil the lupine roots cannot influence the even dense soil and increase its bulk density. In the result of that and thanks to the low density of roots self, the bulk density of soil will decrease. Earlier experiments with planted Canadian thistle growth on compacted soil impruved the ability of thistle roots to loose compacted soil layers (Rentam and Kuht, 1999). The soil loosening effect of lupine and also of Canadian thistle can be attributed to the biopores formed by the roots. Biopores formed by the roots of the plants can be very stable and they are more resistant compared to biopores formed by earthworms (Mc Kenzie and Dexter, 1998a, 1998b). The biopores with the diameter of over 4 mm formed by alfalfa (Medicago sativa L.) tolerate the pressure of over 200 kPa (Blackwell et al., 1990). In the opinion of some researchers is possible to use the lupine and also other deep-rooted plants for biological soil tillage (Henderson, 1989).

Conclusions

The results of investigation showed the positive effect of lupines growing on compacted soils. The negative correlation between dry biomass of lupines roots and soil bulk density was detected. The same trend was also observed with biomass of lupines roots and cone resistance of different soil layers. The root systems of lupines were able to penetrate the compacted subsoil in all investigated soil compaction variants. Soil compaction decreased the lupine shoot mass but did not inhibit the roots developing (by dry mass). Roots of lupine were able to spread at least into the 60 cm soil on all investigated compaction variants. That means lupine is able to raise biopores in deep soil. Using lupine for biomeliorative aims deserves further completing investigations.

Acknowledgements

The study was supported by grants no. 5418 and 4801 of the Estonian Science Foundation.

References

Bennie, A.T.P., 1996. Growth and mechanical impedance. In: Waisel, Y., Eshel, A., Kafkafi, U. (Eds.), Plant roots: The Hidden Half, 2nd Edition. Marcel Dekker, New York, pp. 453–470.

Blackwell, P.S., T.W. Green, and W.K. Mason. 1990. Responses of biopore channels from roots to compression by vertical stress. Soil Sci. Soc. Am. J.: 54, 1088–1091.

Dexter, A. R. 1991.Ameliration of soil by netural processes. Soil and Tillage Research, 20, 87–100.

Duke, J. A. 1981. Handbook of Legumes of World Economic Importance. Plenum Press, New York. 345 pp.

Etana, A., Håkansson, I., Zagal, E., Bucas, S., 1999. Effects of tillage depth on organic carbon content and physical properties in five Swedish soils. Soil Tillage Res. 52, 129–139.

Gardner, W.K., Parbery, D.G. and Barber, D.A. 1982. The acquisition of phosphorus of Lupinus albus L.: II. The effect of varying phosphorus supply and soil type on some characteristics of the soil/root interface. Plant and Soil 68: 33–41.

Goss, M.J., 1991. Consequences of the activity of roots on soil. In: Atkinson, A. (Ed.), Plant Root Growth. An Ecological Perspective. Spec. Publ. Br. Ecol. Soc., vol. 10. Blackwell, Oxford, pp. 171–186.

Håkansson, I., Lipiec, J., 2000. A rewiew of the usefulness of relative bulk density values in studies of soil structure and compaction. Soil Tillage Res. 53, 71–85.

Hartmann, C. and Aldag, R. 1989. N2-Fixierung und Ertragsstruktur der Wei§en Lupine (Lupinus albus L.) im Vergleich zu Vicia faba L. und Glycine max (L.) Merr. Auf verschiedenen Standorten (N2-fixation and yield structure of white lupine (Lupinus albus L. in comparison to Vicia faba L. and Glycine max (L.) Merr. on different sites). Journal of Agronomy and Crop Science 163: 201–211.

Henderson, C.W.L. 1989. Lupine as a biological plough: evidence for and effects on wheat growth and yield. – Aust. J. Exp. Agric., 29, p.99–102.

Kuht, J., and K. Lopp. 1997. Restoration of ecological status of a super compacted soil by biological methods. Problems of Field Crop Husbandry and Soil Management in Baltic States. Collection of scientific articles. Kaunas. Lithuania. 38–43.

Kuht, J., and E. Reintam. 1998. About restoration of ecological status of a super compacted soil by biological methods. Proceedings of the workshop on Sustainable Tillage Systems. USDA–ARS National Soil Dynamics Laboratory, Agricultural Engineering Department, Auburn University, and Agronomy and Soils Department, Auburn University. July 8–10, 1998. Auburn. Alabama. USA, p. 41–50.

