SOIL REVITALIZATION

Global Policy Draft & Solutions Handbook

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Introduction

Global warming, pollution, deforestation – these are all well-known aspects of the environmental crisis that we face right now. Yet, very few have noticed the elephant in the room: soil degradation. This is the most immediate challenge before us. All terrestrial life, including ours, is sustained by just a few inches of topsoil. For the extremely fragile life that we are, our actions have been too reckless and whimsical, raining unprecedented damage upon this precious resource.

According to the United Nations (UN), we may have only 60 years of cultivable soil left. We are losing one acre of fertile soil every second. This means in the near future, agriculture will not yield sufficient food for human populations. We are quietly but surely speeding towards disastrous famines on a global scale.

The good news is that we can reverse this catastrophe if we act now. Conscious Planet's Save Soil Movement is an effort to awaken citizens around the world to the state of soil, and urge their governments to frame and execute the necessary policies to regenerate soil.

This book seeks to offer practical, scientific solutions that governments can put into action to revitalize the soil in their nation. Please note, this is a sincere effort to develop a policy for soil regeneration on the planet, based on soil types, latitudinal positions, and agricultural traditions of a given nation. It is a draft soil policy document which is subject to various inputs from scientists. Anyone who is knowledgeable in this field is most welcome to send any contributions they may have to enrich the soil policy. All such inputs will definitely be considered. Please feel free to email your contributions to info@consciousplanet.org.

In Chapter 1, we delve into how soil degradation has happened and the ramifications for ecology and human society. Chapter 2 briefly covers the components of soil biology and explains how the fundamental solution to revitalizing soil is to bring back its organic content. We also look at the principles of sustainable soil management practices. In Chapter 3, we assess current policy ecosystems and provide policy recommendations to revitalize soil. Lastly, Chapter 4 details Conscious Planet's approach to sustainable soil management solutions based on agroecological zones and soil types for various regions of the world.

Healthy soil is the right of our future generations. A global concerted effort is the need of the hour to save soil. Let us make it happen.

CHAPTER 1: Why Soil and Why Now?

It is common knowledge today that human behavior has altered the environment on a planetary scale. In the pursuit of making our lives easier through technological advancements, we began obliterating the very basis of all our comforts: nature itself. We are pushing the limits of our natural resources and systems – soil, water, and air; we are living in opposition to the natural systems that provide for our existence. It is time to wake up to the fact that we are axing the tree branch on which we are precariously seated.

To reverse this ecological degradation that we have unleashed, and restore the planet for future generations, we must turn to the soil.

Soil is at the center of the natural systems and cycles of our planet. Unfortunately, this critical resource is undergoing tremendous damage across the world. According to the most recent Food and Agriculture Organization (FAO) report, "The State of the World's Land and Water Resources for Food and Agriculture (SOLAW)", 2021, there has been an alarming trend of land resource exploitation.[1] Fifty-two percent of the world's agricultural land is already degraded.[2] If current trends are not arrested, 90% of the Earth's land surface could be degraded by 2050.[3] Considering that 95% of the food we eat comes from land,[4] and that 87% of the planet's biomass is land-based,[5] the ongoing destruction of soil holds truly terrifying implications for life on Earth.

1.1 Agriculture – The Problem and Solution for Soil

One does not have to look far to find the primary driver of global land degradation. It is on our plates!

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1. *The State of the World's Land and Water Resources for Food and Agriculture (SOLAW).* (2021). Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/land-water/solaw2021/en/

2. Stewart, N., & Etter, H. (eds.). (2015). Report for policy and decision makers: Reaping economic and environmental benefits from sustainable land management. *Economics of Land Degradation (ELD) Initiative.* http://www.eld-initiative.org/fileadmin/pdf/ELD-pm-report_08_web_72dpi.pdf

3. *World Soil Day 2020: Keep soil alive, protect biodiversity.* United Nations Convention to Combat Desertification (UNCCD). https://www.unccd.int/news-events/world-soil-day-2020-keep-soil-alive-protect-biodiversity

4. *Global Symposium on Soil Erosion: Key Messages.* Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/about/meetings/soil-erosion-symposium/key-messages/en/

5. Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. *PNAS, 115*(25). https://www.pnas.org/content/115/25/6506

Half of the world's soil can be found in agricultural lands, and the rest is in uncultivable lands in mountains, deserts, etc. By and large, the deteriorating state of soil that we see today is a result of the conventional agriculture that is prevalent throughout the world. The present systems of farming and food systems often treat soil as an inert material upon which agricultural activity – growing crops and fodder, and animal rearing – is practiced. This system of farming refuses to recognize the living ecosystems that inhabit soil in the form of microbes, bacteria, fungi, nematodes, vertebrates, mites, earthworms, arthropods, birds, etc. and which interact symbiotically with plant life that grows on the soil.

This failure to acknowledge soil ecosystems has exacerbated the condition of soils across the world. While there are many facets to soil degradation, one of the most important ones is the measure of Soil Organic Matter (SOM).[6]

1.2 Soil Organic Matter

Soil Organic Matter can be defined as "any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process."[7] The signs of declining SOM and strain on the soil ecosystems include: reduction or stagnation of crop yields, desertification of lands, reduced water holding capacity, reduced nutritive value of produce grown on these soils, and increased contribution of these lands to global warming through accelerated carbon dioxide release.

Sufficient SOM is key to ensuring healthy soil as it preserves the soil's life-sustaining physicochemical properties and structure. Healthy soil, in turn, is central to correcting ecological damage which is a consequence of human activity. In the following sections, we look deeper into the ramifications of soil degradation, both in terms of ecology and humanitarian crises, and how increasing SOM can counter them. These ramifications include: hunger, nutritional poverty, water scarcity, climate change, biodiversity loss and unrest in society.

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6. Obalum, S. E., Chibuike, G. U., Peth, S., & Ouyang, Y. (2017). Soil organic matter as sole indicator of soil degradation. *Environmental Monitoring and Assessment, 189*, 176. https://doi.org/10.1007/s10661-017-5881-y

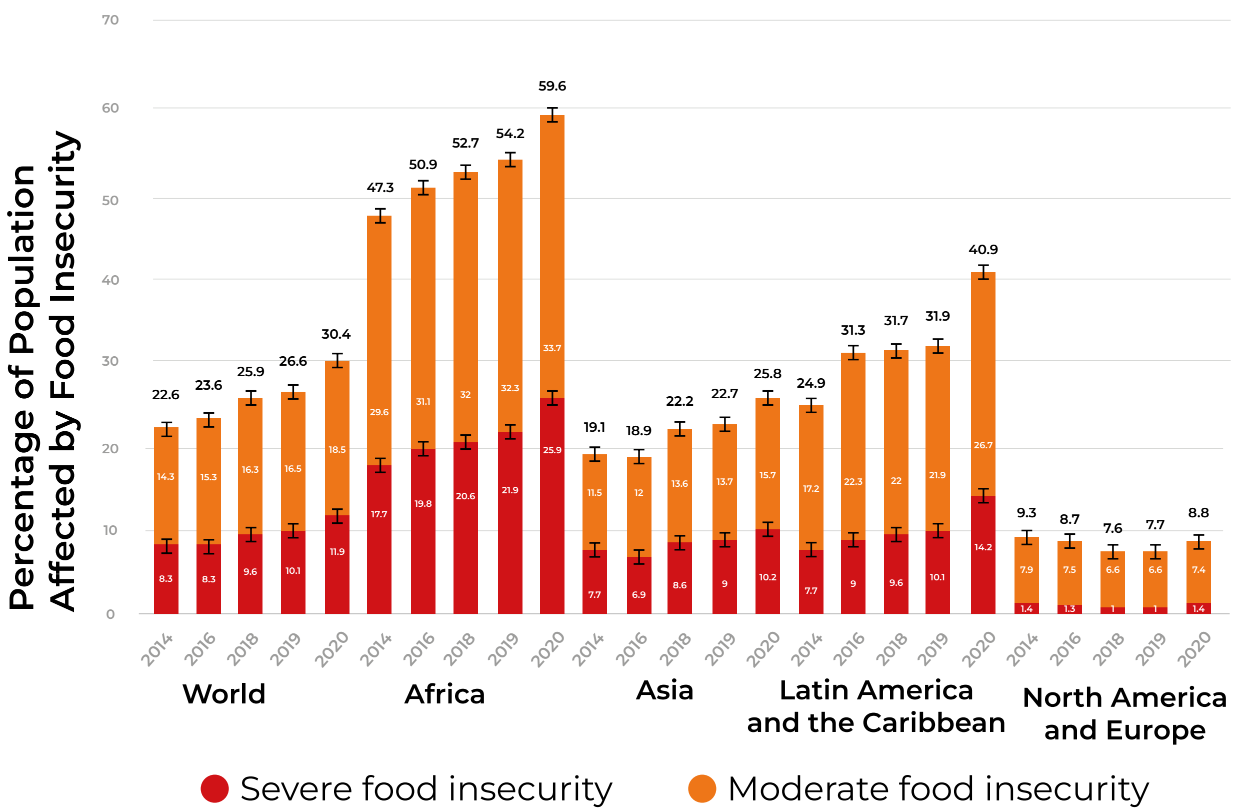
7. Bot, A., & Benites, J. (2005). The importance of soil organic matter: Key to drought-resistant soil and sustained food production. *Food and Agriculture Organization of the United Nations (FAO).* https://www.fao.org/3/a0100e/a0100e04.htm

1.3 Hunger

According to the HungerMapLIVE, the World Food Programme's Hunger monitoring platform, as of January 27, 2022, there are 826 million people across 92 countries who do not have access to sufficient food.[8] The future continues to look bleak. According to the FAO's "The State of Food Security and Nutrition in the World (SOFI)", 2021, there will be 660 million people hungry in 2030, falling woefully short of the goal to eliminate world hunger by 2030.

Moderate or severe food insecurity at the global level has gradually risen between 2014 and 2020, and affects more than 30% of humanity. Figure 1 shows the rise in food insecurity in various regions of the world.

Figure 1: Food Insecurity Index[9]

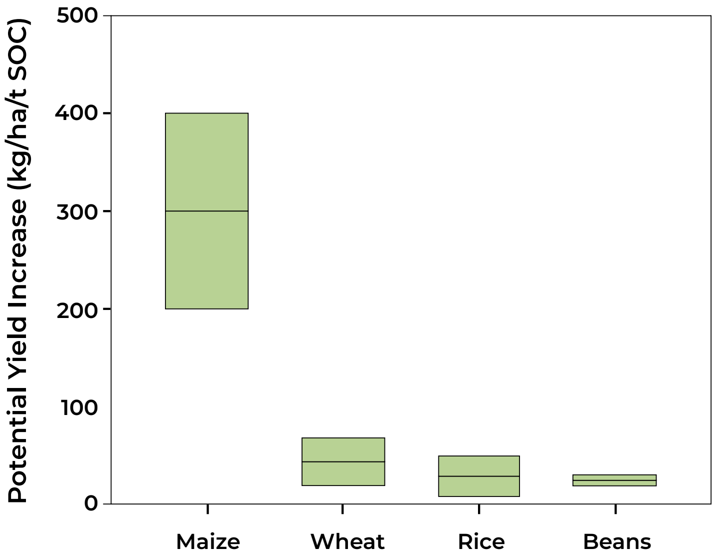


8. *HUNGERMAP: Global insights and key trends.* (2022). https://static.hungermapdata.org/insight-reports/latest/global-summary.pdf

9. *The State of Food Security and Nutrition in the World (SOFI)*. Food and Agriculture Organization of the United Nations (FAO). (2021). https://www.fao.org/state-of-food-security-nutrition

If soils are healthy, with a good amount of SOM, it not only increases soil fertility and therefore crop yields (Figure 2), but also makes crops more resilient to climate shocks. This can, in turn, play a huge role in tackling world hunger. The positive correlation between SOM and crop yields and the health of the farm has been well established by experts. In fact, at the Conference of the Parties (COP) held in 2019, the United Nations Convention to Combat Desertification (UNCCD) urged that soil organic carbon (SOC) be conserved to combat desertification.[10]

Figure 2: Potential yield increase per tonne SOC for each crop species (maize, wheat, rice and beans).[11]



1.4 Nutritional Poverty – Malnourishment

Malnutrition, in all its forms, includes undernutrition (wasting, stunting, underweight), inadequate vitamins or minerals, overweight, obesity, and resulting diet-related noncommunicable diseases. According to the World Health Organization (WHO), almost one in three people in the world suffered malnutrition in 2017.[12]

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10. *UN urges soil organic carbon conservation to fight desertification.* Sci Dev Net. (2019). scidev.net/asia-pacific/news/un-urges-soil-organic-carbon-conservation-to-fight-desertification/

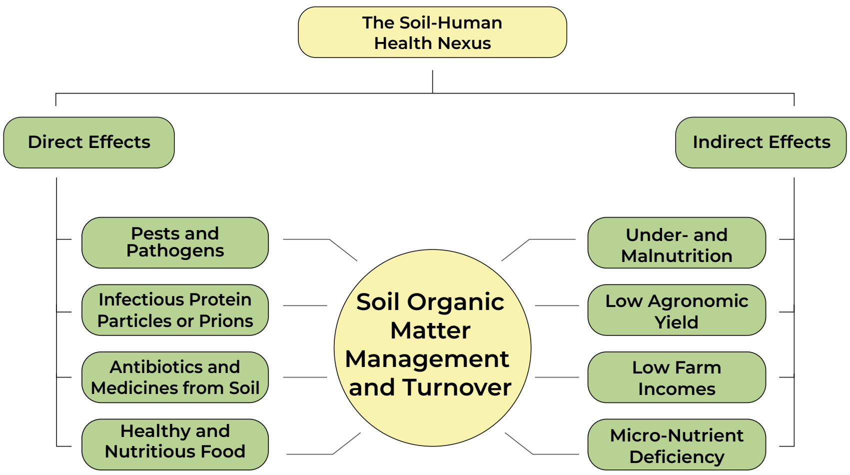
11. Lal, R. (2011). Sequestering carbon in soils of agro-ecosystems. *Food Policy, 36*(1), S33–S39. https://doi.org/10.1016/j.foodpol.2010.12.001

12. *The double burden of malnutrition: Policy brief.* World Health Organization (WHO). (2017). https://www.who.int/publications/i/item/WHO-NMH-NHD-17.3

One significant reason for this malnourishment is that food itself lacks sufficient nutrients. Deficiency of micronutrients in degraded soil, which takes place due to the depletion of SOM, is an important factor impacting human health.[13] A study in the United States found that compared to the early 20th century, levels of calcium, magnesium and iron in vegetables like cabbage, lettuce, spinach and tomatoes have reduced by 80–90%.[14] A similar study that analyzed twenty vegetables in the United Kingdom found that on average, calcium levels had declined by 19%, iron by 22% and potassium by 14%.[15] There exist similar findings for India as well,[16] indicating that this is a global phenomenon.

According to numerous studies, there is a positive correlation between SOM and nutrient supply systems of soil. Even to ensure the effective uptake of fertilizers applied to the soil from outside, SOM plays a critical role. Thus, increase in SOM leads to reduction in risk of nutritional poverty (Figure 3).

Figure 3: Direct and indirect effects of soil health on human health through SOM management and turnover.[17]



13. Lal, R. (2009). Soil degradation as a reason for inadequate human nutrition. *Food Security, 1(1),* 45–57. https://doi.org/10.1007/s12571-009-0009-z

14. Workinger, J. L., Doyle, R. P., & Bortz, J. (2018). Challenges in the diagnosis of magnesium status. *Nutrients.* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6163803/

15. Mayer, A. M. (1997). Historical changes in the mineral content of fruits and vegetables. *British Food Journal, 99*(6), 207–211. https://www.emerald.com/insight/content/doi/10.1108/00070709710181540/full/html

16. Kukreti, I. (2017). Protein levels are rapidly declining in all foods in India. *Down To Earth.* www.downtoearth.org.in/news/food/protein-levels-are-rapidly-declining-in-all-foods-in-india-58121

17. Lal, R. (ed.). (2020). *The Soil-Human Health-Nexus.* CRC Press.

1.5 Water Scarcity

Global freshwater resources are under pressure. Water stress is high across all basins that are intensely irrigated and densely populated. While Europe faces low levels of water stress[18] at 8.3%, East Asia, Western Asia, Central & South Asia, and Northern Africa face stress levels of 45%, 70%, more than 70% and above 100%, respectively. The rate of withdrawal is greater than the rate of replenishment in many basins. If this continues, water scarcity in the world will become even more severe. This will multiply the pressure on existing resources.

It has been proven that an increase in SOM leads to increased porosity of soil. These pores act as storage space for water to be held in the soil. This water is then readily available to plants and microbes in the soil.[19] Although this sounds simple, to understand the enormity of this process, we must keep in mind that water stored in the soil meets about 90% of the water demand for global agricultural production.[20,21] According to Jehangir *et al.*, increasing SOM by just 1% can increase soil's water holding capacity by up to 20,000 gallons per acre.[22]

Adding to the stress of water scarcity is the pollution of freshwater bodies due to agricultural chemicals used by conventional practices – in the form of fertilizers, pesticides, livestock pharmaceuticals, plastics, etc. that run off from farms. Of the total pollution of water bodies, agricultural water pollution in the form of agricultural effluents contributes 56%, amounting to 1260 km^3 a year.

Soil can act as a significant filter of water-borne pollutants. The pores of the soil act like any other physical filtration material. Additionally, when soil is rich with organic matter, the soil biota decompose the chemicals and contaminants that enter the

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18. Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use.

19. Rabot, E., Wiesmeier, M., Schlüter, S., & Vogel, H.-J. (2018). Soil structure as an indicator of soil functions: A Review. *Geoderma, 314*, 122–137. https://doi.org/10.1016/j.geoderma.2017.11.009

20. Sposito, G. (2013). Green Water and Global Food Security. *Vadose Zone Journal, 12*(4). https://doi.org/10.2136/vzj2013.02.0041

21. Kim, Y. J., Jung, J. Y., & Mishra, U. (2021). Managing soil organic carbon for climate change mitigation and food security. *Soil Organic Carbon and Feeding the Future*, 25–46. https://doi.org/10.1201/9781003243090-2

22. Bhadha, J. H., Capasso, J. M., Khatiwada, R., Swanson, S., & LaBorde, C. (2017). Raising soil organic matter content to improve water holding capacity. *EDIS*. https://doi.org/10.32473/edis-ss661-2017

soil through excessive use of fertilizers or other chemicals.[23] Therefore, the solution to address water pollution from agricultural sources lies in increasing SOM.