Kuht, J., Reintam, E. 2001. The Impact of Deep Rooted Plants on the Qualities of Compacted Soils. Sustaining the Global Farm. Selected papers from the 10th International Soil Conservation Organization Meeting held May 24–29, 1999 at Purdue University and the USDA-ARS National Soil Erosion Laboratory. West-Lafayette, Indiana, USA, p. 632–636.

Materachera, S.A., Alston A.M., Kirby, J. M., Dexter, A.R. 1993. Field evaluation of laboratory techniques for predicting the ability of roots to penetrate strong soil and the influence of roots on water sorptivity. – Plant and Soil, 149, p.49–58.

Materachera, S.A., Dexter, A.R. and Alston A.M. 1991. Penetration of very strong soils by seedling roots of different plant species. – Plant and Soil, 135, p.31–41.

Mc Kenzie, B. M., and A. R. Dexter. 1988a. Axial pressures generated by earthworm Aporrectodea rosea. Biol. Fertil. Soils. 5, 323–327.

Mc Kenzie, B. M., and A. R. Dexter 1988b. Radial pressures generated by earthworm Aporrectodea rosea. Biol. Fertil. Soils. 5, 328–332.

Reintam, E., Kuht, J. 1999. About influence of some components of agrophytocoenose on the properties of dense soils (Estonian). Transactions of the Estonian Agricultural University 205, 65–71.

Rosolem, C.A., Foloni, J.S.S., Tiritan, C.S. 2002. Root growth and nutrient accumulation in cover crops as affected by soil compaction. Soil Tillage Res. 65, 109–115.

White, P.F. and Robson, A.D. 1989 Rhizosphere acidification and Fe^{3+} reduction in lupines and peas: iron deficiency in lupines is not due to a poor ability to reduce Fe^{3+}. Plant and Soil 119:163–175.

Whitely, G. M., Dexter, A. R. 1984. The behaviour of root encountering cracs in soil. I Experimental methods and results. Plant and Soil, 77, 141–149.

Water and wind erosion and its influencing by climate conditions

Dufkova, J.[1] – Toman, F.

Introduction

It is necessary to know occurrence, distribution and intensity of precipitation for the soil erosion control purposes. Torrential rains are crucial factor for the water erosion processes, from 99 % they occur since May till the end of September in the conditions of Central Europe. The amount of winter and spring precipitation plays a big part in wind erosion origination, it determines the soil humidity and hereby influences the soil erodibility by wind.

Materials and Methods

For the purpose of determination of specific impacts of climate change on the erosive process development, it is necessary to check the mutual relations between climate conditions (precipitation, temperature, etc.) and other factors, which assert themselves during erosion origin. Some factors, that influence these processes, are not static, they are under dynamic changes. The evaluation of the changes was made by the determination of trends of certain meteorological factors for the selected areas of Czech Republic, Central Europe. There were used data from four professional climatological stations of Czech Hydro-meteorological Institute, Telc-Kostelni Myslova, Velke Mezirici, Znojmo-Kucharovice, and Brno-Turany (tab. 1). The analyses of water erosion were done for the period of 1901-1950 and 1961-2000, the analyses of wind erosion for the period of 1961-2000.

Analyses of rainfall sums from four chosen professional climatological stations, Telc-Kostelni Myslova, Velke Mezirici, Znojmo-Kucharovice, and Brno-Turany, were done. The data of rainfall sums were evaluated for the period of 1961-2000 and the basic statistical evaluation was done from the database of the data. Trends in annual and monthly rainfall sums and in rainfall sums of the period with the highest occurrence of extreme rainfalls (May and September) were determined for the selected stations. On the basis of the pluviograph records analyses, there were made evaluations of the occurrence frequency of the torrential rain with the intensity above 20 mm per hour and abundance above 10 mm. All the calculations were made by use of statistical programs (Kadlec and Toman, 2002).

The characterization of a landscape humidity feature is usually done by climatological indexes. On the basis of the accessibility of the data, which are needed for the calculation of characteristics, three climatological indexes were chosen, i.e. Koncek's Humidity Index, Lang's Rainfall Factor, and Minar's Moisture Certainty. Their values were compared subsequently for three climatological stations of Czech Republic, Telc-Kostelni Myslova, Znojmo-Kucharovice, and Brno-Turany. The data of average annual rainfall sums, average annual air temperatures, average temperatures per a vegetative period, and average wind velocities at 2 p.m. per a vegetative period were evaluated for the period of 1961-2000 and the basic statistical evaluation was done (Dufkova and Toman, 2003).