1.6 Climate Change

While fossil fuels are consistently blamed for climate change, very rarely is the role of agriculture acknowledged. Around a third of the greenhouse gas emissions since 1850 can be directly attributed to changes in land use on the planet.[24]

Around 133 gigatons of carbon (GtC) have been emitted into the atmosphere since the dawn of agriculture via loss of SOM and soil erosion,[25, 26, 27] and 379 GtC through forest clearing and burning.[28, 29] In general, 50–70% of soil carbon stocks in cultivated soil have been lost.[30] Agricultural fields today often contain less than 2% SOM,[31] whereas SOM in grasslands or forests usually amounts to 8–15% or even more. This reflects the potential of soils under agriculture. On the other hand, if the soils of the world are not revitalized, global warming could cause 230 billion tonnes of carbon

23. Day, M. (2015). Want clean water? Filter with soil. *Michigan State University Extension.* https://www.canr.msu.edu/news/want_clean_water_filter_with_soil

24. *Putting carbon back where it belongs – the potential of carbon sequestration in the soil.* Foresight. United Nations Environment Programme. (2019). https://wedocs.unep.org/bitstream/handle/20.500.11822/28453/Foresight013.pdf

25. Lal, R. (2018). Digging deeper: A holistic perspective of factors affecting soil organic carbon sequestration in Agroecosystems. *Global Change Biology, 24*(8), 3285–3301. https://doi.org/10.1111/gcb.14054

26. Sanderman, J., Hengl, T., & Fiske, G. J. (2018) Soil carbon debt of 12,000 years of human land use. *Proceedings of the National Academy of Sciences, 114*(36), 9575–9580. https://www.pnas.org/content/114/36/9575

27. Teague, W. R., Apfelbaum, S., Lal, R., Kreuter, U. P., Rowntree, J., Davies, C. A., Conser, R., Rasmussen, M., Hatfield, J., Wang, T., Wang, F., & Byck, P. (2016). The role of ruminants in reducing agriculture's carbon footprint in North America. *Journal of Soil and Water Conservation, 71*(2), 156–164. https://doi.org/10.2489/jswc.71.2.156

28. Zomer, R. J., Bossio, D. A., Sommer, R., & Verchot, L. V. (2017). Global sequestration potential of increased organic carbon in cropland soils. *Scientific Reports,* 7(1), 15554. https://doi.org/10.1038/s41598-017-15794-8

29. Machmuller, M. B., Kramer, M. G., Cyle, T. K., Hill, N., Hancock, D., & Thompson, A. (2015). Emerging land use practices rapidly increase soil organic matter. *Nature Communications,* 6(1), 6995. https://doi.org/10.1038/ncomms7995

30. Zomer, R. J., Bossio, D. A., Sommer, R., & Verchot, L. V. (2017). Global sequestration potential of increased organic carbon in cropland soils. *Scientific Reports,* 7(1), 15554. https://doi.org/10.1038/s41598-017-15794-8

31. Beste, A. (2018). What is Europe's agriculture doing to the soil. *Agricultural and Rural Convention.* https://www.arc2020.eu/andrea-beste-soil-matters/

dioxide to be released into the atmosphere due to carbon loss from heating of the soil. This is more than all of humanity's emissions in the last 30 years combined.[32]

1.7 Biodiversity

The larger ecosystems across water and land have been under threat for many generations now. In this context, how we treat agricultural soil is significant as 87% of biomass on the planet is terrestrial.[33] Alarmingly, every year we are losing 27,000 species from the soil habitat in the tropics alone.[34] It is well proven that the two major factors for the loss in biodiversity are loss of SOM and intensive exploitation by humans.[35]

1.8 Peaceful Society

There are over 688 million people who live in abject poverty, 75% of whom come from rural areas with agriculture as their occupation. Their livelihoods depend on the quality of soil. If soil continues to degrade, then the number of people in abject poverty will only rise.[36]

In an advanced and developed economy like the European Union, a farmer on an average earns only half of what can be earned through other jobs.[37] This is leading to fewer younger people taking up agriculture in Europe. Less than 15% of EU farmers fall into the bracket of 35–44 years of age and this percentage is only decreasing.[38] Similar trends can be observed in poor African, Asian and Middle-Eastern farming

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32. *Warming of 2°C would release billions of tons of soil carbon.* Science Daily (2020). https://www.sciencedaily.com/releases/2020/11/201102072915.htm

33. Bar-On, Y. M., Phillips, R., & Milo, R. (2018). The biomass distribution on Earth. *PNAS.* https://www.pnas.org/content/115/25/6506

34. Wilson, E. O. (1999). *The Diversity of Life.* W.W. Norton & Company.

35. Larbodière, L., Davies, J., Schmidt, R., Magero, C., Vidal, A., Arroyo Schnell, A., Bucher, P., Maginnis, S., Cox, N., Hasinger, O., Abhilash, P. C., Conner, N., Westerburg, V., & Costa, L. (2020). Common ground: Restoring land health for sustainable agriculture. *IUCN*. https://doi.org/10.2305/iucn.ch.2020.10.en

36. Bourguignon, F., & Bussolo, M. (2013). Income distribution in computable general equilibrium modeling. *Handbook of Computable General Equilibrium Modeling, 1*, 1383–1437. https://doi.org/10.1016/b978-0-444-59568-3.00021-3

37. *CAP Specific Objectives – Ensuring viable farm income*. European Commission. (2018). https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/cap_specific_objectives_-_brief_1_-_ensuring_viable_farm_income.pdf

38. *CAP Specific Objectives – Structural change and generational renewal.* European Commission. (2019). https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/cap-briefs-7-structural-change_en.pdf

communities. In short, no farmer's child wants to be a farmer in much of the world. The present farming practices, the risks associated with agriculture, and the incomes do not present a sensible means of livelihood for anyone. If this continues, one has to wonder, who will feed the world a few decades from now?

Furthermore, degraded soils are forcing an exodus from rural areas to cities, putting higher pressure on urban areas. According to a report published by the Institute for Economics and Peace, 1 billion people living in vulnerable areas of sub-Saharan Africa, Central Asia and the Middle East may be forced to migrate by 2050.[39]

Improving SOM can provide an effective solution in securing the livelihoods of the vast majority of the world's poor, preventing mass migrations and the security repercussions that follow, and is key to establishing a peaceful and thriving human society.

1.9 SOM and Sustainable Development Goals

The areas of concern listed in this chapter are incorporated, along with other factors, into the seventeen UN Sustainable Development Goals (SDGs). The SDGs provide "a shared blueprint for peace and prosperity for people and the planet, now and into the future."[40] Increasing SOM and revitalizing soil will address four SDGs directly and eight indirectly. These are presented in Figure 4.

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39. Baker, L. (2020). More than 1 billion people face displacement by 2050 – Report. *Reuters.* https://www.reuters.com/article/ecology-global-risks-idUSKBN2600K4

40. *Sustainable Development Goals.* Department of Economic and Social Affairs, Sustainable Development. United Nations. https://sdgs.un.org/goals

Figure 4: Increasing SOM and revitalizing soil addresses (a) four SDGs directly, and (b) eight SDGs indirectly.

(a) SDGs directly addressed

(b) SDGs indirectly addressed

CHAPTER 2: Revitalizing Soil – The Principal Solution

2.1 Soil Diversity

Soil is a naturally occurring three-dimensional body that has been formed due to the combined influence of climate and living organisms acting on parent rock material, as conditioned by the terrain over a period of time.

Just as the inception, development and adaptations of plants and animals are a product of the environment, similarly, a particular soil profile is a product of the climate, rock and vegetation. As there is considerable variety in climate, organisms, parent rock and terrain, their combinations number in the thousands. For example, in the United States alone, there are 14,000–15,000 different soils,[1] known technically as "soil series."

For ease of study, research and management, the thousands of different soils in the world are categorized in a soil taxonomy pyramid with the broadest level of categorization being "soil order." In the past, various systems of soil classification were followed across the world by organizations such as the USDA and FAO. In 2015, they were unified under one system of classification, the World Reference Base (WRB). In this publication we have adhered to the WRB's system of soil classification with 34 groupings of different soil types.

2.2 Agriculture Based on Soil Type

Any external intervention affects the equilibrium of the soil ecosystem. It is thus important that farmers understand the delicate balance of their soil ecosystem before they work with the soil. Soil cannot be viewed as just a mere medium that supports plants, and we cannot claim one common prescription for cultivating the numerous soil types. In fact, the rapid deterioration found in the world's soils today is a consequence of not taking into consideration the diversity and the unique equilibrium of each soil type.

The majority of current conventional agricultural practices do not produce optimal results because they are not calibrated for the specific soil profile of the land. Instead, blanket interventions are applied. For example, two farmers use the same nutritional supplements though their crops and soil types are very different; or some farmers

1. Smith, G., (2003) The Guy Smith Interviews: Rationale for concepts in Soil Taxonomy. *National Soil Survey Center, Natural Resources Conservation Service, U.S. Department of Agriculture*. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_051535.pdf

overutilize fertilizers while others underutilize for a given soil type. These blanket approaches have contributed to the large-scale failure of agriculture that we are seeing today.

Calibrating agricultural practices for a specific soil type depends on various attributes of the soil. A detailed analysis of how each component of a soil type influences what agricultural practices are applicable to it would run into hundreds of pages. The Conscious Planet team has collated and cataloged successful country-specific Sustainable Soil Management (SSM) practices from around the world, which stem from an understanding of each country's specific soil types and its thermal climatic zone. These can be found on our website: savesoil.org.

However, regardless of the complexity of each soil type, when it comes to soil productivity, the answer largely boils down to SOM as a common factor. Therefore, in this publication, we will focus on how to increase SOM in agricultural lands. If we have to achieve this, we must first understand a little more about what SOM is.

2.3 Humus

One of the main components of SOM is humus. Humus is organic matter that is the result of a food chain, in which a series of organisms feed on dead plant and animal residue. Humus and weathered rock form the solid portion of the soil. Together they form a clay-humus complex, or a bond between clay particles and humus, which is not easily broken down, as it is not so reactive with other compounds. Therefore, humus is one of the most stable forms of organic matter.

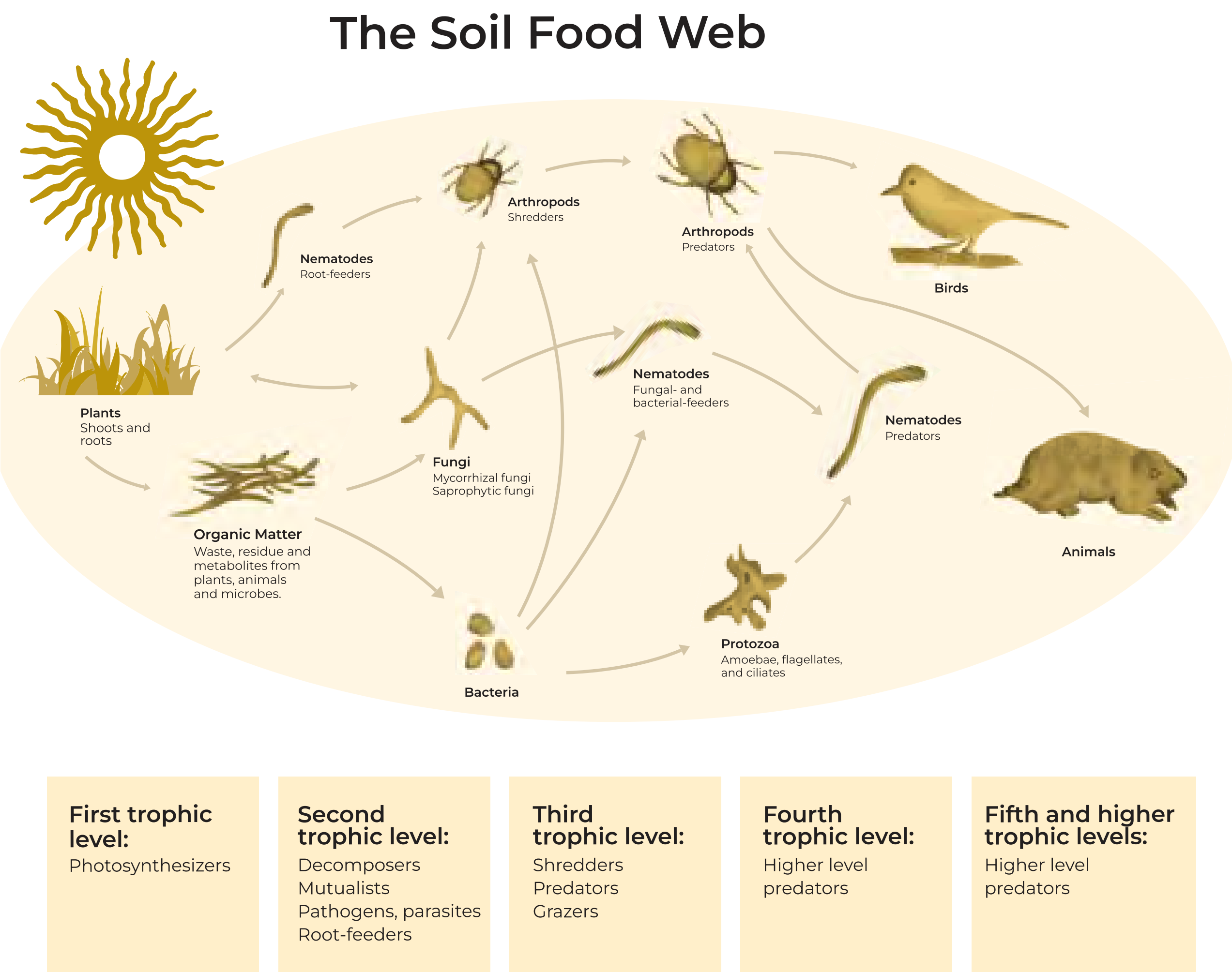
When there is sufficient humus, the soil will be porous in structure, which means there are numerous air pockets. These allow plant roots to easily grow. More humus also increases the soil's ability to absorb and retain water. Humus is also a vital source of nutrients for plants. Thus, increasing SOM is an integral part of soil health and sustainable agriculture.

2.4 The Soil Food Web

Soil organic matter is inextricably linked to the soil biome. Soil biology comprises macrofauna like moles, spiders and earthworms; plant roots; and microorganisms like bacteria, amoebae and fungi. These soil organisms are important not only as individual species but also in terms of how they interact with each other. As with any other food chain, these interactions are not linear. Rather, they are a complex web, which Dr. Elaine Ingham, a pioneer researcher in soil biodiversity, describes as "the soil food web". This is depicted in Figure 1.

When in balance, organisms interact with each other and create a thriving ecosystem. Before the advent of fertilizers, for millions of years, these organisms supplied the nutrients that plants needed.

Figure 1: Relationships between microbes, plants, organic matter, and birds and mammals. (Source: USDA Natural Resources Conservation Service[2])



2. Ingham, E. R. (n.d.) Soil Food Web. *Natural Resources Conservation Service. United States Department of Agriculture.* https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/biology/?cid=nrcs142p2_053868

Macrofauna, through their movement and the network of underground galleries, help aerate the soil, increase water percolation and recycling of insoluble and soluble chemicals. They also ensure that soil of various depths mixes well, thereby making mineral nutrients from deeper layers of soil accessible to plant roots. Their excrement is also an important source of nutrients for plants.

Plant roots penetrate the soil, open up its compact structure, and secrete exudates.[3] These exudates serve as food for microorganisms and are essential for healthy soil with a diverse microbial population. The plants produce these exudates through the process of photosynthesis.

Microorganisms in the soil are of various kinds. They receive food, directly or indirectly, from plant roots, and in turn make nutrients available to plants in a form that plants can consume. These microorganisms collectively self-regulate their populations based on the type of plant life growing in the soil. Together they form a dynamic soil biome.

Bacteria constitute the most varied and numerous group among the microorganisms. Some bacteria feed on mineral matter in the soil, while others feed on organic matter. In the process, they transform the chemistry of the soil, and make mineral nutrients available to plants. Without the bacteria, plants would not be able to absorb the minerals they need from the soil. Other types of bacteria feed on nitrogen in the atmosphere and fix it into nitrogen compounds in the soil (nitrates), which are then absorbed by plants. There are even bacteria that perform photosynthesis.

Bacteria are the first organisms to consume organic matter. For example, when a blade of grass falls on the ground, the bacteria break down the cellulose fiber of the grass. The cellulose gets converted into lignin fibers which remain within the bacterial cells. The bacteria are in turn eaten by amoebae, and the lignin fibers are set free.

3. Root exudates refer to a suite of substances in the rhizosphere that are secreted by the roots of living plants and microbially modified products of these substances. They consist of low-molecular-weight organic compounds that are freely and passively released root-cell material and mucilage associated with roots.

Fungi further break down the lignin fiber and form humus – an incredibly important constituent of fertile soil. Fungi also provide the physical support to hold soil particles together in their mycelium nets.[4] This ensures the structural stability of the soil.

Amoebae (protozoa) are the regulators of the microbial world, among the many other functions they perform. When there are too many bacteria in the soil, it becomes inhospitable for fungi. Amoebae keep the bacterial population in control and thus allow the fungi to function as well. A hectare of soil can contain around 100–300kg of protozoa.[5]

Actinomycetes are a specific category of bacteria which are intermediaries between fungi and other bacteria. They can secrete antibiotics like fungi and carry out biochemical reactions like other bacteria. They also contribute to the formation of humus, especially in the process of composting. The antibiotics they generate can pasteurize unwanted germs in the compost. They also mineralize organic matter, thus providing food for plants.

Algae live only on the surface of soil since they function through photosynthesis. They play the important role of fixing nitrogen into the soil.

2.5 Soil Organic Matter – A Single-Point Focus to Revive Soil

The present state of soil with its very poor SOM is the outcome of anthropogenic disturbance of the soil food web. The web is now broken and, as a consequence, there is large-scale soil degradation and erosion, and our food security and several other aspects are at stake.

The soil biome is sensitive to both heat and humidity. In conventional agriculture, the earth is opened wide with a plow, exposing the organisms. This leads to heating of the land and also loss of soil moisture through evaporation, which harms the soil food web. Additionally, the unbridled and injudicious use of fertilizers, herbicides and pesticides has destroyed some of the critical links in the soil food web.[6]

4. Mycelium is the vegetative part of a fungus or fungus-like bacterial colony, consisting of a mass of branching, thread-like hyphae.

5. Bourguignon, C. (2005). *Regenerating the Soil: From Agronomy to Agrology*. Other India Press.

6. Ingham, E. R., & Slaughter, M. D. (2004). The soil foodweb-soil and composts as living ecosystems. *First International Conference Soil and Compost Eco-Biology*. León, Spain.

There are many ways in which the soil biome can be restored. It may take a few months to a few years depending on the land management practices adopted, and how scientifically suitable it is to the crops being grown. As there are specific nutritional requirements for different crops, which are specified by a Package of Practices, there is also a specific soil biome composition for each crop. If one can catalyze the development of that specific soil biome, soil will be regenerated.

The Save Soil Movement of Conscious Planet is the culmination of 20 years of work with farmers, dealing with various levels of degraded lands. All of this experience points towards one thing: the only solution to address all the issues ailing agricultural soil in the world is to have a single point focus on increasing the Soil Organic Matter (SOM) to a minimum of 3–6%.

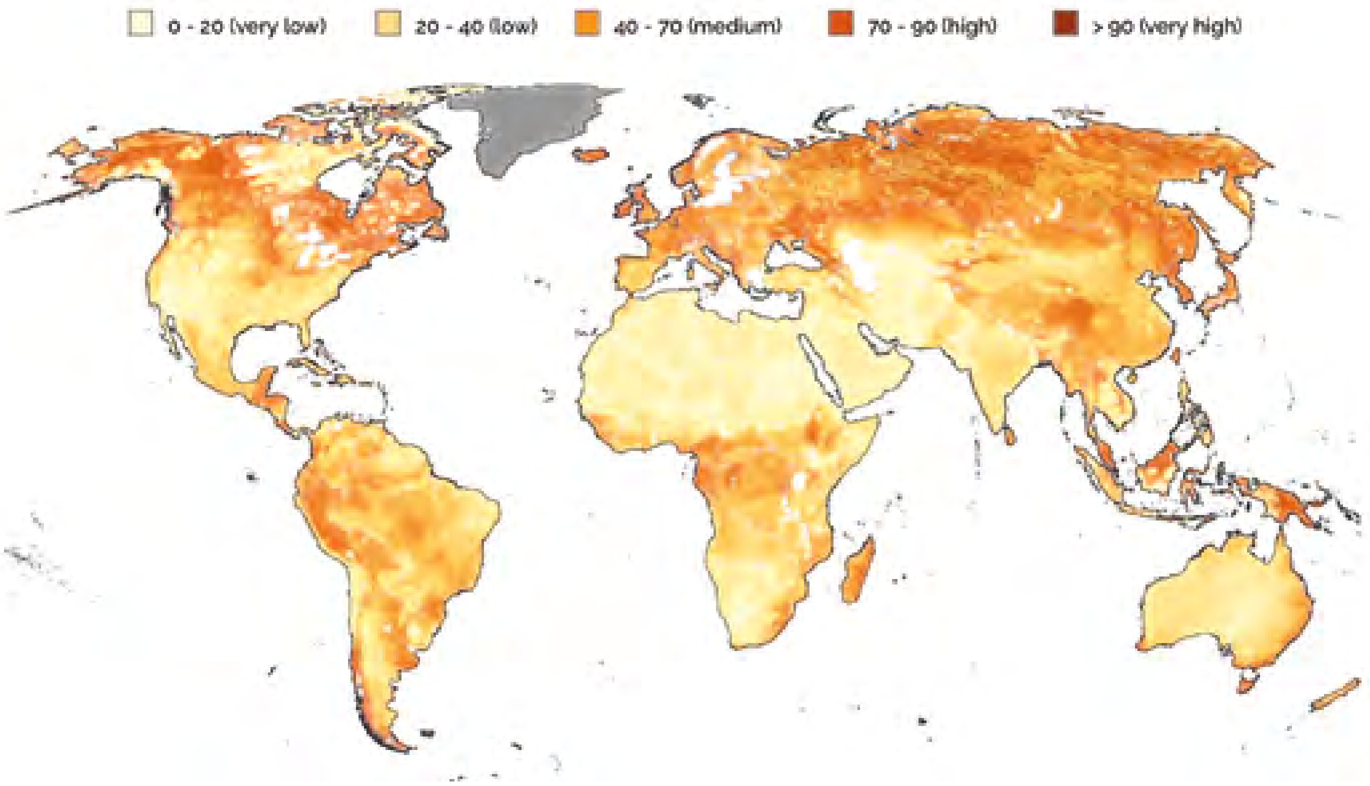
Although this solution may seem simplistic, increasing SOM will nourish soil biology and bring life back to the soil and, in the process, address soil degradation, soil erosion, water scarcity, climate change and the larger wellbeing of society. It is imperative that farmers are supported to adopt relevant sustainable soil management practices, like agroforestry and natural farming methods, that will improve SOM and soil fertility, as well as their own livelihood. Such practices will convert large swathes of degraded soil back into fertile soil by creating an environment for all soil life forms to thrive.

Soil testing labs are instrumental in helping farmers decide on the appropriate soil biology interventions in their lands. At present, soil testing predominantly tests the physical and chemical properties of the soil, not the soil biology. Soil testing labs run by governments across the world should also test for SOM, soil biological activity, the soil microbiome (bacteria, fungi, etc.). Farmers would need to test the biological parameters of their soil once every crop cycle to see the nutrient abstraction from crops grown and therefore assess the amount of organic matter and specific nutrients that need to be recycled back into the soil.

There are a few enterprises in the United States and India, which conduct soil biology tests for farmers. The testing can be conducted pre-harvest and post-harvest to assess the soil biology activity. These laboratory tests currently cost up to USD 200 per test. However, advances are being made with which field-testing kits in the market will be able to deliver results for less than USD 10 per test.

Map 1 shows the amount of Soil Organic Carbon (SOC)[7] across the globe. SOC and SOM are directly correlated, and it can be observed that most of the world's soil has less than 3% SOM.

Map 1: Global Soil Organic Carbon, 2019 (tonnes/ha)[8, 9]



2.6 Principles and Practices of Sustainable Soil Management

A number of agricultural practices have been found to be effective in improving SOM in farms across the world. Apart from the economic benefits that all these practices bring for farmers – better yields and higher incomes – the common fundamental

7. SOM = 1.7 x SOC

8. In the legend of the map, the conversion of SOC (tonnes/ha) to percentage SOC and percentage SOM is approximately as follows:
0–20 tonnes/ha SOC equals less than 0.5% SOC or less than 0.85% SOM
20–40 tonnes/ha SOC equals 0.5–1% SOC or 0.85–1.7%% SOM
40–70 tonnes/ha SOC equals 1–1.75% SOC or 1.7–2.98% SOM
70–90 tonnes/ha SOC equals 1.75–2.25% SOC or 2.98–3.83% SOM
> 90 tonnes/ha SOC equals more than 2.25% SOC or more than 3.83% SOM

9. *The State of the World's Land and Water Resources for Food and Agriculture (SOLAW)*. (2021). Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/land-water/solaw2021/en/

principle lies in Sustainable Soil Management (SSM) that is specific to crop types grown on particular soil types in particular agro-ecological land conditions. There are different SSM principles for land used for cropping and grazing.

General SSM Principles for Croplands

There are many systems of SSM for agricultural lands, such as Conservation Agriculture practices,[10] Climate Smart Agriculture,[11] and Integrated Soil Fertility Management,[12] which can be found in well curated databases such as that of the FAO and the World Overview of Conservation Approaches and Technologies (WOCAT), among others. We have cataloged some of these practices and details of country-specific case studies, the soil types and agroecological zone(s) in Chapter 4.

Some of the generic SSM practices for croplands that can be followed to regenerate soil are: no till or minimum till on land; ensure soil is always under shade and shielded from wind; growing leguminous cover crops; use of green manure for cover / mulch (summer and winter cover crops); increase the diversity of crops grown on soil; crop rotations; integration of animals; recycling green manure and animal waste; and scientific and judicious chemical usage.

Outcomes of SSM Practices for Croplands

Broadly, all SSM practices for agricultural land will have the following characteristics:[13]

- Minimal rates of soil erosion by water and wind.
- The soil structure is not degraded (e.g. soil compaction) and provides a stable physical context for movement of air, water, and heat, as well as root growth.
- Sufficient surface cover (e.g. from growing plants, plant residues, etc.) is present to protect the soil.

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10. *The Three Principles of Conservation Agriculture*. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/conservation-agriculture/en/

11. *Climate-Smart Agriculture*. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/climate-smart-agriculture/en/

12. Fairhurst, T. (ed.). (2012). Africa Soil Health Consortium: *Handbook for Integrated Soil Fertility Management*. CABI Publishing.

13. Baritz, R., Wiese, L., Verbeke, I., & Vargas, R. (2017). Voluntary guidelines for sustainable soil management: Global action for healthy soils. *International Yearbook of Soil Law and Policy 2017,* 17–36. https://doi.org/10.1007/978-3-319-68885-5_3

- The store of SOM is stable or increasing and close to the optimal level.
- Availability and flow of nutrients are appropriate to maintain or improve soil fertility and productivity, and to reduce their losses to the environment.
- Soil salinization, sodification and alkalinization are minimal.
- Water (e.g. from precipitation and irrigation) is efficiently infiltrated and stored to meet the requirements of plants, and the drainage of any excess is ensured.
- Contaminants are below toxic levels.
- Soil biodiversity provides a full range of biological functions.
- The soil management systems for producing food, feed, fuel, timber, and fiber rely on optimized and safe use of inputs.
- Soil sealing is minimized through responsible land use planning.

SSM Principles for Grazing Lands

Managed Grazing[14] and Holistic Planned Grazing[15] are two examples of sustainable livestock rearing. An important part of the regenerative ranching process is regenerative grazing, where the use of livestock grazing is integrated into the ecological process to improve soil health and plant diversity. Regenerative grazing involves adaptive multi-paddock grazing (AMP or adaptive grazing) – moving cattle and other pastured animals (sheep, goats, turkeys, bison, pigs) cyclically through small sections of the overall land, and allowing grazed land adequate rest and recovery.

The common element across all sustainable agricultural and livestock rearing practices is that they lead to an increase in SOM, which facilitates regeneration of soils where degraded, and improvement of soils where the quality is good to begin with.

SSM practices need to be supported with the necessary policies for them to be implementable. In the next chapter, we detail our approach to assessing existing policy ecosystems and providing policy recommendations for various regions of the world.

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14. *Managed Grazing*. Project Drawdown.
https://drawdown.org/solutions/managed-grazing

15. *What is Holistic Planned Grazing?* Savory Institute. (2015).
https://savory.global/wp-content/uploads/2017/02/about-holistic-planned-grazing.pdf

CHAPTER 3: Conscious Planet Policy Recommendations

At Conscious Planet, we have assessed the state of soils and present policy ecosystems in different regions across the globe, and have put forth policy recommendations to bring a minimum of 3–6% Soil Organic Matter in agricultural lands.

Just a millennium ago, agricultural land made up only 4% of the world's ice-free and non-barren land area.[1] But today, around half of the world's habitable land is used for agriculture. Therefore, addressing soil health requires us to consider agricultural practices.

The large-scale agriculture in the world today has massive implications for the planet. For example, livestock gas emissions on farmlands are the second major source of greenhouse gas emissions (after fossil fuels), and are responsible for an estimated 18–24% of annual greenhouse gases.[2, 3] The legacy emissions from agricultural land use change are 136 ± 55 petagrams of carbon (Pg C). From the start of the Industrial Revolution, carbon lost from soil degradation, through the depletion of Soil Organic Carbon (SOC), accounts for a further contribution of 78 ± 12 Pg C.[4] The total emissions thus come to 214 ± 67 Pg C. This is 80–90% of the emissions from fossil fuel, which is 270 ± 30 Pg C. As we saw in Chapter 1, this loss of Soil Organic Matter (SOM) has ramifications for food security, nutritional security, water scarcity, soil biodiversity, climate change and world peace. According to one estimate, global land degradation costs us USD 300 billion every year.[5]

Reversal of degradation by increasing SOM may generate up to €1.2 trillion per year of economic benefits globally.[6] For an individual farmer, increase in SOM builds resilience to climate risks, improves yield and income prospects. For anyone else who consumes

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1. Ritchie, H. (2019). Half of the world's habitable land is used for Agriculture. *Our World in Data.* https://ourworldindata.org/global-land-for-agriculture

2. Hawken, P. (2017). *Drawdown: The most comprehensive plan ever proposed to reverse global warming.* Penguin Books.

3. *AR5 Synthesis Report: Climate Change 2014.* IPCC. https://www.ipcc.ch/report/ar5/syr/

4. Lal, R. (2004). Agricultural activities and the global carbon cycle. *Nutrient Cycling in Agroecosystems, 70, 103–116. https://doi.org/10.1023/b:fres.0000048480.24274.0f*

5. Nkonya, E., Mirzabaev, A., & von Braun, J. (2016). Economics of land degradation and improvement: an introduction and overview. In: Nkonya, E., Mirzabaev, A., & von Braun, J. (eds.). Economics of land degradation and improvement: A global assessment for sustainable development. *Springer Open*. https://doi.org/10.1007/978-3-319-19168-3_1

6. *Questions and Answers on the EU Soil Strategy.* European Commission. (2021). https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_5917

food, drinks water or breathes air, it improves the quality of all these resources and enhances our health and quality of life!

Hence, the policy recommendations from Conscious Planet's Save Soil Movement are focused towards agriculture and the food bowls of the world. We are aware that other kinds of land use (forests, urban areas, industry) also have a bearing on climate change, biodiversity and water scarcity. But interventions in agricultural land have manifold positive impacts on all these environmental aspects compared to interventions on other types of land.

The policy recommendations detailed in this publication strongly advocate for farmers to increase SOM in farmlands. This is a supply-side policy intervention. To ensure the interventions happen at an accelerated pace, we need the pull factors in play as well. For farmers, the pull factor will come from both backward and forward linkages and the end consumer – the citizens of a nation. These are the demand-side interventions. The Save Soil Movement will work towards building the demand from citizens by generating awareness. The goal is to touch over 3.5 billion citizens who will voice their intention to their governments to prioritize soil regeneration and a supportive policy ecosystem for food production on lands with higher SOM.

Forward linkage interventions can come from agricultural businesses, which can have differentiated procurement strategies for food grown on farms with regenerative practices. Additional costs can be passed on to the customer. FMCG companies can strive to mention what types of farms supplied their raw material on their labels. There can also be similar incentivization of farmers from backward linked entities who supply them with seeds, nutrients and other inputs. Backward linked agribusinesses can incentivize farmers for judicious and scientific use of the products they supply to farmers. The mechanisms to operationalize the demand-side interventions will vary with every country. Aspects of these mechanisms will be detailed in this publication only to a limited extent.

In 3.1, we articulate the high-level policy recommendations to help achieve the minimum 3–6% SOM across the world. In the following sections of Chapter 3, we analyze the state of soils in major regions of the world, their existing policy ecosystems, and suggest specific policy interventions to increase SOM.

In order to put forth policy recommendations for countries around the world, we have grouped countries into different regions according to their present-day policy practices and geographical contiguity. For example, Europe is made up of European Union (EU) member nations and a few others. The policies of the EU and those of adjacent regions that trade with the EU are comparable. Therefore, policy recommendations pertaining to technical aspects for the EU are applicable for adjacent countries as well. For the remaining countries in the region, we address their distinct country-specific aspects and give specific recommendations where needed.

Every small area of farmland is unique in terms of soil type, and every farmer lives in unique technical, social and political contexts. Overall, however, geographical contiguity signifies similar conditions for farmland and farmers, in terms of creating policies. For example, in Caribbean nations, the common feature is that they are all small islands, and each of them face natural disasters in the form of hurricanes or volcanic eruptions year on year. Similarly, farmers in African nations have many commonalities, such as small landholdings (unlike their European and North American counterparts), poor access to nutritional inputs, and land tenure challenges. These are issues unique to the African region, but are common across countries within Africa. This is the rationale behind our approach to policy analysis and recommendation based on region.

We have looked into the policies of the following major regions of the world:

1. African Union
2. Asia
3. Europe
4. Latin America and the Caribbean (LAC)
5. Middle East and North Africa (MENA)
6. North America
7. Oceania

3.1 Policies for the World

In this section, we explain our approach to bringing a minimum of 3–6% SOM in agricultural lands across the world, through four pillars of intervention: Knowledge Systems; Farmer Support Ecosystem; Legal Provisions; and Monitoring and Learning Systems.

Soil Organic Matter (SOM) in agricultural lands is fundamental to the wellbeing of human beings and the terrestrial ecosystems of the world. A minimum of 3–6% of SOM is fundamental to ensuring food security and nutritional security, addressing water scarcity, improving soil biodiversity and mitigating climate change.

A substantial percentage of soil in agricultural lands is in critical condition. To rejuvenate these soils, governments of the world need to take urgent, concerted and timebound measures so that we do not endanger the very basis of life of present and future generations. The primary custodians of the world's agricultural lands are farmers, of whom 80% are small landholders. Thus, farmers are indispensable in increasing SOM in agricultural lands.

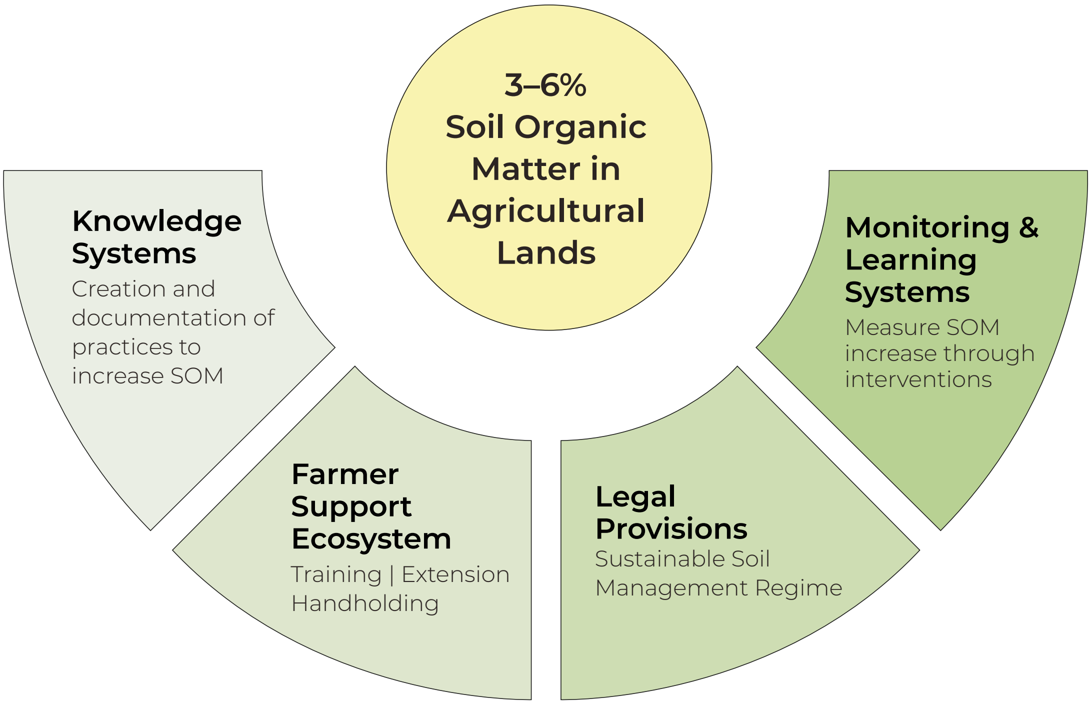
This overarching objective of ensuring a minimum 3—6% of organic content for agricultural soil can be achieved with a pragmatic three-pronged strategy:

1. Provide attractive incentives for farmers to strive to reach the minimum threshold of 3–6% organic content. Such incentives would create an aspirational race amongst farmers.
2. Facilitate and streamline carbon credit for farmers. The current processes for farmers to avail of carbon credit benefits are far too complex – and therefore need significant simplification.
3. Develop a mark of superior quality for food grown from soils that have the target 3–6% organic content level. Alongside this, we should also clearly articulate the various health, nutritional, and preventive health benefits of consuming such foods. As a result of this initiative, people would be more healthy, more productive, and more resilient – thereby leading to gains in man-days, and a lower stress on our health care systems. It is therefore evident that such a mark of superior quality food would have far more meaning than the current system of just trying to distinguish between so-called ‘organic’ and ‘non-organic’ produce.

Our approach to actioning the strategy for increasing SOM in farmers' lands is made up of establishing and executing four pillars of intervention:

- Knowledge Systems
- Farmer Support Ecosystem
- Legal Provisions
- Monitoring and Learning Systems

Figure 1: Conscious Planet's approach to facilitating increase in SOM in the world's agriculture lands.



Knowledge Systems

Cataloging and creation of Sustainable Soil Management (SSM) Package of Practices: For farmers to transition from their present agricultural practices to those that will increase SOM, there must be a database of clear Package of Practices (PoP) cataloged for various crop types and soil types. These PoPs are right now spread across research publications, institutional reports and specialized databases for sustainable land management or soil management practices. Dedicated national and subnational agricultural research institutions should host all this information in one place and make it easily accessible for farmers and farmer extension workers (i.e. soil doctors). Wherever there is no PoP for a particular cropping system, agricultural institutions should create a PoP. The PoPs in the databases should be specific to crop type based on its specific nutritional requirement and across various soil types of that nation or region. The nutritional requirements and means of production for these crops should be precise to avoid problems that arise due to excess usage of inputs or application of the wrong inputs – both organic and inorganic.

Farmer Support Ecosystem

Generate farmer-friendly information: Knowledge catalogued and produced in the knowledge systems pillar should be translated into “farmer-friendly information” and made available to farmers.

Trainings: Training sessions on SSM, regenerative agricultural practices, and PoPs for specific crops must be conducted for farmers. Agricultural research institutions should also arrange for model farm plots that demonstrate the benefits of such practices, such as improvement in crop yield. It should be noted that such training sessions have maximum impact when conducted by fellow progressive farmers whose livelihoods depend on agriculture.

Soil doctors: Investment in training and nurturing grassroots farmers who can address specific issues of other local farmers is a must. The concept of soil doctors was developed and adopted in certain countries of Africa. Also, there should be an optimal ratio of soil doctors to farmers in order to ensure effective outreach to farmers.

Legal Provisions

Most countries in the world have legislation to govern and manage natural resources like water and air. However, soil is often seen as an input commodity, an inert material for agriculture. Soil is usually only vaguely covered in environmental laws. Legal and policy frameworks that define what constitutes healthy soil, the responsibility of the custodians of soil, and the incentives and disincentives regarding agricultural practices should be articulated.

The European Union is one government which is in the process of formulating its Soil Health Law. The proposal, as it stands, focuses on clearly defining healthy soil and the mechanism to measure the outcome of any interventions on the quality of soil. Even within soil health, while there are a number of parameters, the single most important one is SOM. Countries should strategize on making significant headway on this parameter, as it has far-reaching impact on soil health, covering a wide scope of issues. Once there is sufficient understanding of the significance of SOM, and SSM farm practices become common knowledge, further interventions to improve other indicators of soil health can be introduced.

Monitoring and Learning Systems

Standardize indicators to assess soil health: There have been many grant programs in Africa and Asia towards SSM interventions. There have also been budgets allocated towards SSM practices under the European Commission. However, there is no stringent list of indicators, definitions of indicators, or measurement of these indicators to assess the effectiveness of interventions on soil health, specifically SOM. The FAO has suggested some of the indicators that can be measured to assess soil quality improvement through adaptation of SSM practices.[7] These indicators should be measured along with regular physical and chemical properties of soil.