Table 1. Characterization of selected climatological stations

Indicative	Name	Latitude North	Longitude East	Altitude m above sea
636	Telč-Kostelní Myslová	49° 09' 36"	15° 26' 21"	569
687	Velké Meziříčí	49° 21' 14"	16° 00' 31"	452
698	Znojmo-Kuchařovice	48° 53' 00"	16° 05' 00"	334
723	Brno-Tuřany	49° 09' 35"	16° 41' 44"	241

Koncek's Humidity Index

Koncek's humidity index comes out of Humidity Index according to Thornthwaite. As the climatological index, it is usually used for the classification of climate, i.e. macroclimate and mesoclimate. Formula gives the humidity index for the whole vegetative period (April-September) (Koncek, 1955) (1):

$$I_Z = \frac{R}{2} + \Delta r - 10t - \left(30 + v^2\right), \qquad (1)$$

[1] Mendel University of Agriculture and Forestry Brno, Institute of Landscape Ecology, Zemedelska 1, 613 00 Brno, Czech Republic, Tel.: 00 420 545 136 071; Fax: 00 420 545 136 059; E-mail: janadufkova@email.cz

where I_Z = Koncek's humidity index, R = rainfall sum per a vegetative period in mm, Δr = positive deviation of rainfall amount of three winter months (December-February) from the value of 105 mm in mm (negative figures are not taken), t = average air temperature per a vegetative period in °C, and v = average wind velocity in $m.s^{-1}$ at 2 p.m. per a vegetative period.

Lang's Rainfall Factor

Lang's rainfall factor expresses natural irrigation conditions of landscape by the relationship between rainfalls and air temperature (2) (Sobisek, 1993):

$$f = \frac{R}{t}, \tag{2}$$

where f = Lang's rainfall factor, R = average annual rainfall sum in mm, and t = average annual air temperature in °C.

Minar's Moisture Certainty

Minar's moisture certainty characterizes moisture conditions of study locality (3). Ratio of average rainfall amount in a definite period and of average air temperature of the same period gives rainfall amount that falls on every degree of average temperature of the definite period (Brablec, 1948):

$$J = \frac{R - 30(t + 7)}{t}, \tag{3}$$

where J = Minar's moisture certainty, R = average annual rainfall sum in mm, and t = average annual air temperature in °C.

Results and Discussion

The comparison of the average values of annual and monthly rainfall sums for the period of 1901-1950 with the period of 1961-2000 shows lower volumes of rainfall in the second period in all the chosen climatological stations. The decrease varies according to the stations and its value fluctuates from 30 to 91 mm per year. The difference is mainly influenced by the precipitation since October till April (26-61 mm). The decreasing value is lower at the stations Telc-Kostelni Myslova and Velke Mezirici than at the stations Znojmo-Kucharovice and Brno-Turany. The largest difference was found out at the station Znojmo-Kucharovice (91 mm), the smallest at the station Telc-Kostelni Myslova (30 mm). The most important decrease in monthly rainfall sums was noted on October, November and December at all the stations. The largest difference was found out at the station Brno-Turany on October (21 mm).

For the determination of the occurrence frequency of torrential rains with the intensity above 20 mm per hour and abundance above 10 mm, there were pluviograph records analysed. The occurrence frequency is in table 2. Graphic representation of the time course and precipitation trend in the station Velke Mezirici gives figure 1.

Table. 2 Occurrence frequency of torrential rains in the period of 1961-2000

	Telč-Kostelní Myslová		Velké Meziříčí		Znojmo-Kuchařovice		Brno-Tuřany	
	number	%	number	%	number	%	number	%
May	7,0	7,5	7,0	9,9	12,0	14,1	15,0	18,5
June	27,0	29,0	22,0	31,0	27,0	31,8	23,0	28,4
July	29,0	31,2	21,0	29,6	22,0	25,9	22,0	27,2
August	23,0	24,7	15,0	21,1	21,0	24,7	11,0	13,6
September	7,0	7,5	6,0	8,5	3,0	3,5	10,0	12,3
total	93,0	100,0	71,0	100,0	85,0	100,0	81,0	100,0
average occurrence per year	2,3		1,8		2,1		2,0	

Linear trend of Koncek's humidity index that was calculated according to the equation (1) is decreasing for all the stations. The decrease appears during the vegetative period (April-September) as so as during the whole year. The average values of Koncek's humidity index of the vegetative period of 1961-2000 for the station Brno-Turany are shown in the figure 2.

The results from Lang's rainfall factor are very similar to these mentioned above with Koncek's humidity index. Its decreasing linear trend means loss of natural irrigation of the landscape. The average values for the station Znojmo-Kucharovice are in the figure 3.