Soil testing: Soil testing laboratories should also be equipped to conduct tests for biological properties of soil, along with the physical and chemical properties of soil. The testing facilities should be at nominal fee and accessible for farmers. For example,

7. *Protocol for the assessment of Sustainable Soil Management.* Food and Agriculture Organization of the United Nations (FAO). (2020). https://www.fao.org/fileadmin/user_upload/GSP/SSM/SSM_Protocol_EN_006.pdf?fbclid=IwAR2Ob5F2SaNyA1d473bL7p_jC14YNMbujT9IgnC5C7lRqhLRq3QhhVEt7RY

the French government has a free soil sampling scheme[8] to encourage farmers to test their soil and, accordingly, carry out interventions on their land. This will provide farmers with evidence of their soil's health and bring about a change in their behavior towards managing their soils sustainably. Farmers' decisions on use of nutrition (organic / inorganic) and its quantity, choice of sustainable soil management practice (cover crop species / intercrop mix, etc.) will be guided by their soil report and the nutritional needs of the crop(s) they intend to grow on their farm. This testing will also help soil doctors and farmers decide which type of SSM practice will increase productivity on their land and decrease input cost.

Figure 2: Recommended indicators that can be monitored to assess Sustainable Soil Management (Source: FAO)9

Indicator	Parameter/ Metric	Measurement Methods	Sample Characteristics
Soil organic carbon	Organic carbon (%)	**Walkley-Black method** *http://www.fao.org/3/ca7471en/CA7471EN.pdf* **or Dumas method** *http://www.fao.org/3/ca7781en/ca7781en.pdf*	Representative soil sample
Soil biological activity	Soil respiration rate (gCO_2 m^{-2} d^{-1}) Ideally combined with at least one other biological indicator	Laboratory based soil respiration measurement (static or dynamic)	Representative soil sample to be analyzed within hours or refrigerated
Soil productivity	Agricultural productivity or biomass in dry matter (t ha^{-1} $year^{-1}$)	Dry weight of vegetation quadrats, or yield measurements	Quadrat method or yield measurement
Soil physical properties	Bulk density (kg dm^{-3}) In some cases, bulk density can be complemented by available water capacity, or other relevant soil physical properties	The Core Method	Undisturbed representative sample with known volume

8. *Gis Sol – Base de Données d'Analyses des Terres – BDAT.* https://www.gissol.fr/le-gis/programmes/base-de-donnees-danalyses-des-terres-bdat-62

9. *Protocol for the assessment of Sustainable Soil Management*. Food and Agriculture Organization of the United Nations (FAO). (2020). https://www.fao.org/fileadmin/user_upload/GSP/SSM/SSM_Protocol_EN_006.pdf?fbclid=IwAR2Ob5F2SaNyA1d473bL7p_jC14YNMbujT9IgnC5C7lRqhLRq3QhhVEt7RY

Actioning Policy to Save Soils

To ensure our suggested approach is rolled out such that there is marked change in the condition of SOM within a decade, we suggest the SSM policies be phased as “Recommendations Phase”, “Incentivization Phase” and “Phase to Wind Down Incentives”. In other words, there should be a phased program of implementation over a number of years – with the first phase being that of providing inspiration, followed by a second phase of providing incentives, and eventually having a third phase with some appropriate disincentives.

Actioning recommendations: Large countries with federal governance structures like Brazil, Australia, India and political/economic unions like the European Union and African Union have a 2-year window for member states to adopt any new policy or legislation. This window can be a learning period where abiding by policies can be voluntary, and governments work to understand the challenges farmers face in making the transition, while fine-tuning the implementation of the policy.

Actioning incentivization: In this second phase of the policy rollout (the 2-year period after the learning period) governments can incentivize farmers and other stakeholders – like soil doctors, soil testing laboratories, research institutes – to facilitate large-scale implementation of SSM practices. For example, Uzbekistan’s food production which grew by 7.2% from 2016–2020,[10] is attributed to the attention given to multipurpose farms. These farms were exempted from paying any tax on all types of activities related to crop growing. In India, the 2022 central budget announced a plan to incentivize farmers to bring land under shade through agroforestry, to grow more legume species and to follow natural farming practices.[11]

10. *Uzbekistan is taking efforts to make its economy sustainable and green.* WION. (2021). https://www.wionews.com/world/uzbekistan-is-taking-efforts-to-make-its-economy-sustainable-and-green-375475

11. *Union Budget 2022: Govt to promote Kisan drones, chemical-free natural farming in 2022–23, Sitharaman says*. The Times of India. (2022). https://timesofindia.indiatimes.com/business/india-business/govt-to-promote-kisan-drones-chemical-free-natural-farming-in-2022-23-nirmala-sitharaman/articleshow/89268246.cms

Actioning wind-down incentives: Once a critical mass of farmers have taken up SSM practices to improve their SOM and have benefited from it personally, the SSM policies need not be bolstered by heavy incentives. The knowledge of beneficial farm economics will spread among farmers naturally. The incentive structure for SSM practices can be modified as deemed necessary by governments. In this phase, governments can explore how to rope in carbon credit markets to pay for the carbon sequestered by farmers. Payments can be based on changes in select indicators such as SOC, the soil's water retention capacity, soil biodiversity, concentration of fertilizers in runoff from farmlands, etc. If environmental accounting systems are in place, governments and private entities can also compensate farmers for the ecosystem services they deliver.

3.2 Policies for the African Union

Nations in the African Union (AU): Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sahrawi Republic, Sao Tome & Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Tunisia, Uganda, Zambia, and Zimbabwe.

African Union Statistics[1]

Total Population: 1.303 billion

Nominal GDP:[2] USD 2.478 trillion

GDP Per Capita: USD 1902

Total Landmass Area: 29.62 million km²

Landmass under Agriculture: 11.6 million km²

Population Dependent on Agriculture as a Percentage of Total Employment: 50% (388 million people)

Average Farm Size: 1–10 ha

Executive Summary

Among the 55 nations of Sub-Saharan Africa (SSA) that are engaged in agriculture, 60% of the agricultural potential lies in only nine countries, and three countries – Ethiopia, Nigeria and Tanzania – contribute to half of the 60%. According to a McKinsey report, agriculture productivity in Africa has a scope to increase 2–3 times of what it is right now.[3] *However, at present, a country like Thailand, which has landmass six times smaller than Africa, exports more agricultural goods than the entire SSA region.*[4] *To have Africa realize its full agricultural potential, investments should be made in the agriculture sector across the entire value chain, starting from restoring soil health, nutrients on fields, seeds, irrigation, storage, basic infrastructure and trade. Investments in agriculture are even more imperative as Africa is losing approximately USD 25 billion a year due to malnutrition.*[5]

It is the restoration of soil health which forms the foundation for all other investments in the agriculture sector to ensure Africa becomes secure in terms of food and

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1. Hamadeh, N., Atamanov, A., Fu, H., & Baffes, J. (2022). *World Bank Open Data.* https://data.worldbank.org/

2. Based on data from the International Monetary Fund (IMF).

3. Goedde, L., Ooko-Ombaka, A., & Pais, G. (2019). Winning in Africa's agricultural market. *McKinsey & Company*. https://www.mckinsey.com/industries/agriculture/our-insights/winning-in-africas-agricultural-market

4. Bourne, J. K. (2014). The Next Breadbasket. *National Geographic.* https://www.nationalgeographic.com/foodfeatures/land-grab/

5. *Continental Nutrition Accountability Scorecard*. The African Union Commission. (2022). https://au.int/en/documents/20220203/continental-nutrition-accountability-scorecard

nutrition. But African soil is in an alarming state of degradation due to soil erosion, loss of organic matter, chemical decomposition, and soil compaction. According to an International Food and Policy Research Institute (IFPRI) report, Africa is losing USD 65 billion every year due to land degradation.[6] Though in the last two years the agriculture policies have directed their focus to bringing the continent out of hunger, nutritional insecurity and poverty, there has been very little focus on regenerating soil health. This lack of focus is reflected in the budgetary expenditures by nations under the CAADP framework, and also in the dearth of legal provisions to protect soil health.

In the policy recommendation section, we clearly articulate the interventions needed across the verticals of Knowledge Systems, Farmer Support Ecosystem, Legal Provisions, and Monitoring and Learning Systems to improve soil health. The recommendations focus on a single-point agenda to bring in a minimum of 3–6% Soil Organic Matter (SOM), which will build a strong foundation for soil regeneration.

The State of Agricultural Soil in the African Union

Africa is the world's second largest continent with 55 distinct nation states and a population estimated to be over 1.3 billion in 2019. Africa's economy is heavily dependent on agriculture, which employs 50% (389 million) of the total employed population. Agriculture contributes to over 18% of the continent's overall GDP of USD 2.4 trillion.

Despite this, hunger, famine and food insecurity are an ongoing, everyday challenge in most of Africa. For example, according to a Reuters report on February 9, 2022, 13 million people are affected by hunger in the Horn of Africa.[7] Another example is the 2021–2022 cyclone season, which brought floods in Malawi[8] and South Africa,[9] causing enormous crop damage. A third example can be found in Madagascar, where cyclone

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6. Mwangi, W. (2018). Country Profiles Reveal Global Cost of Land Degradation. *International Institute of Sustainable Development*. http://sdg.iisd.org/news/country-profiles-reveal-global-cost-of-land-degradation/

7. Lawrence, J., & Hudson, A. (Eds.). (2022). Millions facing severe hunger in Horn of Africa – U.N. Food Agency. *Reuters*. https://www.reuters.com/world/africa/millions-facing-severe-hunger-horn-africa-un-food-agency-2022-02-08/

8. Masina, L. (2022). UN Kicks Off Relief Assistance to Malawi Flood Victims. *VOA*. https://www.voanews.com/a/un-kicks-off-relief-assistance-to-malawi-flood-victims/6423409.html

9. Sguazzin, A. (2022). South Africa's Heaviest Rain on Record Causes Destructive Floods. *Bloomberg Green*. https://www.bloomberg.com/news/articles/2022-01-25/south-africa-s-heaviest-rain-on-record-causes-floods

Batsirai left more than 150,000 people in food insecurity in February 2022.[10] Besides these fundamental challenges, socio-political factors have exacerbated hunger, malnutrition and poverty. For example, in Somalia in 2010–2012, 250,000 people – half of whom were children – died in a famine.[11] Though media reports largely portrayed the famine as being caused by drought, in reality, there were multiple factors that contributed to it – conflict, rapidly-rising global food prices and other long-standing structural factors played a role.[12]

Considering all these factors, the importance of soil as the source of food security cannot be overstressed. African farmers' plight is the state of the soil in general – naturally poor and degraded – resulting in low productivity. For example, in the northern and western African nations, the expanding Sahara Desert is forcibly displacing farmers[13] and has led to drought and land degradation. Moreover, according to a climate change study, the Sahara has expanded by 10% since 1920.[14]

10. *Cyclone Batsirai poses 'serious threat to millions' in Madagascar*. The Guardian. (2022). https://www.theguardian.com/world/2022/feb/05/cyclone-batsirai-poses-serious-threat-to-millions-in-madagascar

11. Ford, L. (2013). Somalia famine in 2010–12 'worst in past 25 years'. *The Guardian.* https://www.theguardian.com/global-development/2013/may/02/somalia-famine-worst-25-years

12. Maxwell, D., & Fitzpatrick, M. (2012). The 2011 Somalia famine: Context, causes, and complications. *Global Food Security, 1*(1), 5–12. https://www.sciencedirect.com/science/article/pii/S221191241200003X

13. Sikiti da Silva, I. (2019). Displaced by the Desert: An expanding Sahara Leaves Broken Families and Violence in Its Wake. *Relief Web.* https://reliefweb.int/report/mali/displaced-desert-expanding-sahara-leaves-broken-families-and-violence-its-wake

14. Thomas, N., & Nigam, S. (2018). Twentieth-Century Climate Change over Africa: Seasonal Hydroclimate Trends and Sahara Desert Expansion. *Journal of Climate*, *31*(9), 3349–3370. https://doi.org/10.1175/jcli-d-17-0187.1

Table 1: Land Degradation Severity in Sub-Saharan Africa[15]

Land Degradation Severity	% of SSA
None	33
Light	24
Moderate	18
Severe	15
Very Severe	10
Total (Light—Very Severe)	65

As Table 1 shows, about two-thirds of Sub-Saharan Africa (SSA) is degraded, and effective soil fertility management remains a major challenge.[16] Soil degradation can happen due to the physical loss of soil itself, such as when wind erosion carries soil away. Degradation also occurs when physiochemical changes to the structure of soil take place, which renders it unsuitable to cultivation.

There are two major factors causing soil degradation in Africa: biophysical and anthropogenic (human-induced) processes.

Biophysical properties are factors related to climate, topography, soil and vegetation. These include: the distribution, quantity and intensity of rainfall; frequency of floods, storms and high velocity winds; drought; land terrain; soil erodibility characteristics; density of vegetation, etc. For example, Africa sees high rainfall variations, frequent storms and extreme droughts, which lead to soil erosion. Global warming and associated changes in soil temperature and water also affect soil processes.

Sixty-six percent of Africa is classified as desert or dryland, which includes arid, semi-arid, and sub-humid areas,[17] which applies to most of the agricultural land, especially in the SSA region. The fragility of these dryland soils makes them more susceptible to

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15. Lal, R., & Stewart, B. A. (2019). *Soil degradation and restoration in Africa*. CRC Press, Taylor & Francis Group.

16. Onduru, D. D., De Jager, A., Muchena, F. N., Gachimbi, L., & Gachini, G. N. (2007). Socio-economic factors, soil fertility management and cropping practices in mixed farming systems of Sub-Saharan Africa: A study in Kiambu, Central Highlands of Kenya. *International Journal of Agricultural Research*, *2*(5), 426–439. https://doi.org/10.3923/ijar.2007.426.439

17. Blaikie, P., & Brookfield, H. (1987). Economic costs and benefits of degradation and its repair. *Land Degradation and Society*, 110–125. https://doi.org/10.4324/9781315685366-16

land degradation and desertification. Poor soil quality is unable to support agricultural production and is less responsive to sustainable management methods.

The anthropogenic interventions that have harmed soils in SSA are deforestation, overgrazing, agricultural land mismanagement, and overexploitation of land and its vegetative cover. A unique feature of African farming, and the root cause of its weak soil, is nutrient mining. Nutrient mining refers to the steady depletion of nutrients from soil, as the nutrients extracted from soil through crop harvests are not compensated by nutrient addition through fertilizers or organic matter input.

Anthropogenic processes give rise to various kinds of degradation as shown in Table 3. The most significant soil degradation is caused by water erosion (46%), followed by wind erosion (38%), chemical degradation (12%) and lastly, by compaction and waterlogging (4%).[18]

Table 2: Soil Degradation by Land Use in Africa[19]

		Degraded	
Land Use	**Total Area (Mha)**	**Area (Mha)**	**(%)**
Agricultural land	187	121	65
Permanent pasture	793	243	31
Forest and woodland	683	130	19
All land uses	1663	494	30

18. Lal, R., & Stewart, B. A. (2019). *Soil degradation and restoration in Africa.* CRC Press, Taylor & Francis Group.

19. *ibid.*

Table 3: Anthropogenic-Induced Soil Degradation in Africa[20]

	Area (Mha)				
Degradation type	**Light**	**Moderate**	**Strong**	**Extreme**	**Total**
Water erosion	57.5	67.4	98.3	4.2	227.4 (46%)
Loss of topsoil	53.9	60.5	86.6	3.8	204.9
Terrain deformation	3.6	6.9	11.7	0.4	22.5
Wind erosion	88.3	89.3	7.4	—	186.5 (38%)
Loss of topsoil	79.1	84.2	7.4	—	170.7
Terrain deformation	9.2	5.1	—	—	14.3
Overblowing	—	—	0.5	1.0	1.5
Chemical degradation	26.0	27.0	8.6	—	61.5 (12%)
Loss of nutrients	20.4	18.8	6.2	—	45.1
Salinization	4.2	7.7	2.4	—	14.8
Acidification	1.1	0.3	<1	—	1.5
Pollution	—	0.2	—	—	0.2
Physical degradation	1.8	8.1	8.8	—	18.7 (4%)
Compaction	1.4	8.0	8.8	—	18.2
Waterlogging	0.4	0.1	—	—	0.5
Total degraded area	173.5 (35%)	191.8 (38%)	123 (25%)	5.2 (1%)	494.2

Soil Erosion

Eighty-four percent of soil degradation in Africa is attributed to soil erosion as a result of human activity. Human exploitation of land, water, vegetation, and soil resources through deforestation, overgrazing, soil tilling, and shifting cultivation, have accelerated soil erosion beyond the tolerance limit. Erosion reduces soil quality through nutrient loss in the soil, damages the land, and reduces crop yield. It leads to surface soil loss, and can result in landslides or river bank erosion.

Soil erosion takes place in the form of water erosion or wind erosion. For example, in

20. Lal, R., & Stewart, B. A. (2019). *Soil degradation and restoration in Africa*. CRC Press, Taylor & Francis Group.

the Ethiopian highlands, where soil is shallow and the land slopes, both water and wind erosion may lead to irreversible loss of soil and severe degradation. Therefore, these lands are often abandoned.

The primary reason for wind and water erosion is change in land use (from forest or grasslands to croplands) that take place without planning for sustainability. This generally reduces the vegetative cover, which exposes the land and leaves it susceptible to erosion.

Water Erosion

Water erosion is the most widespread process across the world through which topsoil is lost. In Africa, it accounts for 46% of soil degradation (227 million ha).[21] Water erosion washes nutrients out of soil, which then flow into water bodies and pollute them. Water erosion intensifies with increased annual rainfall, and is a prominent feature in sloping areas.

Northern Africa, Madagascar, and South Africa experience the most severe water erosion in the continent. An assessment of soil erosion in the Volta basin in West Africa and the Nile basin in North Africa, which cover 105,000 km^2 and 2.9 million km^2 respectively, indicated an average soil loss of 35 Mg/ha per year for the Volta and 75 Mg/ha per year for the Nile basin.[22] Water erosion is also particularly destructive in the humid tropical regions of Africa where the convergence of deforestation, population pressure and torrential rain episodes can lead to annual soil losses greater than 50 Mg/ha per year.[23]

Wind Erosion

Wind erosion causes 38% of land degradation in Africa. Unlike water erosion, wind erosion is significant in regions with relatively lower rainfall, where average annual rainfall is below 600 mm. Wind erosion occurs as wind blows over soils with

21. Bridges, E. M., & Oldeman, L. R. (1999). Global assessment of human-induced soil degradation. *Arid Soil Research and Rehabilitation*, *13*(4), 319–325. https://doi.org/10.1080/089030699263212

22. Tamene, L., & Le, Q. B. (2015). Estimating soil erosion in sub-Saharan africa based on landscape similarity mapping and using the revised universal soil loss equation (RUSLE). *Nutrient Cycling in Agroecosystems*, *102*(1), 17–31. https://doi.org/10.1007/s10705-015-9674-9

23. Nana-Sinkam, S. C. (1997). Land and Environmental Degradation and Desertification in Africa: Issues and Options for Sustainable Economic Development with Transformation. *Monograph – Joint ECA/FAO Agriculture Division (ECA/FAO).*

relatively dry surfaces in arid and semi-arid regions – where vegetation is sparse and temperatures are high. The Sahel region (just south of the Sahara) and southern Africa are the most vulnerable. Desertification is the ultimate outcome of wind erosion.

Chemical Degradation

Chemical degradation of soil is a change in the soil's chemical properties due to human intervention, which leads to reduced soil quality. It includes salinization, acidification, pollution, etc. This accounts for 12% of soil degradation in Africa (62 Mha).[24]

The loss of nutrients (nutrient mining) is the most important form of chemical degradation in Africa and a primary cause of soil infertility in the region.[25] Food production in the continent is mostly rainfed, and farmers are too poor to afford fertilizers. Nutrient outputs have therefore exceeded inputs for decades across SSA, exhausting soil nutrient pools.[26]

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24. *The Economics of Land Degradation in Africa: Benefits of Action Outweigh the Costs.* ELD Initiative & UNEP. (2015). https://www.eld-initiative.org/fileadmin/pdf/ELD-unep-report_07_spec_72dpi.pdf

25. Osman, K. T. (2014). *Soil degradation, conservation and remediation*. Springer Netherlands.

26. Sanchez, P. A., Shepherd, K. D., Soule, M. J., Place, F. M., Buresh, R. J., Izac, A.-M. N., Mokwunye, A. U., Kwesiga, F. R., Ndiritu, C. G., & Woomer, P. L. (1997). Soil fertility replenishment in Africa: An investment in natural resource capital. In: Buresh, R. J., Sanchez, P. A., & Calhoun, F. (Eds.). *Replenishing Soil Fertility in Africa, 51*. Soil Science Society of America and American Society of Agronomy, Madison, WI.