Only values of Minar's moisture certainty show increasing of the linear trend at the station Telc-Kostelni Myslova (fig. 4). Anyway, this station belongs into the cool and humid area of Czech Republic and this is the reason of the increasing trend.

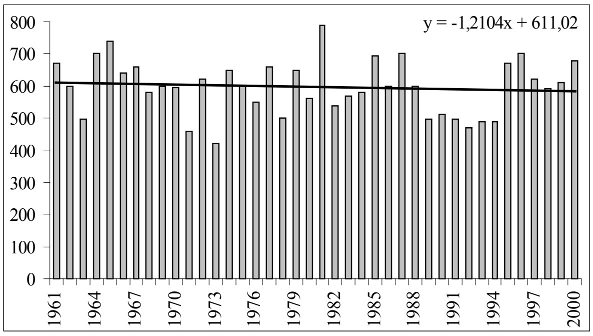


Figure 1. Trend of annual rainfall sums (mm) of the period of 1961-2000 at the station Velke Mezirici

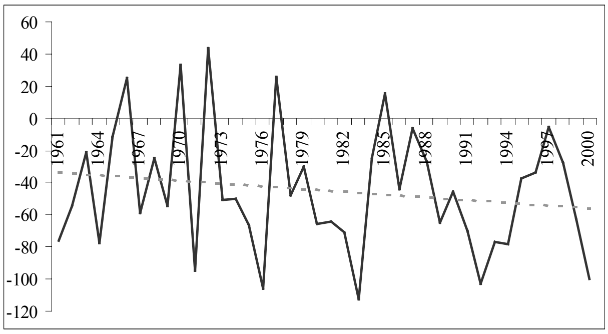


Figure 2. Koncek's humidity index of the vegetative period of 1961-2000 at the station Brno-Turany with its linear trend

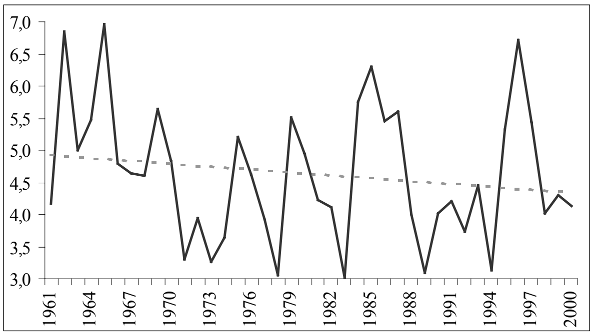


Figure 3. Lang's rainfall factor of the vegetative period of 1961-2000 at the station Znojmo-Kucharovice with its linear trend

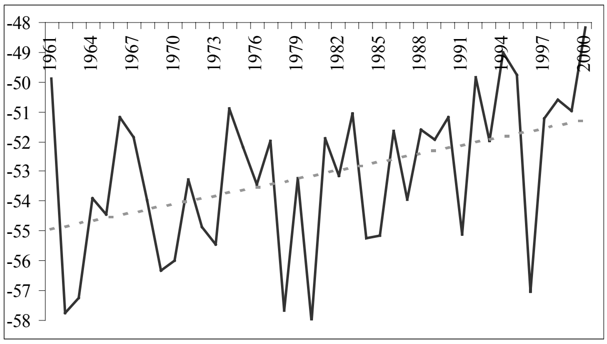


Figure 4. Minar's moisture certainty of the vegetative period of 1961-2000 at the station Telc-Kostelni Myslova with its linear trend

Conclusions

Analyses that were done for the discovery of the expected climate change impacts on the soil erosion confirm the assumption about the rainfall amount decreasing. Various scenarios of climate change mention decrease in the atmospheric rainfalls, potentially maintaining of their amount at the same level, and change in the distribution during the year as so as increase in the occurrence of extremes. All the consequences have or will have negative impacts on the soil, so both types of erosion mentioned in this study will then endanger much more areas.

Acknowledgements

Results of the study are part of research plan MSM 432100001, which is solved by Agronomic Faculty of Mendel University of Agriculture and Forestry Brno.

References

BRABLEC, J. Contribution to the Research and Detection of Arid Areas of Czech Republic. *Meteorological News*, 1948, vol. II, no. 5, p. 104. (in Czech)

DUFKOVA, J., TOMAN, F. Comparison of Climatological Indexes that Describe Humidity Character of Landscape. In: International Bioclimatological Workshop Function of Energy and Water Balance in Bioclimatology Systems. Rackova Valley: Slovak Bioclimatological Society, 02.-04.09.2003, p. 38. ISBN 80-8069-244-0 (in Czech)

KADLEC, M., TOMAN, F. Analyses of Historical Rainfall Series from the Viewpoint of Soil Erosion Control. In: X. International Poster Day Transportation of Water, Chemicals, and Energy in the System of Soil -

Crop Canopy - Atmosphere. Bratislava : Institute of Hydrology of the Slovak Science Academy, 28.11.2002, p. 201-208. ISBN 80-968480-9-7. (in Czech)
KONCEK, M. Humidity Index. Meteorological News, 1955, vol. VIII, no. 4, p. 96-99. (in Czech)
SOBISEK, B. Meteorological Lexicon. Prague : Academia, 1993. 594 p. ISBN 80-85368-45-5. (in Czech)

Modelling the effect of soil redistribution by water and tillage on carbon dynamics in agricultural landscapes

Van Oost, K.[1] – Govers, G. – Heckrath, G. – Olesen, J.

Soil erosion is widely considered as an important threat to the world soil resource. It is therefore quite surprising that very few models allow to assess the impact of soil erosion on soil properties and hence, soil quality, in a two- or three-dimensional context. In this paper we first briefly describe the SPEROS model. SPEROS is a two-dimensional, spatially distributed model that simulates soil redistribution by water and tillage processes using a time step of one year. By linking SPEROS with the ICBM carbon dynamics model model we were able to assess the long term effect of soil redistribution on carbon dynamics. The combined SPEROS-ICBM model represents space using matrices of grid cells. In each grid cell, different carbon stores are simulated: (i) the plough layer, (ii) the buried plough layer (in case of deposition) and (iii) a subsoil layer. SPEROS is used to model the lateral and vertical transfers of carbon between these stores. The ICBM model is then used to simulate the within-store dynamics of carbon for all grid cells and stores.

The coupling of both models allows to study the spatial and temporal dynamics of carbon on agricultural land and provides insight in the effects of erosion on carbon sequestration. The model is applied on agricultural fields in Europe. First model results show that although large amounts of carbon are exported from the field by water erosion, total carbon inventories have significantly increased over recent years. This is due to the increased deposition of soil and carbon by tillage on specific landscape positions. These landscape positions act as carbon sinks as carbon in the buried plough layer is protected from water erosion and decomposition. Due to the increased intensity of soil tillage since World War II, the within field carbon storage is now significantly more important than the export of carbon by water erosion. Consequently, soil erosion often leads to increased carbon storage at the field scale rather than carbon depletion.

[1] Laboratory for Experimental Geomorphology, KU Leuven. Redingenstraat 16b, 3000 Leuven, Belgium; Tel.: +003216326407; Fax: ++003216326400; E-mail: Kristof.vanoost@geo.kuleuven.ac.be

Comparing wind erosion (field measurements) with simulated by WEPS

Dikkeh, M.[1]

Introduction

Wind erosion is a serious problem in many part of the world. Wind erosion in Hungary, especially in the middle and south of country between Duna and Tisza rivers. These regions are characterized by sandy soils, low precipitation and the soil is very susceptible to wind erosion. The highest climatic erosive in March and April coincide with the lowest resistance of the soils against wind erosion. This soil is agricultural sandy soil use to planting. Also some part of the country area located in the east of country where the soil characterized by clay, loam and organic soil, this soil use to seeding Sugar beet, Corn and other crops. Wind erosion occurs especially in spring where caused big damage by plant abrasion and plant burying.

The most comprehensive summary on wind-induced surface movements in desert soils has been made by Bagnold (1941), while a similar work has been done by Chepil and Woodruff (1963) for agricultural land. The wind erosion-soil-loss prediction equation has been done by Woodruff and Siddoway (1965). In other publication we can read about observations experience gained on different protective and computerized prediction methods. Skidmore (1988) Skidmore and Layton (1988), Hagen (1988), Bodolayine (1966), Borsy (1974), Kiraly and Karacsony (1977), Dikkeh, (1990).

Objective

Comparison of wind erosion (field measurements) with simulated soil losses by WEPS.

Materials and methods

Wind erosion (field measurement) was studied for two years on one hector (100m in square) measuring plot located in Jakabszallas (Kecskemet). In table 1. shown the soil analysis.

We measured the soil transport caused by wind, with regard to the principles governing the wind erosion dynamics, we chose a simple measuring technique.