Table 4: Annual Nutrient Depletion and Average Fertilizer Use (2011–2015) in Agricultural Soils of Selected Countries in Southern Africa[27]

	Nutrient depletion (kg ha^{-1} $year^{-1}$)			Fertilizer use (kg ha^{-1} $year^{-1}$)		
Country	**N**	**P**	**K**	**N**	**P**	**K**
Benin	–16	–2	–11	3.1	1.0	2.0
Ethiopia	–47	–7	–32	11.9	4.1	1.0
Cameroon	–21	–2	–13	4.4	0.6	2.4
Ghana	–35	–4	–20	5.1	2.1	3.6
Kenya	–46	–1	–36	21.9	4.2	2.4
Malawi	–67	–10	–48	20.2	2.2	3.0
Tanzania	–32	–5	–21	4.3	0.8	0.5
Mozambique	–23	–4	–19	4.2	0.3	0.5
Zambia	–13	–1	–12	34.9	3.7	3.2
Zimbabwe	–27	2	–26	11.1	3.0	3.2
Botswana	–2	0	–2	52.6	0.9	2.0
Rwanda	–60	–11	–61	3.9	1.2	1.2

Nutrient Mining

A study of the nutrient balance in key agro-ecological regions of Africa estimated that during the cropping seasons between 2002–2004, around 85% of farmlands in Africa had nutrient mining rates exceeding 30 kg/ha per year of NPK (nitrogen, phosphorus, potassium). Forty percent of farmlands had rates exceeding 60 kg/ha per year. The highest rates of nutrition mining were greater than 100 kg/ha per year – which occur in Eastern Africa, namely Rwanda, Burundi, and Malawi.[28] Eastern and Southern Africa experience high nutrient depletion rates due to: (i) high population density and continuous cultivation with low or no nutrient addition; (ii) hilly and mountainous terrain rendering land susceptible to erosion; (iii) and soils that are still fertile and have

27. Lal, R., & Stewart, B. A. (2019). *Soil degradation and restoration in Africa*. CRC Press, Taylor & Francis Group.

28. Henao, J., & Baanante, C. (2006). Agricultural Production and Soil Nutrient Mining in Africa: Implications for Resource Conservation and Policy Development. *IFDC.* https://vtechworks.lib.vt.edu/bitstream/handle/10919/68832/4566_Henao2006_Ag_production_nutrient_mining_.pdf?sequence=1&isAllowed=y

a lot to lose in terms of plant nutrients supply.[29] In Sudano-Sahelian zones, continuous cultivation, high SOM decomposition rates, and wind erosion are the major paths for nutrient loss. In the equatorial forest zone, with high rainfall and a favorable soil moisture regime, water erosion, leaching, reduced fallow, and residue burning are the major nutrient loss paths.[30]

Other Forms of Chemical Degradation

In addition to nutrient mining, soils in SSA are also experiencing low nutrient holding capacity, declining cation exchange capacity (CEC), cation imbalances, high acidity / declining soil pH (which can lead to aluminum toxicity), alkalization, and salinization. Particularly, soil degradation through salinization and alkalization is considered one of the most important threats jeopardizing sustainable irrigated rice cropping in the semi-arid regions of SSA. These chemical constraints to soil productivity are exacerbated by overexploitation through continuous cropping and low rates of nutrient application.

Secondary soil acidification can occur due to the long-term application of relatively high rates of N fertilizers (mostly in South Africa) or continuous cropping without organic inputs,[31] leaching of nitrates, and acid rain.

Alkalization can occur when perennial vegetation is lost, or when calcareous subsoil material is incorporated into the topsoil as a result of erosion or tillage.

Some soils are naturally saline, and some are made saline by the mismanagement of crops, particularly improper irrigation and drainage (i.e., changing hydrological balance). Salinization may occur in arid and semi-arid regions of SSA where scarcity of water and high evaporation limit the leaching of salts, and also in humid regions where excess irrigation or poor drainage cause the groundwater table to rise to the root zone and make soil saline. About 15 Mha of land have been degraded by salinization in Africa.

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29. Stoorvogel, J., & Smaling, E. M. A. (1990). Assessment of Soil Nutrient Depletion in Sub-Saharan Africa: 1983–2000. *The Winand Staring Centre*. https://edepot.wur.nl/486598

30. Buerkert, A., & Hiernaux, P. (1998). Nutrients in the West African Sudano-Sahelian zone: Losses, transfers and role of external inputs. *Zeitschrift fuer Pflanzenernaehrung und Bodenkunde, 161*(4), 365–383. https://doi.org/10.1002/jpln.1998.3581610405

31. Juo, A. S., R., Dabiri, A., & Franzluebbers, K. (1995). Acidification of a kaolinitic Alfisol under continuous cropping with nitrogen fertilization in West Africa. *Plant and Soil*, *171*(2), 245–253. https://doi.org/10.1007/bf00010278

Soil Compaction and Waterlogging

Important physical properties linked to soil quality, fertility and productivity include soil texture, structure, porosity, bulk density, soil water and air, and soil temperature. Soil compaction affects all of these properties except for soil texture. The less compact the soil is, the better the soil health, and hence, agriculture.

Compaction, sealing and crusting, and waterlogging are the various processes of physical degradation of soil. Heavy machinery used on soils with low structural stability causes soil compaction. In agriculture, soil compaction reduces porosity, which affects infiltration, drainage, bulk density and other physical properties. The movement of water and gases in soil is thus reduced, which causes surface runoff, leading to floods and water erosion.

Four percent of soil degradation, covering about 18 Mha, in Africa is caused by physical degradation. Compaction is particularly evident across the Sahel, South Africa, and Zambia.[32]

Improper soil management is the primary reason behind physical degradation of soil. For example, excessive tilling breaks soil aggregates, which causes rapid decomposition of organic matter, rendering soil susceptible to wind and water erosion. Poor management of soils through overgrazing and excess tilling leads to compaction of surface or subsurface soil layers,[33] resulting in reduced infiltration and water logging.

Role of Soil Organic Matter in Reversing Degradation

It is pertinent to note that all the different types of degradation noted in the previous sections are interconnected, and an intervention to increase SOM will positively address all of them.

Increasing SOM will help in alleviating all the natural constraints of the poor-quality soil that Africa is endowed with. For example, SOM improves soil structure, reduces

32. Jones, A., Breuning-Madsen, H., Brossard, M., Dampha, A., Deckers, J., Dewitte, O., Gallali, T., Hallett, S., Jones, R., Kilasara, M., Le Roux, P., Micheli, E., Montanarella, L., Spaargaren, O., Thiombiano, L., Van Ranst, E., Yemefack, M., Zougmore, R. (Eds.). (2013). Soil Atlas of Africa. *European Commission, Joint Research Centre.*

33. Collins, A. L., Walling, D. E., Sichingabula, H. M., & Leeks, G. J. L. (2001). Suspended sediment source fingerprinting in a small tropical catchment and some management implications. *Applied Geography*, *21*(4), 387–412. https://doi.org/10.1016/s0143-6228(01)00013-3

the instances and quantum of soil erosion from water and wind, and also ensures shallow soil on slopes is not lost. SOM also increases the capacity of soil to absorb and store moisture, increasing soil health, which is critical to help farmers withstand seasons of drought. Salinity intrusion can also be mitigated to some extent. Due to soil's greater water absorption at higher SOM levels, groundwater recharge becomes more effective. With improved SOM the soil structure improves, becoming more porous with enough soil biodiversity in it. This reduces the possibility of soil compaction.

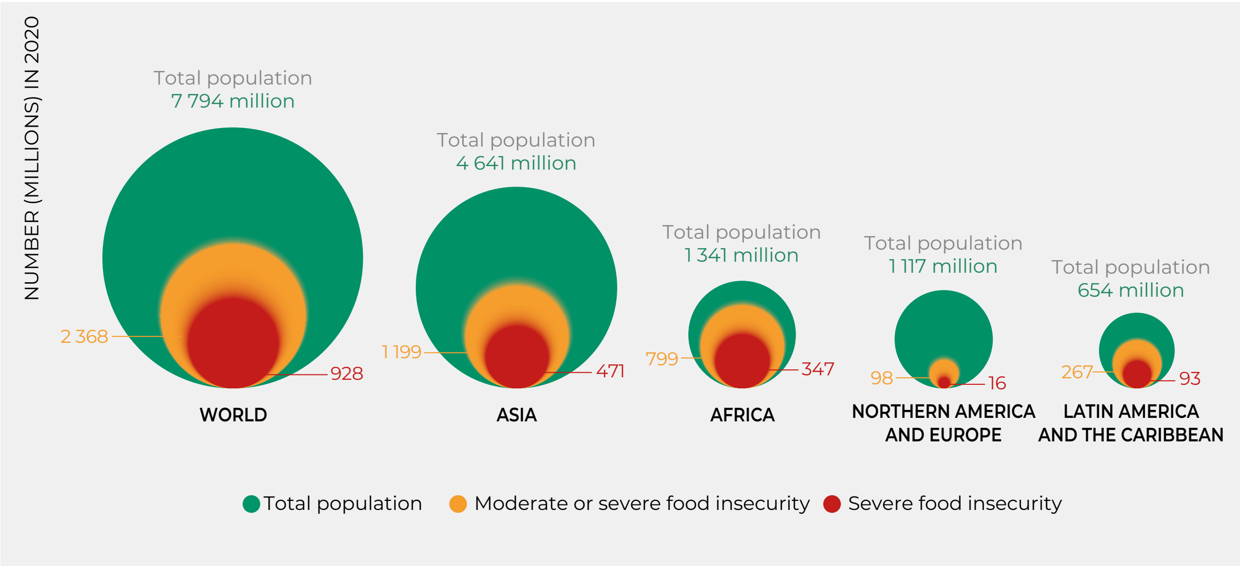
Increasing SOM also ensures rich biodiversity in the soil. The soil organisms play ecologically significant roles, and are essential in making nutrients available to crops by converting inorganic and organic matter in the soil to a form that plants can readily absorb, and by recycling nutrients. Thus, the chemical degradation of land is also addressed when SOM increases.

Ramifications of the State of Soil in the African Union

If the state of soils in the continent is not attended to, the threat to food security, malnourishment, water scarcity, climate change and violence will further deepen and become chronic.

The State of Food Security and Nutrition in the World (SOFI) report of 2021 consistently finds Africa to be one of the most vulnerable regions in the world with respect to food security. The number of people that are food insecure has increased in the last few years. The number of food insecure people as a proportion of population is highest in Africa followed by Asia (Figure 1). Twenty-six percent of the population in Africa is severely food insecure, and 34% people are moderately insecure. In other words, every second person in Africa is food insecure.

Figure 1: A Representation of the Number of Food Insecure People Across the Regions of the World.[34]



Malnourishment among the population is in a similar state. African nations have consistently performed very poorly in addressing the malnourishment of their population. This is no surprise given the state of the soil. Figure 2 is a comparative analysis of where Africa (Eastern, Western, Northern and Southern Africa) stand in the world with respect to malnourishment. Western Africa showed the sharpest increase in prevalence of undernourishment from 2019–2020. The situation has not improved since then. A UN report in February 2022 noted that the Sahel "stares down a horrendous food crisis", and that the number of people on the brink of starvation has increased tenfold in the last three years.[35]

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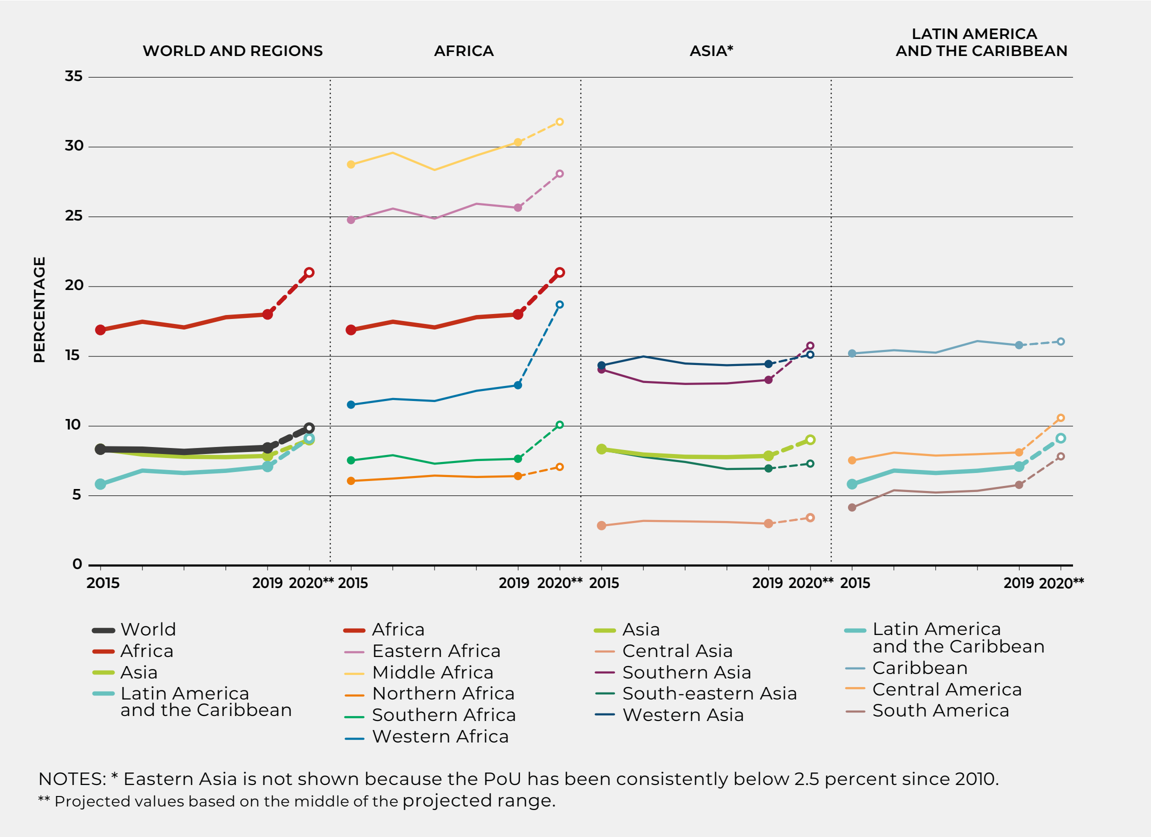
34. Bongaarts, J. (2020). FAO, IFAD, UNICEF, WFP and WHO: The state of food security and nutrition in the World 2020. Transforming Food Systems for affordable healthy diets. *Population and Development Review*, *47*(2), 558. https://doi.org/10.1111/padr.12418

35. *Africa's Sahel region facing 'horrendous food crisis'. UN News. United Nations.* (2022). https://news.un.org/en/story/2022/02/1112122

Figure 2: Prevalence of Undernourishment in the Regions of the World.[36]



The future looks even more challenging, thanks to climate change. According to the State of the Climate in Africa report, Africa is warming faster than the rest of the world. For example, Mount Kenya may be one the first mountains to lose its glaciers due to human intervention.

If climate change is not attended to, desertification will expand across regions of neglect in Africa, which will then descend into conflict and societal unrest. If no interventions are made by 2030, over 118 million extremely poor people will face the brunt of extreme heat, drought and floods in Africa.[37] Sea levels along the tropical and South Atlantic coasts and Indian Ocean, are also rising at a faster pace than the global mean – at approximately 3.6 mm and 4.1 mm per year, respectively.

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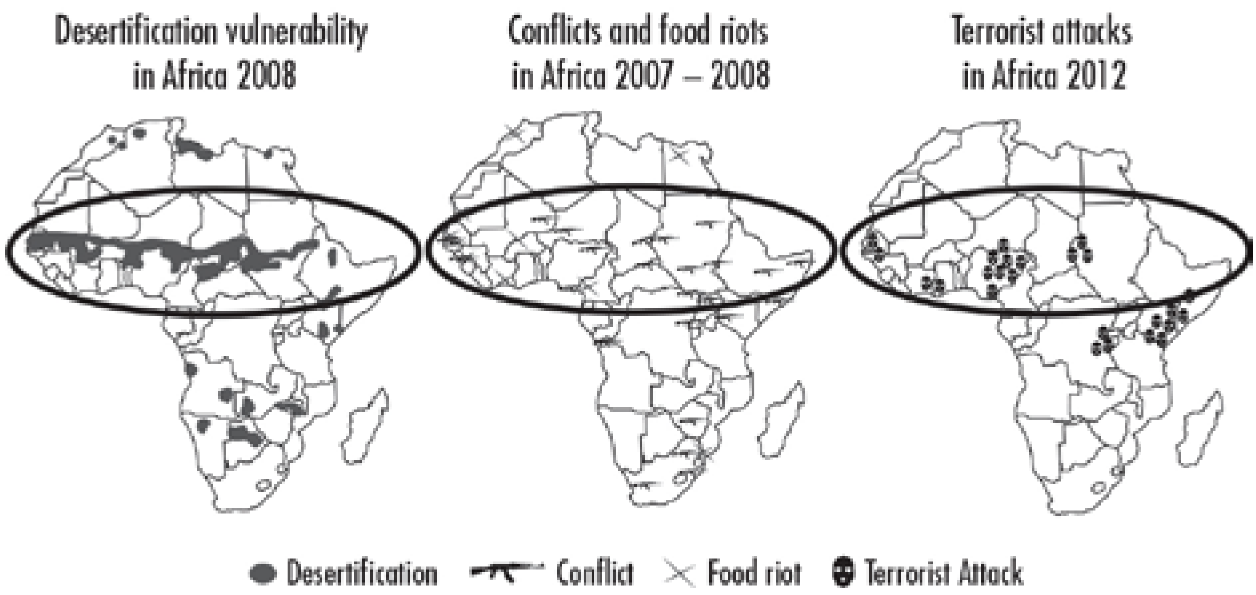
36. Bongaarts, J. (2020). FAO, IFAD, UNICEF, WFP and WHO: The state of food security and nutrition in the World 2020. Transforming Food Systems for affordable healthy diets. *Population and Development Review*, *47*(2), 558. https://doi.org/10.1111/padr.12418

37. *The State of the Climate in Africa 2020*. (2021). World Meteorological Organization, (1275). https://library.wmo.int/doc_num.php?explnum_id=10929

Figure 3: Desertification, Lack of Food, and Violence Are Linked.[38]



Desertification and hunger are deeply related to political instability. As depicted in Figure 3, Stéphane Le Foll, former Minister of Agriculture in the French Government, traces the trajectory.

He has extrapolated on what happens when agriculture becomes unviable for large populations (which happened in Syria a few years ago):

- Mass migration from rural to urban areas.
- Cities become unlivable. With limited employment options in urban areas, unemployment in cities rises.
- More hunger in concentrated urban areas.
- Civil unrest.
- Political instability in urban areas, which further expands to the rest of the country and the entire region.

38. Tickell, J., & Tamminen, T. (2018). *Kiss the Ground: How the Food You Eat Can Reverse Climate Change, Heal Your Body & Ultimately Save Our World*. Simon & Schuster.

Present Policy Ecosystem in the African Union

The agriculture policies across the world can be broadly classified into two types. The first type is where the government wants farmers to improve their productivity to input ratio and overall sustainability of agriculture. The second is where the government only cares about the increase of actual production quantum at any cost. In Africa, governments have focused solely on increasing the production of food over all these years. As around 70% of African farmers are smallholders (making them extremely vulnerable to external shocks from climate change or economic fluctuations,[39] which threaten their agricultural production) such policies affect these farmers substantially. Various governments of the continent have attempted to achieve food and nutritional security.

Here, we will analyze the policies of the African Union (AU),[40] as these policies form the framework for member countries and are indicative of the direction in which the member states aspire to move, with respect to the overall state of their soils.

The major policies of the African Union that are relevant to Sustainable Soil Management (SSM) and agriculture are:

- Comprehensive Africa Agriculture Development Programme (CAADP)
- Malabo Declaration
- Alliance for Green Revolution in Africa (AGRA)
- Agenda 2063
- Continental Nutrition Accountability Scorecard

Other policy elements that affect African soil management include land tenure, and national and regional research ecosystems for agriculture.