There were two types of sand traps and measuring rods applied. A 1ha plot was divided into 16 parcels and two sand traps and a measuring rod was placed on the parcels each. The trap in fact is a perforated hemispheres. One type of the traps is a hemispheres turned upside down with diameter, 2 mm perforations close tone another. So that any particles saltating or suspending on all sides around can enter, the trap was placed on the surface. The other type of traps had ten bore-holes of diameter, 10mm, and was sunk into the soil so that the trap surface be on the level of soil surface. It was measured how much sand moved rolling along on the surface. Next to each trap, there was a measuring rod set up. Prior to experiment, these rods were inserted up to their marked zero sign into the soil. The soil surface status prior to wind erosion hazard was indicated by the zero sign. The extent of blowing out or dumping caused by wind erosion could be observed through reading the mm-values above or under the zero sign of the rods placed on the parcels.

Wind Erosion Prediction System (WEPS)

Wind erosion prediction system (weps) is a process-based daily time step model that simulates weather and field conditions Hagen et al. (1995). Calculations for single events were made with the weps erosion submodel. The erosion submodel decides if erosion can occur based on current surface roughness, quantity of flat and standing biomass, aggregate size distribution, crust and rock cover, loose erodible material on a crust and soil wetness. If the surface conditions are susceptible and wind speed is above the threshold, erosion is computed on sub-hourly basis Hagen (1995). The step in the simulation procedure are as follows: the erosion submodel determines static threshold friction velocity at which erosion begins for each cell. The threshold is calculated based on surface conditions of: random and oriented roughness, flat biomass, crust, and rock cover, cover of loose, erodible aggregates on the crust, aggregate size distribution and density of uncrusted surface, and surface wetness. Soil loss and deposition are calculated for sub hourly periods when friction velocity exceeds the static friction velocity threshold. To aid in evaluation of off-site impact, the soil loss is subdivided into components and reported as saltation/creep, total suspension, and fine particulate matter (PM-10) for each grid cell. Hagen, (1997). Constant input data are the dimension of the simulated area, soil texture and derived properties such as aggregate size distribution and aggregate stability. Event based inputs are soil surface conditions like roughness, crusts and measured data of average wind speed as well as the average wind direction of the day.

[1] Department of Soil, Faculty of Agriculture, Aleppo University; Tel.: 00 963 (41) 418-392; Fax: 00 963 (41) 210-170; E-mail: m-dikkeh@scs-net.org

Results

Three erosion events were measured, soil-material were collected from the soil traps and read the mm-values on the measuring rod after each storm. In table 2. shown the weather data

We calculated the blown soil mass with the following:

$$V = h \times s$$

Where:

V= blown-out material m^3

h= depth of blow out in soil m

s= size of area m^2

The readings made on the measuring rod were used in the above mentioned formula, and gave the amount of the blown away soil, which happened to be the following:

14.04.1988 59.32 m^3/ha (within a duration of 10 hours)
15.04.1988 55.50 m^3/ha (" " " 20 ")
15.04 1988 28.00 m^3/ha (" " " 3.5 ")

Figures 1, 2, display the micromorfological status of the experimental area after soil blowing.
The comparison between measured and simulated soil losses by WEPS, in the following:

Measured m^3/ha	Simulated m^3/h
59.32	61.51
55.50	48.90
28.00	25.45

Table 1. Soil mechanical and chemical analysis

K_A	hy_1	pH		$CaCO_3$	Humus	N	Mechanical fraction mm% (2)					
		H_2O	KCL	%	% (1)	%	>1	1-0,63	0,63–0,32	0,32–0,2	0,2–0,1	<0,1
26	0,23	8,04	7,82	2,66	1,14	0,66	0,2	0,3	4,3	19,7	67,1	8,4

Table: 2. Weather data

Date												
1988	1	2	3	4	5	6	7	8	9	10	11	12
04. 14.	18,7	20,9	19,0	20,3	17,4	18,9	16,5	20,5	24,3	21,7	18,1	16,5
04. 15.	15,3	9,1	10,9	8,8	10,9	10,0	12,7	18,0	20,8	21,9	20,9	16,7
1988.	13	14	15	16	17	18	19	20	21	22	23	24
04. 14.	17,6	17,5	17,6	18,1	19,3	19,8	20,8	15,6	12,6	11,8	11,2	8,8
04. 15.	18,1	15,9	14,0	13,8	16,1	12,8	6,7	2,6	4,9	4,7	4,7	4,7

	April 14.	April 15.
Max.windspeed m/s (3)	12,6	8,8
Average windspeed m/s (4)	4,9	3,4
Average temperature C° (5)	7,0	4,7
Humidity % (6)	62	51

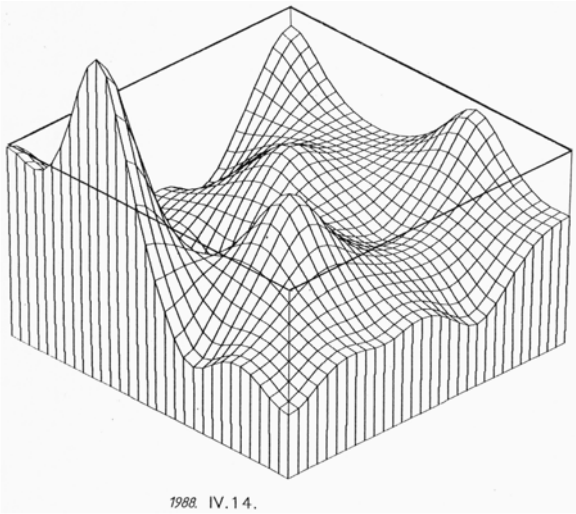


Figure 1. The micromorfological status of the area after soil blowing.

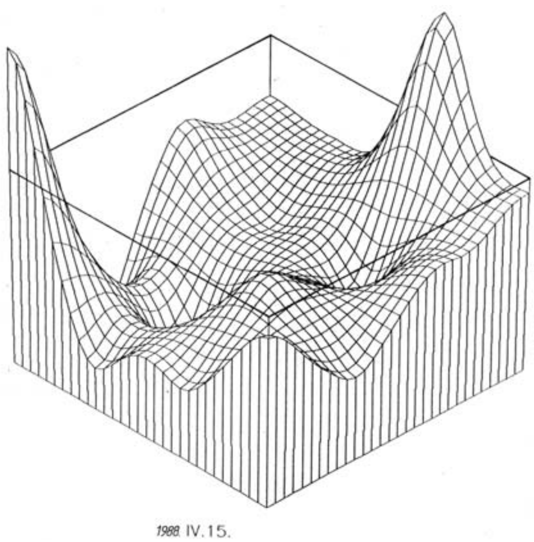


Figure 2. The micromorfological status of the area after soil blowing

References

Bagnold, R.A. (1941): The physics of blown sand and desert dunes. Methuen, London.

Bodolayne. (1965): A szélerózió befolyásoló változó talajfizikai tulajdonságok. Agrokémia és talajtan. 15: 372-383.

Borsy, Z. (1974): A futóhomok mozgásának törvényszerűségei és szélerózió elleni védekezés. Doktori értekezés. Debrecen.

Chepil,W.S.-Woodruff, N.P(1963): The physics of wind erosion and its control. Adv. Agron. 15:211-302

Dikkeh, M.(1990): Measuring soil losses due to wind erosion at Jakabszállás. Noveny Termeles, Tom.39.No.6, 559-567

Hagen, L.(1988): New wind erosion model developments in the USDA. Wind erosion conference. April 11-13.,104-118. Taxas

Hagen, L,J.(1997): Wind Erosion Prediction System: Erosion Submodel. www.weru.ksu.edu/symposium/proceed/hagen.pdf

Skidmore, E.(1988): Wind erosion. Soil erosion research methods. Soil Water Conservation Society, 203-233.

Skidmore, E.- Layton, J.B (1988): Soil measurements to estimate credibility by wind. Proceedings wind erosion conference. Lubbock. April. Taxas

Woodruff, N.P.- Siddoway, F. H (1965): A wind erosion equation. Soil. Sci. Soc. Am. Proc. 29:602-608.

Heavy metal contamination of urban soils: A case study (Nuoro/Sardinia, Italy)

Vacca S.[1] – Capra, G.F. – Muntau, H.W. – Loi, A. – Biagioli, M.

In recent years, systematic soil quality studies at national scale have been started with the aim to establish a nation-wide soil contamination map. In this context, the National Agency of Environmental Protection (APAT) and the Thematic Committee on Soil and Contaminated Sites published an informative dossier on soil contamination in a number of Italian provinces. Major conclusion of this study is that soil contamination in Italy does not exceed the variability margins at international level, while the number of contaminated sites amounts to over 10 500 on the basis of a study in the year 2000, having Sardinia occupying the seventh position at national scale with 410 contaminated sites.

The present study, performed at the city of Nuoro/Sardinia, focuses on metal contamination of urban soils, which for a number of reasons are seldom subjected to systematic screening analysis.

Soil surface samples have been taken in the proximity of roads at the city's traffic accumulation centers, as well as at public and private gardens, which represent in some way the geochemical metal background. The samples were analyzed for lead, cadmium, copper, zinc and nickel.

The results confirm severe soil contamination by lead and zinc in particular, correlated to traffic density. Concentration values of 810 mg/kg and 570 mg/kg, respectively, have been observed, as well as elevated concentrations of cadmium (50 mg/kg) and copper (330 mg/kg).