39. *The Field Report*. International Fund for Agricultural Development (IFAD). https://www.ifad.org/thefieldreport/

40. The African Union (AU) is a continental union consisting of 55 member states located on the continent of Africa. In the Sirte Declaration in Sirte, Libya, on 9 September 1999, the establishment of the African Union was called for.

Comprehensive Africa Agriculture Development Programme (CAADP) (2003–2021)[41]

The CAADP is Africa's policy framework for agricultural transformation, wealth creation, food security and nutrition, economic growth and prosperity for all. Thus far, the mandate of CAAPD has been to ensure that 10% of the GDP of a nation is invested into the agriculture sector, to realize an annual growth rate of 6% in the sector.

CAADP was launched in 2003 as an integral part of the New Partnership for Africa's Development (NEPAD). The principles and values that inform the implementation of CAADP include: African ownership and leadership; accountability and transparency; inclusiveness; evidence-based planning and decision making; and harnessing regional complementarities. In addition, the principles and values important to CAADP include: people-centeredness; private sector driven development; systemic capacity and subsidiarity; and peer learning and multi-sectorialism.

CAADP has three major pillars of expenditure to improve the state of African agriculture. Additionally, there is a support area that fits horizontally across all three pillars. These are:

- Extending the area under sustainable land management and reliable water control systems
- Improving rural infrastructure and trade-related capacities for improved market access
- Increasing food supply and reducing hunger

The common horizontal is: agricultural research, technology dissemination and adoption.

However, CAADP has not been successful in achieving its goals. An IFPRI assessment suggested that contrary to its goal of ensuring at least 10% budgetary allocation to agriculture, adaptation of CAADP in some countries has led to a reduction in budget allocations for agriculture. Even after a decade of signing CAADP, not all of the 44 countries had a plan for the national adaptation of CAADP. Only nations that could raise external funding for agriculture from one or more sources allocated budgets in line with CAADP norms. This was possible because the country did not have to fund CAADP interventions with its own budget. The report's assessment of CAADP's effect

41. Comprehensive Africa Agriculture Development Programme. *African Union, and NEPAD* (2003).

on land and labor productivity was mixed. The effect of CAADP, where adopted, on income and nutrition was insignificant. This insignificance is reflective of the time it takes for the benefits of policies to trickle down to the general economy and people.[42]

At the end of 2021, CAADP's mandate was updated during a CAADP Partnership Platform meeting, with an agenda to end hunger in Africa by 2025 through resilient food systems.[43] The meeting was held under four thematic areas: strengthening systemic capacity to "build back better"; nutrition and food safety; agri-food trade; and science and innovation. The meet also reviewed the Malabo commitments (detailed in the next section) and discussed fast tracking implementations. This will be informed by the annual dialogue at the Malabo Policy Learning Event (MAPLE). There is also a plan for an AU theme year to celebrate 2022 as the year of nutrition. The objective will be to secure greater political commitment and investment in nutrition to address ongoing nutrition challenges. Specific objectives will be to take stock of the state of malnourishment and efforts being made to address it; facilitate learning and intersectoral coordination; and strengthen the monitoring evaluation and accountability framework. For these specific objectives to be realized, data management and information systems, and knowledge generation and dissemination are proposed as priority areas to focus on for 2022.[44]

Malabo Declaration (2014)[45]

While CAAPD focuses on the growth of the entire agricultural sector, the Malabo Declaration focuses specifically on the third pillar of CAADP – increasing food supply and reducing hunger.

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42. Benin, S. (2016). Impacts of CAADP on Africa's Agricultural-led Development. *IFPRI Discussion Paper 1553. International Food Policy Research Institute.* http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/130647

43. *17th CAADP partnership platform: "Ending hunger in Africa by 2025 through Resilient Food Systems"*. African Union Commission (2021). https://au.int/en/17th-caadp-partnership-platform

44. *Draft Concept Note on the AU Theme of 2022: As the Year of Nutrition*. African Union Commission. (2021). https://au.int/en/documents/20220203/draft-concept-note-au-theme-2022-year-nutrition

45. *Three take-away messages from the African Union Summit in Malabo on agriculture and food security*. ECDPM. (2014) https://ecdpm.org/talking-points/three-take-away-messages-african-union-summit-malabo-agriculture-food-security/

The Malabo Declaration was initiated in 2014 by African Heads of State, to reaffirm CAADP's vision and set concrete targets for its next decade of operation till 2025. These targets are:

- Reducing post-harvest losses by half
- Creating job opportunities for at least 30% of the youth in agricultural value chains
- Ensuring that at least 30% of farm, pastoral and fisher households will be resilient to climate and weather-related risks

Along with these concrete goals, attention was paid to activities needed to improve the functioning of agricultural markets and intra-African trade, with an ambitious goal to triple intra-African trade in agricultural commodities. The Malabo declaration also asked the AU Commission and NEPAD's Planning and Coordination Agency (NPCA) to develop an implementation strategy and roadmap to facilitate translating the visions into reality.

Alliance for Green Revolution in Africa (AGRA) (2006)[46]

Founded in 2005, this alliance was launched to solve the productivity problems of African farmers by providing free access to seeds and fertilizers. It has received generous funds from the Bill and Melinda Gates Foundation, the Rockefeller Foundation and other international NGOs. The intent of the organization is to double the productivity of farmers by 100% and reduce food insecurity by half in a set of 13 African countries with 30 million small-farm holders.

A 12-year evaluation report of AGRA found that it helped increase farmer productivity only by 18%. Despite AGRA's aspirations to eliminate hunger in the 13 nations, and eventually throughout Africa, hunger in these 13 countries actually went up by 30%.[47] Poverty levels, food insecurity and malnourishment numbers in Africa have not gone down.

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46. *AGRA 2018 Annual Report.* https://au.int/sites/default/files/documents/41427-doc-AGRA-Annual-Report_v18_FINAL_Print-Ready_LR.pdf

47. Wise, T. M. (2020). Failing Africa's Farmers: An Impact Assessment of the Alliance for a Green Revolution in Africa. *Global Development and Environment Institute, Tufts University, Working Paper,* (20-01). https://sites.tufts.edu/gdae/files/2020/07/20-01_Wise_FailureToYield.pdf

The reason why AGRA's efforts have not yielded results could be due to the fact that other ecosystem requirements are needed to help farm productivity improve. Merely providing a farmer with seeds and access to fertilizers is not enough if the soil on which these are to be applied is already degraded, if there is not enough water for irrigation, or if farmers are not knowledgeable enough to use fertilizers scientifically.

Agenda 2063 (2013)

At the African Union summit in 2013, the heads of states of the African nations at their 50th anniversary laid down a vision for the Africa they want in 50 years – 2063. That vision later came to be known as Agenda 63 – the goal being a peaceful, integrated and prosperous continent by 2063.

While Agenda 63 is informed by the contextual realities and specific aspirations of the AU nations, it was also informed by the UN Sustainable Development Goals which world leaders had signed up to achieve by 2030. Agenda 63 has seven high-level aspirations that are a composite of 20 specific goals. The goals have a subset of priority areas under them.

Of the list of aspirations listed under Agenda 63 (Table 5), Aspiration 1, "A Prosperous Africa, based on Inclusive Growth and Sustainable Development", is directly affected by agricultural policies. Aspiration 4, "A Peaceful and Secure Africa", and Aspiration 7, "An Africa as A Strong, United, Resilient and Influential Global Player and Partner", are affected indirectly by the advancement of the agricultural sector.

Continental Nutrition Accountability Scorecard (2019)

Malnourishment has plagued Africa for a long time. The African Leaders for Nutrition Initiative, set up by the African Union Commission and African Development Bank, devised the Continental Nutrition Accountability Scorecard to assess the progress across African nations in addressing malnourishment. The scorecard scores countries on 12 indicators of malnourishment, and was developed by the AU in collaboration with the Food and Agriculture Organization (FAO), World Bank, International Food Policy Research Institute (IFPRI), World Food Programme (WFP), and the World Health Organization (WHO). This scorecard is a powerful advocacy tool for nations to assess and address malnourishment, and can be found in Figure 4.

Table 5: Agenda 63 Aspirations for Africa Crafted by the African Union Which Are Impacted by Soil Health[48]

Aspiration	Goals	Priority Areas
1) A Prosperous Africa, Based on Inclusive Growth and Sustainable Development	(1) A High Standard of Living, Quality of Life and Well-Being for All Citizens	Incomes, jobs and decent work
		Poverty, inequality and hunger
		Social security and protection, including persons with disabilities
		Modern and livable habitats and basic quality services
	(2) Well Educated Citizens and Skills Revolution Underpinned by Science, Technology and Innovation	Education and STI skills driven revolution
	(3) Healthy and Well-nourished Citizens	Health and nutrition
	(4) Transformed Economies	Sustainable and inclusive economic growth
		Hospitality/tourism
	(5) Modern Agriculture for Increased Productivity and Production	Agricultural productivity and production
	(6) Blue/Ocean Economy for Accelerated Economic Growth	Marine resources and energy
		Ports operations and marine transport
	(7) Environmentally Sustainable and Climate Resilient Economies and Communities	Sustainable natural resource management and biodiversity conservation
		Sustainable consumption and production patterns
		Water security
		Climate resilience and natural disasters preparedness and prevention
		Renewable energy

48. *Goals & Priority Areas of Agenda 2063*. African Union Commission. https://au.int/agenda2063/goals

2) An Integrated Continent Politically United and Based on the Ideals of Pan-Africanism and the Vision of African Renaissance	(8) United Africa (Federal or Confederate)	Framework and institutions for a United Africa
	(9) Continental Financial and Monetary Institutions are Established and Functional	Financial and monetary institutions
	(10) World Class Infrastructure Crisscrosses Africa	Communications and infrastructure connectivity
3) An Africa of Good Governance, Democracy, Respect for Human Rights, Justice and the Rule of Law	(11) Democratic Values, Practices, Universal Principles of Human Rights, Justice and the Rule of Law Entrenched	Democracy and good governance
		Human rights, justice and the rule of law
	(12) Capable Institutions and Transformative Leadership in Place	Institutions and leadership
		Participatory development and local governance
4) A Peaceful and Secure Africa	(13) Peace, Security and Stability Is Preserved	Maintenance and preservation of peace and security
	(14) A Stable and Peaceful Africa	Institutional structure for AU instruments on peace and security
	(15) A Fully Functional and Operational APSA	Fully operational and functional APSA pillars
5) Africa with a Strong Cultural Identity, Common Heritage, Values and Ethics	16) African Cultural Renaissance Is Pre-eminent	Values and ideals of pan-Africanism
		Cultural values and African renaissance
		Cultural heritage, creative arts and businesses
6) An Africa Whose Development Is People Driven, Relying on the Potential Offered by African People, Especially Its Women and Youth, and Caring for Children	(17) Full Gender Equality in All Spheres of Life	Women and girls empowerment
		Violence and discrimination against women and girls
	(18) Engaged and Empowered Youth and Children	Youth empowerment and children
7) An Africa As a Strong, United, Resilient and Influential Global Player and Partner	(19) Africa As a Major Partner in Global Affairs and Peaceful Co-existence	Africa's place in global affairs
		Partnership
	(20) Africa Takes Full Responsibility for Financing Her Development	African capital market
		Fiscal system and public sector revenues
		Development assistance

Figure 4: Continental Nutrition Accountability Scorecard (2019)[49]

Country	Nutrition Status					
	% of Children under 5 years old who are stunted (moderate and severe)	% of Children under 5 years old who are wasted (moderate and severe)	% of Children under 5 years old who are overweight (moderate and severe)	% of women of reproductive age (15-49 years of age) with anaemia	% exclusive breastfeeding (EBF) among infants 0–6 months of age	% of children under 5 years old with anaemia
Algeria	12	4	12	36	25	30
Angola	38	5	3	48	37	51
Benin	34	5	2	47	41	62
Botswana	31	7	11	30	20	40
Burkina Faso	27	8	1	50	50	86
Burundi	56	5	1	27	82	47
Cabo Verde	21	7	0	33	60	55
Cameroon	32	5	7	41	28	63
Central African Republic (CAR)	41	8	2	46	33	72
Chad	40	13	3	48		73
Comoros	31	11	11	29	21	48
Côte d'Ivoire	22	6	3	53	24	73
Democratic Republic of Congo	43	8	4	29	47	63
Djibouti	34	22	8	33	12	42
Egypt	22	10	16	29	40	32
Equatorial Guinea	26	3	10	44	7	64
Eritrea	50	16	2	38	69	57
Eswatini	26	2	9	27	64	42
Ethiopia	38	10	3	23	57	50
Gabon	17	3	8	59	5	63
Ghana	19	5	3	46	52	67
Guinea	32	8	4	51	35	74
Guinea-Bissau	28	6	2	44	53	68
Kenya	26	4	4	27	61	41
Lesotho	33	3	7	27	67	50
Liberia	32	6	3	35	35	69
Libya	21	7	22	33		29
Madagascar	49	15	6	37	42	49
Malawi	37	3	5	34	59	59
Mali	30	14	2	51	8	83
Mauritania	28	15	1	37	41	68
Mauritius	14	16	7	25	21	36
Morocco	15	2	11	37	28	34
Mozambique	43	6	8	51	41	60
Namibia	23	7	4	23	48	47
Niger	42	10	3	50	23	77
Nigeria	44	7	2	50	23	68
Republic of Congo	21	8	4	52	33	64
Rwanda	37	2	8	22	87	36
São Tomé and Príncipe	17	4	2	46	51	65
Senegal	17	7	1	50	36	68
Seychelles	8	4	10	22		35
Sierra Leone	38	9	9	48	31	77
Somalia	25	15	3	44	5	56
South Africa	27	3	13	26	32	37
South Sudan	31	23	6	34	45	58
Sudan	38	16	3	31	55	57
The Gambia	25	11	3	58	47	76
Togo	28	7	2	49	57	71
Tunisia	10	3	14	31	9	29
Uganda	29	4	4	29	66	51
United Republic of Tanzania	35	5	4	37	59	55
Zambia	40	6	6	34	72	54
Zimbabwe	27	3	6	29	48	42
Source	WHO/ World Bank JME	UNICEF and WHO JMP	WHO	WHO	WHO, NLiS	World Bank /UNICEF

LEGEND

On track · progress · Not on track · No data

49. *Continental Nutrition Accountability Scorecard.* (2019). African Union. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Continental_Nutrition_Accountability_Scorecard-EN.pdf

Coverage of Services			Governance, Policy and Legal Provisions		Socio-Economic Impact	Country
% of children aged 6–59 months who received two age-appropriate doses of vitamin A in the past 12 months	Access to clean drinking water (% population)	Access to improved sanitation facilities (% population)	Legislation on mandatory fortification for foods (No=0, Yes=1)	Legislation on code of marketing of breast milk substitutes	Per Capita Income (USD)	
	93	88	1	0	4 123	Algeria
14	41	39	1	0	4 170	Angola
94	67	14	1	1	829	Benin
75	79	60	0	1	7 595	Botswana
99	54	23	1	0	670	Burkina Faso
78	56	50	1	0	320	Burundi
	86	65	1	1	3 209	Cabo Verde
55	65	39	1	0	1 446	Cameroon
40	54	34	1	0	418	Central African Republic (CAR)
85	43	10	1	0	660	Chad
17	84	34	0	0	797	Comoros
72	73	30	1	0	1 662	Côte d'Ivoire
44	42	20	0	0	457	Democratic Republic of Congo
69	77	51	1	0	1 927	Djibouti
68	98	93	1	0	2 412	Egypt
	50	75	0	0	9 850	Equatorial Guinea
51	19	11	0	0	583	Eritrea
39	68	58	0	0	3 224	Eswatini
79	39	7	1	0	767	Ethiopia
2	88	41	1	1	7 220	Gabon
33	78	14	1	1	1 641	Ghana
69	67	22	1	0	825	Guinea
87	69	22	1	0	723	Guinea-Bissau
41	58	30	1	0	1 507	Kenya
67	72	44	1	0	1 181	Lesotho
92	70	17	1	0	456	Liberia
	97	100	0	0	7 998	Libya
97	51	10	1	1	449	Madagascar
91	67	44	1	0	338	Malawi
99	74	31	1	0	338	Mali
75	70	45	1	0	1 136	Mauritania
	100	93	0	0	10 547	Mauritius
89	83	84	1	0	3 007	Morocco
55	47	24	1	1	415	Mozambique
22	79	34	0	0	5 227	Namibia
94	46	13	1	0	378	Niger
56	67	33	1	0	1 968	Nigeria
48	68	15	1	0	1 658	Republic of Congo
96	57	62	0	0	748	Rwanda
34	80	40	1	0	1 913	São Tomé and Príncipe
99	75	48	1	0	1 033	Senegal
	96	100	0	0	15 504	Seychelles
99	58	15	0	0	499	Sierra Leone
	40	16	0	0	499	Somalia
42	85	73	1	1	6 160	South Africa
66	50	10	0	0	237	South Sudan
	59	35	0	0	2 898	Sudan
27	80	42	1	1	483	The Gambia
61	63	14	1	0	617	Togo
	94	93	1	0	3 490	Tunisia
65	39	19	1	1	604	Uganda
92	50	24	1	1	936	United Republic of Tanzania
99	61	31	1	0	1 509	Zambia
34	67	39	1	1	1 079	Zimbabwe
UNICEF	WHO /UNICEF JMP	WHO/ UNICEF JMP	FFI	WHO	World Bank	Source

In close consultation with

Action Contre la Faim, African Leaders Malaria Alliance, African Nutrition Society, African Union Commission, Aliko Dangote Foundation, Big Win Philanthropy, Bill and Melinda Gates Foundation, Forum for Agriculture Research in Africa, Food and Agriculture Organization of the United Nations, Global Panel on Agriculture and Food Systems for Nutrition, Graca Machel Trust, International Center for Tropical Agriculture, International Food Policy Research Institute, New Partnership for Africa's Development, Scaling-Up Nutrition Movement, United Nations Children's Fund, The World Bank, World Food Program and World Health Organization.

Other Policy Elements That Affect African Soil Management

Land Tenure Issues

According to a report by the World Bank, only 10% of rural lands in Africa were registered. It is estimated that inefficient land administration leads to people taking twice as much time and spending twice as much money to have land registered. [50]

According to Makhtar Diop, World Bank Vice President for Africa in 2013, "Improving land governance is vital for achieving rapid economic growth and translating it into significantly less poverty and more opportunity for Africans, including women who make up 70% of Africa's farmers yet are locked out of land ownership due to customary laws. The status quo is unacceptable and must change so that all Africans can benefit from their land."[51]

Land tenure type and policies dictate land use practices and also have an effect on the soil. When land tenure was studied in three countries – Cameroon, Kenya and Zambia – it was found that both customary (traditional tribal systems) and statutory land (law guided by the constitution) tenure is characterized by insecurity. These two coexisting yet incongruous land tenure types also cause conflict and unsustainable use of soil. For example, the land tenure of "community" owned lands can be taken away from communities for national development.[52]

National and Regional Research Ecosystems

Africa's knowledge systems and infrastructure to conduct agriculture research are not robust, held back by insufficient allocation of human, financial and physical resources. In an Agriculture Science and Technology Indicators (ASTI) initiative assessment led by IFPRI, it was found that the agricultural research setup in the region, including institutions, human resources, and expertise needed bolstering.

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50. Byamugisha, F. F. K. (2013). Securing Africa's land for shared prosperity: A program to scale up reforms and investments. *Africa Development Forum Series, Open Knowledge Repository, World Bank*. https://openknowledge.worldbank.org/handle/10986/13837?locale-attribute=en

51. *Africa's land reform policies can boost agricultural productivity, create food security and eradicate poverty*. World Bank. (2013). https://www.worldbank.org/en/region/afr/publication/securing-africas-land-for-shared-prosperity

52. Ginzky, H., & Ruppel, O. C. (2022). Soil Protection Law in Africa: Insights and recommendations based on Country Studies from Cameroon, Kenya and Zambia. *Soil Security, 6*. https://doi.org/10.1016/j.soisec.2021.100032

In the past, all agricultural research conducted in Africa was driven by colonizing nations – England, Belgium and France. It took a few decades after independence for African nations to build their own research ecosystems. However, these ecosystems are still inadequate. In fact, the number of researchers per thousand agricultural laborers has reduced over the decades. Even today, the agriculture research agenda and budgets in the region are heavily dependent on foreign donor funding and donor funded researchers.