High positive correlation has been observed for lead and zinc (r^2=0,56) and for nickel and copper (r^2=0,54).

The observed concentrations leave a number of question marks with respect to human intoxication by inhalation of contaminated soil particles following to eolic transport in extremely dry climate conditions. Toxic effects on plants, trees in particular, may occur as well.

The metal concentrations measured were compared to the threshold values imposed by the Italian law (DM.of 25th October, 1999, no. 471) and the findings confirm the non-compliance of many samples with respect to the above mentioned law, as anticipated by the Urban Traffic Plan, established by the city of Nuoro in 2001.

All spatial and alphanumerical information was geo-referenced, creating a Geographical Information System, which allows verification and modification of the acquired data.

[1] University of Sassari, Department of Botany and Plant Ecology, Section of Pedology, Nuoro, Tel.: 0784/214948, Fax: 0784/205292, E-mail pedolnu@uniss.it

A contribution to the knowledge about anthropogenic soils on and in urban waste deposits

Vacca S.[1] – Capra, G.F. – Biagioli, M. – Muntau, H.W. – Buondonno, A. – Loi, A.

The research area, called "Tuccurutai", close to the city of Nuoro/Sardinia, was employed for city waste dumping from 1969-1990. Due to the lack of any kind of official registers there is little information available as to the contents and hence, the potential release of contaminants into the surrounding environment.

Profile studies reveal the presence of materials such as glass, metal scrap, ceramics, many types of plastic, textiles and paper. Non-degradable materials constitute a significant portion of the deposit's content.

An inevitable consequence of the latter aspect is the lack of pedogenetic development, which at present seems to be absent at all. During this study, however, the presence of a superficial A-horizon of little depth (0-30 cm) has been observed, the characteristics of which anyway confirm its very slow development due to the presence of remarkable quantities of un-degradable materials of anthropogenic origin along the profile.

Analysis of the mineral components (<2 mm), the more alterable part, shows their presence in all individual horizons hence, some hope for the future pedogenetic development of the soil.

From the taxonomic point of view, the soil has been classified as Garbic and Urbic Anthropic Regosoil (WRBSR, World Reference Base for Soil Resources, 1999), an anthropogeomorphic soil, the mineral and unconsolidated organic materials of which are of anthropogenic origin such as land fills, garbage deposits, dredgings and mining waste deposition, materials which in any case did not find the time needed for a meaningful expression to the pedogenetic process.

Analysis of metals (As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn) has shown that in almost all horizons total metal concentrations exceed the limits set by the actual national norms (DM 471/99). Cadmium, copper, lead and zinc in particular, were always found above national limits.

It must be stressed, however, that the acetic acid-soluble metal fractions were found in all cases at extremely low concentrations (µg/l), which means that at the time being the metals are present in immobile chemical forms, leaving any danger from metal dispersion from the deposit to the surroundings to the future. The risk for future environmental contamination from the deposit is enhanced by the fact that the pedogenetic characteristics of the soil, being deprived from clay minerals and humic substances, able to retain metal ions and complexes, indicate high soil permeability.

Element analysis (Si, Al, Fe, Ca, Mg, Na, K, Ti, Mn, P, Ba, Co, Cr, Cu, Ni, Pb, S, V, Zn) and subsequent correlation analysis revealed a number of strong correlations (r of Pearson), such as Fe-Ca (r^2=0,86), Mg-Na (r^2=0,90), Ni-Pb (r^2=0,84), which are pointing towards the common sources of these elements in the deposit, such as pigments, metal scrap, glasses etc., and might also allow some predictions for the future developments inside the deposit and connected element release. More detailed data analysis by multivariate analysis shall offer information in this respect.

A first orientative analysis for organic persistent pollutants showed no significant results with the exception of the inferior horizons, where aliphatic and polycyclic aromatic hydrocarbons have been encountered

References

IUSS, ISRIC, FAO, ISSDS, 1999 – World Reference Base for Soil Resources, ISSDS, Firenze.

VACCA S., CAPRA G. F., BIAGIOLI M., MUNTAU H. W., BUONDONNO A., 2003 – Caratterizzazione di suoli antropogenici di discarica: il caso della discarica di R.S.U. della città di Nuoro, Convegno della Società Italiana delle Scienze del Suolo, Sezione Poster, Siena.

[1] University of Sassari, Department of Botany and Plant Ecology, Section of Pedology, Nuoro, Tel.: 0784/214948, Fax: 0784/205292, E-mail pedolnu@uniss.it