Governments, however, are interested and eager to pursue R&D efforts. This can be seen in the large budgetary allocations in some nations. For example, under CAADP's National Agriculture Investment Plan for Nigeria and Senegal, 40% of their budget is allocated to R&D. There is a flipside to this however. Other nations, such as Mali and Niger, allocate less than 5% of their budget to R&D, betraying the fact that many nations do not have the wherewithal to invest in R&D.

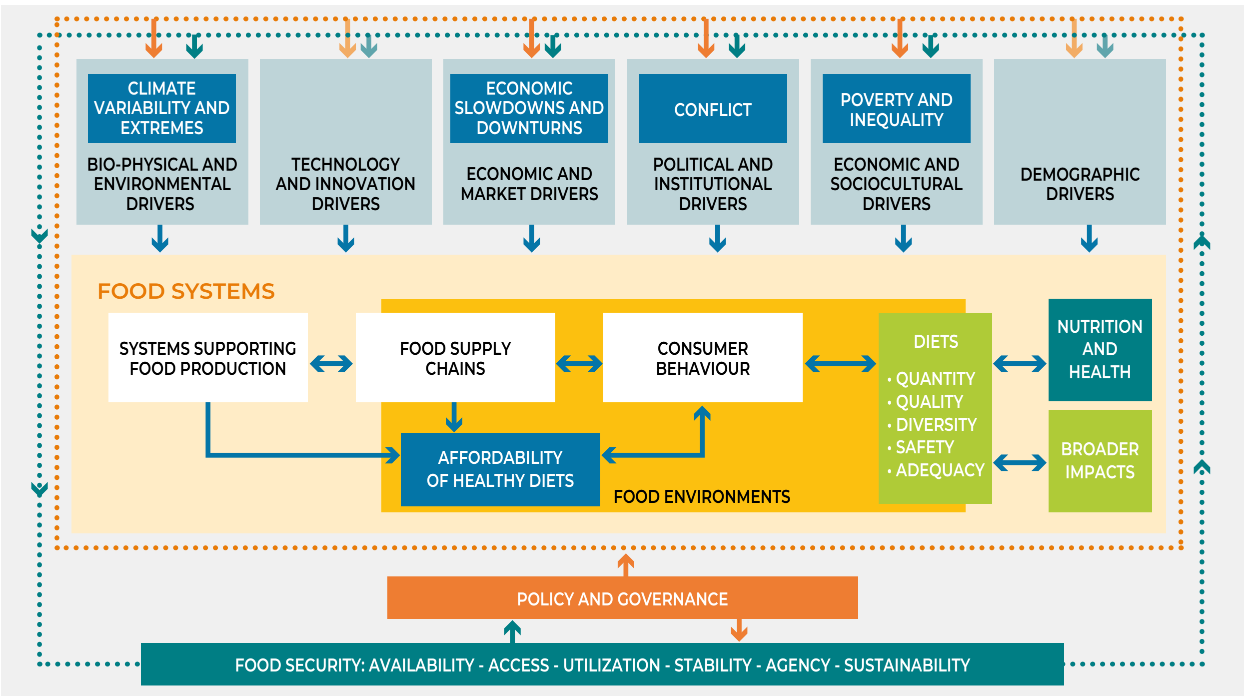
A special note must be made of one entity that has been dedicated to improving the state of African agriculture through R&D, namely the Consultative Group for International Agricultural Research (CGIAR), which has operated several research stations in Africa for many decades.

Policy Recommendations for the African Union

"If nothing happens, I fear we will have a forceful expansion of the desertification of soil. Global water and wind erosion of soil will be catastrophic. Secondly, I fear if we don't move concretely forward with this project, the biodiversity of soil itself will be lost. If we do nothing, I fear we will lose the fertility of soil. We will lose biodiversity. We will lose agricultural soil and at the end there will be escalating hunger and enormous problems in terms of feeding the planet. The longer we wait the higher the likelihood we will unleash this irreversible process. Because once it becomes infertile, it takes a very long time for soil to regain fertility." – Stéphane Le Foll, French Agriculture Minister, excerpted from *Kiss the Ground*[53]

While there are several issues at large in the continent, the most pressing are hunger and poverty. Figure 5 gives the framework from the SOFI report, which establishes the relationship between all parameters that affect food security in any region.

Figure 5: Framework to Ensure Food Security in Any Region of the World[54]



53. Tickell, J., & Tamminen, T. (2018). *Kiss the Ground: How the Food You Eat Can Reverse Climate Change, Heal Your Body & Ultimately Save Our World*. Simon & Schuster.

54. FAO, IFAD, UNICEF, WFP and WHO. (2021). The State of Food Security and Nutrition in the World 2021: Transforming food systems for food security, improved nutrition and affordable healthy diets for all. *FAO*.

Within the given framework of existing policies in the African Union, there should be concerted efforts taken to ensure that SSM practices that improve SOM are taken up by farmers with a sense of urgency. A minimum SOM of 3–6% should be the aspiration of all farmers.

The agriculture practices of tilling the soil and low plant diversity adversely affect the soil microbiome, and by extension SOM.[55] This is especially detrimental for smallholder farmers in SSA who are dealing with inherently poor-quality soil. These practices must therefore be avoided. Instead, farmers must ensure that the soil is not left barren, and is either covered with cover crop, mulch or reduced tilling. All the principles that are mentioned in Chapter 2 of this publication are to be followed. When these practices are adopted, SOM increases, leading to an increase in Soil Organic Carbon (SOC) also.

A caveat here is that considering the diversity of African states with regard to the level of urbanization/industrialization, political systems, history, and societal realities, the recommendations listed are the ones that apply to the maximum number of countries. These recommendations should be further analyzed, contextualized with local experiences and concretized before being applied.

In summary, if SSM practices appropriate to the context of soil type and agroecological condition are adopted to increase SOM, the four main drivers of soil degradation can be adequately addressed.

Achieving a minimum of 3–6% SOM will need four pillars of intervention:

- Knowledge Systems
- Farmer Support Ecosystem
- Legal Provisions
- Monitoring and Learning Systems

55. McDaniel, M. D., Tiemann, L. K., & Grandy, A. S. (2014). Does agricultural crop diversity enhance soil microbial biomass and organic matter dynamics? A meta-analysis. *Ecological Applications, 24* (3), 560–570. https://doi.org/10.1890/13-0616.1

Knowledge Systems

Africa is a huge landmass having various thermo-climatic zones – tropical (tropical lowlands, tropical highlands), subtropical (subtropical summer rainfall, subtropical winter rainfall, subtropical low rainfall). The interventions for SSM strategies should be in line with these regions, and this will be possible only when there is an ecosystem with researchers, extension workers and training to support farmers.

Soil scientist Dr. Rattan Lal, in a summit held on food systems of Africa, suggested that there be a research ecosystem that is staffed by African researchers from within the country, or at the very least from within the continent. This will ensure that expertise is built within the region.[56] Being native to the region will also equip researchers with the socio-political context of the region. There are a few countries such as Zambia, Kenya and Ghana where R&D organizations are doing some very relevant work for the farmers of their region.

As already mentioned, current agricultural research in Africa is partly donor-funded and substantially donor-guided. These donor-driven activities should also deploy experts from within the local country, or at least from Africa. This will build internal expertise in the country and region. Donor nations should ensure that they follow SSM practices when intervening in any aspect of agriculture.

The research ecosystem should be looking at helping farmers adopt SSM practices without much loss during the transition period. Advisory and research should also facilitate climate resilience for farmers.

Farmer Support Ecosystem

The farmer ecosystem in the continent is quite inadequate at this point in time. Given the expanse of the countries and the number of farmers, this pillar of intervention requires a lot of attention and work.

Access to Training: For farmers to transition to SSM practices, they need hands-on training on their land. There has to be access to training material and experts round the clock, as on-farm emergencies like a pest attack cannot afford a delay in response.

56. *A Food Systems Approach to Transforming Africa's Soil Health: Policy, Science, Implementation and Impact*. IFDC. (2021). https://ifdc.org/2021/10/25/a-food-systems-approach-to-transforming-africas-soil-health-policy-science-implementation-and-impact/

Soil Doctors: The concept of soil doctors has been developed and adopted in certain countries of Africa. They are grassroots farmers who are trained to address specific local issues of farmers. Soil doctors must be developed and nurtured to support farmers in their region. The soil doctors to farmers ratio should be such that it ensures effective extension work to farmers.

Reward Farmers: Farmers must be incentivized and rewarded for putting SOM back into soil by measuring SOC. Carbon credit markets can pay farmers for sequestration in their lands. However, pricing must be fair, transparent and just. Middle men and evaluators should not earn more than 10% as a commission or administrative fee.[57]

Reward Monitoring of SOM: Farmers must be rewarded for ecosystem services provided by their SSM practices. This can be achieved by monitoring SOM, other soil biology parameters, and terrestrial biodiversity on their land.[58]

Incentives and Resource Support During Transition: Farmers should be supported in the transition to SSM practices with access to free seeds, and with incentives to follow specific practices such as cover cropping and similar interventions. The transition to SSM will need a change in equipment to be used on the land. The government can set up equipment lending for groups of farmers.

Legal Provisions

The current state of land tenure in Africa is not conducive to SSM. In a study conducted on soil protection laws in Cameroon, Kenya and Zambia, it was found that there is no explicit mention of soil protection. There is also no substantive provision for SSM in the constitutions of these countries, although some of them have an overarching environmental protection plan that only cursorily mentions soil. However, these cursory mentions found in environmental acts were not enforced.[59]

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57. *A Food Systems Approach to Transforming Africa's Soil Health: Policy, Science, Implementation and Impact*. IFDC. (2021). https://ifdc.org/2021/10/25/a-food-systems-approach-to-transforming-africas-soil-health-policy-science-implementation-and-impact/

58. Lal, R. (2022). *Soil Organic Carbon and Feeding the Future: Basic Soil Processes*. CRC Press.

59. Ginzky, H., & Ruppel, O. C. (2022). Soil Protection Law in Africa: Insights and recommendations based on Country Studies from Cameroon, Kenya and Zambia. *Soil Security, 6*. https://doi.org/10.1016/j.soisec.2021.100032

There is therefore a need for framework legislation[60] to sustainably manage soil.[61] The overarching planning instruments to achieve SSM can be drawn from Land Degradation Neutrality principles. This framework legislation could also outline the general institutional roles, competencies and responsibilities in managing soil health.

Monitoring and Learning Systems

Soil Health Map: Currently, there is no map of soil parameters for Africa that can be used for land use planning. Mapping of soils across all agroecological zones, at a resolution that is suitable for land use planning is necessary. The preferred resolution is 1:10,000 or 1:20,000, and should be no less than 1:50,000.[62] GSOC[63] maps and GLOSIS of the Global Soil Partnership can help set up the overall mapping infrastructure. They can also train local cartographers and researchers to collect samples that can be further used for model generation.

Soil Testing Ecosystem: Soil biology should be made a part of soil testing reports, and the testing ecosystem – non-existent at present – should be established and strengthened. Instead of setting up elaborate infrastructure for laboratories like the rest of the world, Africa can try to use field testing kits that are being developed across the world. The soil testing kits can be used extensively to help farmers make scientific decisions on crop inputs. There can be some physical infrastructure laboratories run by research organizations for a more detailed understanding of what is happening to the soil.

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60. "Framework legislation" refers to legislation that sets out structures for governance and accountability or other processes for guiding the decisions and actions taken by government or the executive.

61. Ruppel, O. C., & Ginzky, H. (2021). African Soil Protection Law: Mapping out options for a model legislation for improved sustainable soil management in Africa – a comparative legal analysis from Kenya, Cameroon and Zambia. *Nomos, Law and Constitution in Africa, 41.* https://www.nomos-shop.de/shopfiles/leseprobe_978-3-8487-6693-2_leseprobe.pdf

62. *A Food Systems Approach to Transforming Africa's Soil Health: Policy, Science, Implementation and Impact*. IFDC. (2021). https://ifdc.org/2021/10/25/a-food-systems-approach-to-transforming-africas-soil-health-policy-science-implementation-and-impact/

63. *Global Soil Organic Carbon (GSOC) Map*. Global Soil Partnership. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/global-soil-partnership/pillars-action/4-information-and-data-new/global-soil-organic-carbon-gsoc-map/en/

3.3 Policies for Asia

East Asia: China, Democratic People's Republic of Korea, Japan, Mongolia, and Republic of Korea

South East Asia: Brunei, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor Leste, and Vietnam

South Asia: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka

Central & West Asia:[1] Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkey, Turkmenistan and Uzbekistan

1. Eurasia according to the Global Soil Partnership.

Asia Statistics[2]

Total Population: 4.3 billion

GDP: USD 29.08 trillion

GDP per Capita: USD 1,960 (South Asia) – USD 13,065 (East Asia)
(Varies significantly across the region)

Total Landmass Area: 25.9 million km²

Landmass under Agriculture: 14.081 million km²

Population Dependent on Agriculture as a Percentage of Total Employment: 31%

Average Farm Size: 0.3 ha[3] – 55 ha[4]
(Land holding size varies drastically across Asian nations.)

Executive Summary

Asia is the largest and most populated continent that is home to 60% of the human population. Seventy percent of Asia's population lives in rural areas.[5] The high population density of Asia is an outcome of the fertile soils, moderate temperatures and adequate rains that East, South East and South Asian countries are endowed with, and the temperate climatic conditions of Central and West Asia.

The East, South East and South Asian regions are characterized by high rainfall, high temperatures and existence of extensive lowlands that are inundated by monsoons. These unique features make Asia a leader in rice production, supplying 90% of the world's rice demand and earning it the title of 'rice granary' of the world.[6] These regions of Asia also have some of the largest rivers in the world, such as the Yellow River, Yangtze, Mekong, Ganga, Brahmaputra, and Indus, which create alluvial plains and deltas, and fertile lands. In contrast, the high-altitude regions are low in soil fertility and susceptible to soil erosion.

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2. *World Bank Open Data*. https://data.worldbank.org/

3. Ritchie, H., & Roser, M. (2021). Farm size. *Our World in Data*. https://ourworldindata.org/farm-size

4. *FAO Country Programming Framework (CPF) in the Republic of Belarus (2014–16)*. Ministry of Agriculture and Food & FAO Regional Office for Europe and Central Asia. https://www.fao.org/3/bp574e/bp574e.pdf

5. *Asia Population (LIVE)*. Worldometer. https://www.worldometers.info/world-population/asia-population/

6. Ahmad, N. S. B. N., Mustafa, F. B. B., Yusoff, S. Y. M., & Didams, G. (2020). A systematic review of soil erosion control practices on the agricultural land in Asia. *International Soil and Water Conservation Research*, *8*(2), 103-115. https://doi.org/10.1016/j.iswcr.2020.04.001

Meanwhile, the countries in West Asia generally have temperate climates with warm summers and cold winters (e.g., Armenia, Azerbaijan and Georgia), except for Turkey, which is characterized by a Mediterranean climate, with hot, dry summers, and cold, rainy winters. The Central Asian nations of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan have arid and semi-arid climates with sparse vegetation and ecosystems susceptible to desertification.

Asia as a continent has been successful in pulling the largest number of people out of poverty and food insecurity through various interventions. Starting from 1950, land reforms such as redistribution of land to small farmers, increase in investments in irrigation, improvement in seed varieties – were instrumental in achieving this. This was bolstered by the Green Revolution through the mid-1960s until 1990. Governments supported farmers to transition to chemical farming by providing access to modern machinery. This resulted in an increase in per capita production of rice and wheat (the staples of the region) by 41% and 246%, respectively.[7]

While the soils have yielded to all these interventions for food security in the past, they are now beginning to show signs of fatigue. The health of soils in Asia is slowly degrading. Over 1.7 billion ha of land in Asia[8] *are affected by desertification. Although the natural arid and semi-arid climatic conditions in some areas are prone to desertification, the acceleration of desertification is due to unsustainable land use such as overgrazing, not integrating enough organic content back into the soil, deforestation, and other such agricultural practices. Millions of hectares of land in Asia are threatened by loss of Soil Organic Carbon (SOC), soil salinization and sodification, soil erosion, soil contamination from injudicious use of agrochemicals in agricultural lands, other forms of pollutants, and nutrition imbalance in soils due to either excess or reduced use of fertilizers/pesticides. A study conducted by the UN Environment Programme (UNEP) on land degradation trends in Asia from 2002–2013 found that there has been enormous cost due to degradation, to the tune of USD 733 billion from reduced productivity due to topsoil loss.*[9]

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7. *Asia's Journey to Prosperity: Policy, Market, and Technology over 50 Years: Manila*. Asian Development Bank. (2020). http://dx.doi.org/10.22617/TCS190290

8. Van Cotthem, W. (2019). Desertification in Asia – Annex II. *Desertification*. https://desertification.wordpress.com/2019/08/07/desertification-in-asia-annex-ii/

9. Tilahun, M., Kumar, P., Singh, A., Apindi, E., Schauer, M., Libera, J., & Lund, G. (2018). The Economics of Land Degradation Neutrality in Asia: Empirical Analyses and Policy Implications for the Sustainable Development Goals. *ELD and UNEP*. https://wedocs.unep.org/bitstream/handle/20.500.11822/33098/ELDA.pdf?sequence=1&isAllowed=y

The FAO has predicted that Asia needs to increase food production by 60% to become food secure.[10] *If the threats to soil that are discussed here are not solved with a sense of urgency, there is a very high risk of famines, water scarcity and civil unrest.*

In this policy section for Asia, we cover the state of its soils and the ramifications of it, the existing policy ecosystem through a focus on soil health, and finally, Conscious Planet's policy recommendations to ensure the threats to soil are addressed holistically. If sustainable soil policies are to be adopted, there will be a cost to transition which amounts to USD 2,494/ha in Asia according to the UNEP report. This investment will translate to a benefit of USD 8,663/ha, which is 350% of the cost.[11]

The State of Agricultural Soil in Asia

According to an FAO report on the status of the world soils published in 2015,[12] soils in Asia are facing various threats to different degrees. The threats include: reduction in SOM, erosion from water and wind, soil contamination, soil acidification, soil salinization and sodification, loss of soil biodiversity, waterlogging, nutrient imbalance, soil compaction, and soil sealing and capping. Among the above-mentioned ten threats, changes in SOM, erosion, salinization and sodification, and nutrient imbalance are the major contributors to soil deterioration in East, South East and South Asia. The major threats that affect Central Asian countries are soil contamination, reduction in SOM, salinization and sodification. Therefore, in this section we will discuss these major soil threats:

- Reduction in SOC/SOM
- Salinization and sodification
- Erosion
- Nutrient imbalance
- Contamination

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10. *The water-energy-food nexus: A new approach in support of food security and sustainable agriculture*. Food and Agriculture Organization of the United Nations (FAO). (2014). https://www.fao.org/3/bl496e/bl496e.pdf

11. Tilahun, M., Kumar, P., Singh, A., Apindi, E., Schauer, M., Libera, J., & Lund, G. (2018). The Economics of Land Degradation Neutrality in Asia: Empirical Analyses and Policy Implications for the Sustainable Development Goals. *ELD and UNEP*. https://wedocs.unep.org/bitstream/handle/20.500.11822/33098/ELDA.pdf?sequence=1&isAllowed=y

12. Montanarella, L., Pennock, D., & McKenzie, N. (2015). Status of the World's Soil Resources (Technical Summary). *FAO, Rome, Italy*.

The root cause of these soil threats in Asia is unsustainable agricultural practices, such as plowing, leaving lands open, lack of crop rotation, lack of integration of animal manure in the soil, inappropriate irrigation and injudicious use of fertilizers and pesticides.

Reduction in SOC/SOM

China occupies the largest land area in the region (760 million ha). Between 1980–2000, the SOC in croplands (0–20 cm depth) was estimated to have gone up by 260 Tg C,[13] due to increased yields and retention of crop residue in the fields. However, this was offset by the degradation of over 5.29 million ha of grassland, which has led to depletion of SOC.[14] Thus, over twenty years, a net 2.86 Pg C was lost through grassland degradation, which amounts to approximately 3.4% of China's total SOC storage.

India occupies the second largest area (329 million ha). It is estimated that forests accumulated SOC at the rate of 0.041 Pg C per year over a 100-year period from 1880–1981. However, SOC has dwindled in agricultural lands to a mere 0.3–0.4%.[15] In a 2004 study,[16] eminent soil scientist Dr. Rattan Lal observed that agricultural land had 5 g SOC / kg of soil compared with uncultivated lands which had 10–15 g SOC / kg of soil. This disparity is due to plowing, removal of crop residue and other biosolids, and mining of soil fertility. According to the Wasteland Atlas released by the Government of India, 29.32% (94.4 million ha) of land is undergoing various stages of land degradation, and 28.7% (82.64 million ha) of land is desertified.[17]

Other Asian countries have also seen a loss in SOC. In Indonesia, it is due to deforestation, intensive cropping and land pool management practices.[18] In Mongolia,

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13. Yu, Y. Y., Guo, Z. T., Wu, H. B., Kahmann, J. A., & Oldfield, F. (2009). Spatial changes in soil organic carbon density and storage of cultivated soils in China from 1980 to 2000. *Global Biogeochemical Cycles, 23*. https://doi.org/10.1029/2008GB003428

14. Han, Y. W. & Gao, J. X. (2005). Analysis of main ecological problems of grasslands and relevant countermeasures in China. *Res. Environ. Sci., 18,* 60–62. [in Chinese]

15. Jaisankar, C. (2014). Decline in soil organic carbon content worries ICAR. *The Hindu.* https://www.thehindu.com/news/cities/Tiruchirapalli/decline-in-soil-organic-carbon-content-worries-icar/article6678512.ece

16. Lal, R. (2004). Soil carbon sequestration in India. *Climatic Change*, *65*(3), 277–296. https://doi.org/10.1023/B:CLIM.0000038202.46720.37

17 *Desertification and Land Degradation, Atlas of India.* ISRO, Government of India. 2011–13. https://www.isro.gov.in/desertification-and-land-degradation-atlas-released

18. Hartanto, H., Prabhu, R., Widayat, A. S. E., & Asdak, C. (2003). Factors affecting runoff and soil erosion: plot level soil loss monitoring for assessing sustainability of forest management. *Forest Ecology and Management, 180*(1), 361–374. https://doi.org/10.1016/S0378-1127(02)00656-4

where 73% of land is under pasture, 7% under forest and 0.4% under arable land, a change in land use was observed over a 20-year period – land under forest was reduced, leading to SOC loss. Additionally, pasture lands saw 20–50% reduction of SOC because of intense grazing.[19] In Central Asia, 4% of its total stock of SOC was lost due to change in land use of rangelands to agricultural lands (both rainfed and irrigated).[20]

Salinization and Sodification

Soil salinization and sodification primarily affect the arid and semiarid zones of Central and West Asia. Although salt-rich soils are present naturally in these countries, the concern is the conversion of non-saline lands into saline lands due to improper agricultural practices, such as irrigation with saline water, and poor drainage systems.[21]

Saltwater intrusion into coastal lands and groundwater aquifers is a looming threat. Although only a relatively small area of coastal lands is affected as of now, this problem can spread inland through unsustainable use of soil and groundwater aquifers. According to Global Assessment of Human-induced Soil Degradation (GLASOD) modeling, at least 42 million ha of land is affected by salinization in the region.[22] Salinization impacts around 4 million ha in Pakistan.[23] Meanwhile, India's own estimates of land affected by salinity is 6.73 million ha,[24] exceeding the 4 million ha estimated by GLASOD. Twenty million ha of India's land is projected to be affected by 2050. The lands reclaimed by South Korea through the Tideland reclamation projects also face salinity issues, which prevents these lands from being used for agriculture.[25]

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19. Chang, X., Bao, X., Wang, S., & Wilkes, A., … & Damdinsuren, B. (2015). Simulating effects of grazing on soil organic carbon stocks in Mongolian grasslands. *Agriculture Ecosystems & Environment*, *212*, 278–284. https://doi.org/10.1016/j.agee.2015.07.014

20. Sommer, R., & de Pauw, E. (2011). Organic carbon in soils of Central Asia—status quo and potentials for sequestration. *Plant and Soil*, *338*(1), 273–288. https://doi.org/10.1007/s11104-010-0479-y

21. Krasilnikov, P., et al. (2016). Regional Assessment of Soil Changes in Europe and Eurasia (Chapter 11). In: Status of the World's Soil Resources: Main Report, pp. 330–363. *FAO.* https://www.fao.org/3/bc600e/bc600e.pdf

22. Global Assessment of Human-induced Soil Degradation (GLASOD). *ISRIC World Soil Information.* https://www.isric.org/projects/global-assessment-human-induced-soil-degradation-glasod

23. *ibid.*

24. Sharma, D. K., & Singh, A. (2015). Salinity Research in India: Achievements, Challenges and Future Prospects. *Water and Energy International, 58*(6), 35–45. https://www.researchgate.net/publication/304395327_Salinity_Research_in_India-Achievements_Challenges_and_Future_Prospects

25. Reclaimed lands: Land reclamation, usually known as reclamation, and also known as landfill is the process of creating new land from oceans, seas, riverbeds or lake beds.

The area that can be categorized as "salt-affected soils" in Central and West Asian countries is 41% of Kazakhstan (111.5 million ha), 46.5% of Uzbekistan (20.8 million ha), 28.7% of Turkmenistan (14.1 million ha), and 79.6% of Turkey that are slightly saline or saline, and around 6% of Azerbaijan (0.51 million ha).[26]

Erosion

The total area in Asia affected by soil erosion in 2001 was 663 Mha.[27] Asia has the highest percentage of lands in the world that are either highly eroded or severely eroded.[28] In 2012, around 80.6% of Asia faced light erosion, 4.9% moderate erosion, 6.9% high erosion, and 7.6% very high erosion.

Most regions of South and South East Asia are affected primarily by water erosion, due to the intense monsoon. In the drier part of East Asia, wind erosion is prevalent. In 2007, 55 Mha of South Asia were affected by water erosion, and 24 Mha by wind erosion.[29] This number would have surely gone up in the fifteen years since. Central and West Asian nations, due to their arid and semi-arid climatic conditions, face more wind erosion, which has affected 67 million ha of land, while water erosion impacted around 30 million ha of land.[30] In Uzbekistan and Tajikistan, water is the cause of erosion in 80% and 60–97% of arable lands. In Turkey, as 80% of soils are on slopes steeper than 15%, 78.7% of the country is affected by wind erosion.[31]

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26. Krasilnikov, P., et al. (2016). Regional Assessment of Soil Changes in Europe and Eurasia (Chapter 11). In: Status of the World's Soil Resources: Main Report, pp. 330–363. *FAO.* https://www.fao.org/3/bc600e/bc600e.pdf

27. Lal, R. (2001). Soil Degradation by Erosion. *Land Degradation and Development*, *12*(6), 519–539. https://doi.org/10.1002/ldr.472

28. Borrelli, P., Robinson, D. A., Fleischer, L. R. *et al*. (2017). An assessment of the global impact of 21st century land use change on soil erosion. *Nature Communications, 8*, 2013. https://doi.org/10.1038/s41467-017-02142-7

29. Lal, R. (2007). Soil Degradation and Environment Quality in South Asia. *International Journal of Ecology and Environmental Sciences, 33*(2), 91–103. https://www.researchgate.net/publication/228420002_Soil_degradation_and_environment_quality_in_South_Asia

30. Krasilnikov, P., et al. (2016). Regional Assessment of Soil Changes in Europe and Eurasia (Chapter 11). In: Status of the World's Soil Resources: Main Report, pp. 330–363. *FAO.* https://www.fao.org/3/bc600e/bc600e.pdf

31. Senol, S. & Bayramin, I. (2013). Soil Resources of Turkey. In: Yigini, Y., Panagos, P., Montanarella, L. (Eds.). Soil Resources of Mediterranean and Caucasus Countries. *JRC Technical Reports, European Commission.* https://esdac.jrc.ec.europa.eu/ESDB_Archive/eusoils_docs/other/EUR25988EN.pdf

Nutrient Imbalance

Nutrient imbalance is caused by injudicious application of agrochemicals for improved yields. Nutrient inputs in Asia vary between countries, between regions of a country and between various farming systems. However, as a region, the nutrient input trend in Asia is higher than the rest of the world. Based on current usage patterns, this trend appears likely to continue.

Nutrient imbalance in Asia is most markedly observable with nitrogen inputs. Nitrogen input trends have been reported across six countries representing developing (China and India), developed (Japan and South Korea) and least developed countries (Laos and North Korea) to understand the difference in nutrient balance. China had the highest input of nitrogen (505 kg/ha of arable land) and Laos the lowest input (59 kg/ha).[32] In the case of the booming economies, China and India, the N input was dominated by chemical fertilizers accounting for 76% and 67% of N input, respectively. In the developed countries of Japan and South Korea, the N input was evenly distributed between natural and chemical sources. In the least developed countries (LDC) of Laos and North Korea, nitrogen inputs came from animal manure, crop residue and biological N fixation.

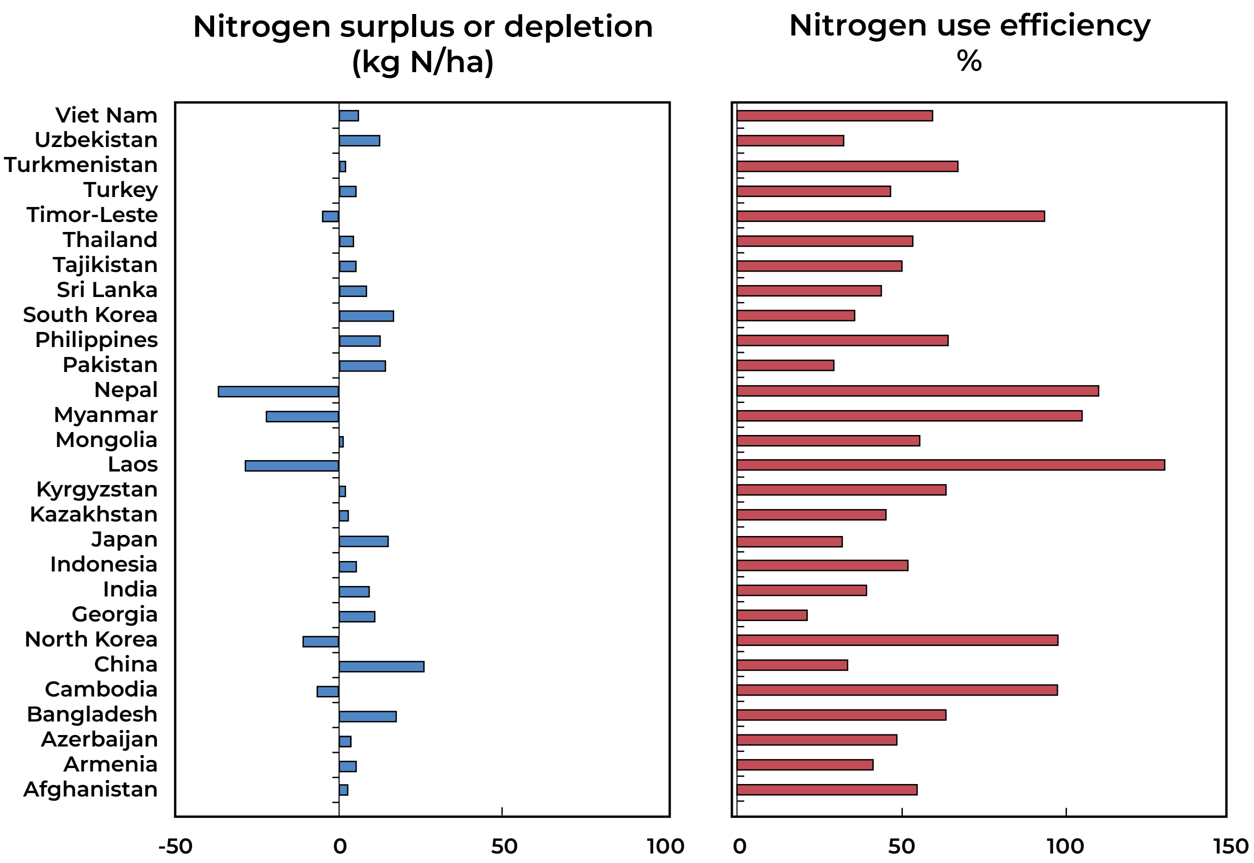
Nitrogen use efficiency (NUE) is defined as the ratio of N output as crop production to the N inputs that are added through fertilizer, biological N fixation and N deposition.[33] The best-case scenario is to have a 100% NUE. In other words, efficient nitrogen use neither mines the nutrient from the soil, nor accumulates it in the soil. All nitrogen that is added is consumed by the plant. However, NUE is not always optimal, and varies across Asian nations, as shown in Figure 1.

In China, 26 kg/ha of excess N is accumulated in the soils per year. As a consequence of excess N application, higher N losses through leaching has happened in soils in China, as well as in Japan and South Korea. However, in Laos and North Korea, N-leaching does not occur as the N inputs are too miniscule to even meet the plants' needs. Instead, these countries face nutrient mining from the soils.

32. Vitousek, P. M., Naylor, R., Crews, T., David, M. B., Drinkwater, L. E., Holland, E., Johnes, P. J., Katzenberger, J., Martinelli, L. A., Matson, P. A., Nziguheba, G., Ojima, D., Palm, C. A., Robertson, G. P., Sanchez, P. A., Townsend, A. R., & Zhang, F. S. (2009). Nutrient imbalances in agricultural development. *Science, 324,* 1519–1520. https://doi.org/10.1126/science.1170261

33. Ma, L., Ma, W. Q., Velthof, G. L., Wang, F.H., Qin, W., Zhang, F. S. & Oenema, O. (2010). Modeling nutrient flows in the food chain of China. *Journal of Environmental Quality, 39*(4), 1279–89. https://doi.org/10.2134/jeq2009.0403

Figure 1: Nitrogen surplus, depletion and use efficiency in Asian countries.[34]



Contamination

Soil contamination in arable lands happens either due to inherent characteristics of the parent material (e.g., geogenic presence of arsenic, cadmium, etc.), industrial mining, agrochemicals (e.g., arsenic, cadmium, mercury, lead, copper, zinc, nickel), sewage sludge application and livestock manure use. Figure 2 maps the pollution due to agrochemicals in the form of pesticides alone, across the worldwide phenomenon.

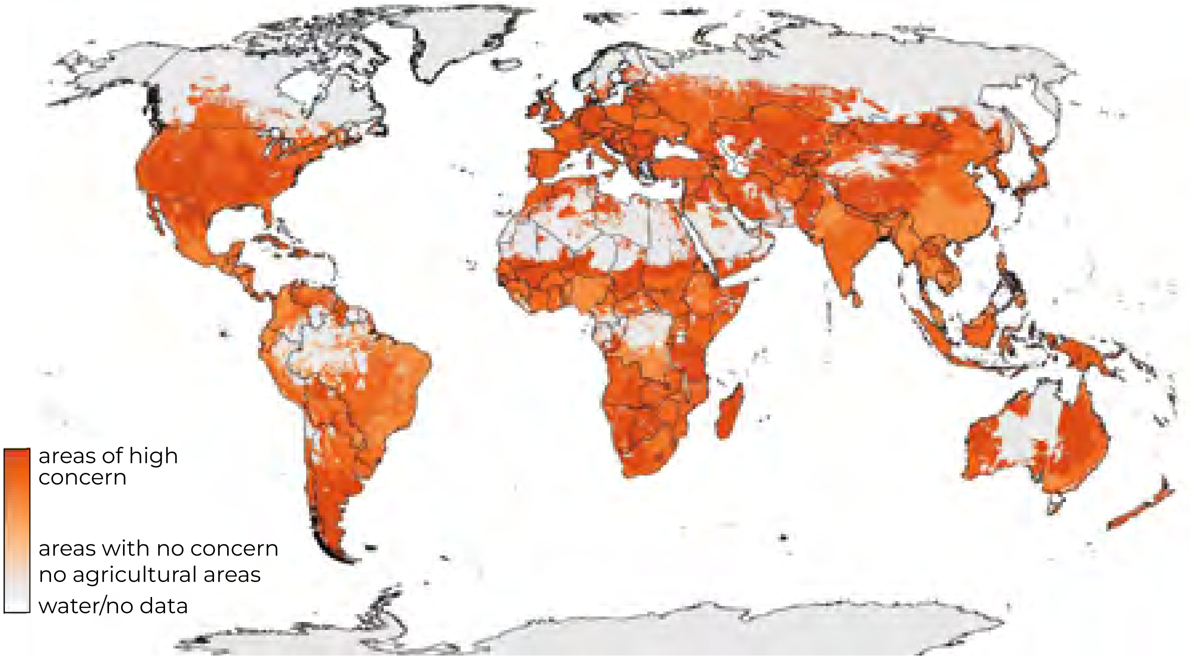
Unfortunately, heavy metal contamination is prevalent in Asia. For example, around 19.4% of agricultural lands in China are polluted by high levels of cadmium, nickel and

34. Yagi, K., Agus, F., Arao, T., Aulakh, M. S., Bai, Z., Carating, R., … & Zhou, D. (2015). Regional Assessment of Soil Change in Asia. In: Status of the World's Soil Resources: Main Report, pp 287–329. *FAO.* https://www.fao.org/3/bc599e/bc599e.pdf

arsenic.[35] Another example is Indonesia, where historic and present rates of intensive pesticide and fertilizer use in agricultural lands have led to the accumulation of organic pollutants and heavy metals in soil.[36]

Extrapolating from Indonesia, we can infer significant agrochemical pollution in the rest of Asia as well, since many Asian nations apply even higher levels of fertilizer and pesticide.[37, 38] Heavy metal pollution is an issue of very serious concern, and cadmium, arsenic, lead, copper and zinc concentrations must be reduced in soils to prevent phytotoxicity and bioaccumulation of chemicals in plants, which lead to health implications for animals and humans in the food chain.

Figure 2: Global Areas Susceptible to Pesticide Pollution[39]



35. Wei, C.Y., & Chen, T.B. (2001). Hyperaccumulators and phytoremediation of heavy metal contaminated soil: a review of studies in China and abroad. *Acta Ecologica Sinica, 21*, 1196–1203. https://www.semanticscholar.org/paper/Hyperaccumulators-and-phytoremediation-of-heavy-of-Chao/c47babcdcb3f45b614502beda0bec3409fca8877

36. Rai, P. K., Lee, S. S., Zhang, M., Tsang, Y. F., & Kim, K. H. (2019). Heavy metals in food crops: Health risks, fate, mechanisms, and management. *Environment International*, *125*, 365–385. https://doi.org/10.1016/j.envint.2019.01.067

37. *Pesticide Use by country*. Worldometer. https://www.worldometers.info/food-agriculture/pesticides-by-country/

38. *Fertilizer consumption (kilograms per hectare of arable land)*. Data. https://data.worldbank.org/indicator/AG.CON.FERT.ZS?view=chart

39. FAO, IFAD, UNICEF, WFP and WHO. (2021). The State of Food Security and Nutrition in the World 2021: Transforming food systems for food security, improved nutrition and affordable healthy diets for all.

Ramifications of the State of Soil in Asia

Soil threats in Asia can reverse the enormous work done by many nations to transition large numbers of people out of poverty in rural areas, and can intensify the effects of poverty on those who are still impoverished. There are three major ramifications of the state of soils in Asia – food insecurity, water stress and agrarian poverty. All three ramifications will be further intensified due to erratic weather patterns caused by climate change in future.

Food insecurity

The food insecurity faced in Asia is a composite of absolute hunger and nutritional deficiency. Of the 2.3 billion people in the world who are facing moderate to severe hunger, around half (1.2 billion) are in Asia. Undernourishment in Asia affects 418 million people. Of the 1.85 billion people in Asia who are unable to afford a healthy diet, 70% live in South Asia (Table 2). The COVID pandemic further caused the number of food-insecure people to increase.

Table 2: Number of people unable to afford a healthy diet in Asia.[40]

	Cost of a Healthy Diet in 2019		People Unable to Afford a Healthy Diet in 2019		
	Cost (USD per person per day)	Change between 2017 and 2019 (percent)	Percent	Total number (millions)	Change between 2017 and 2019 (percent)
ASIA	**4.13**	**4.1**	**44.0**	**1852.8**	**-4.2**
Central Asia	3.42	0.9	16.9	5.8	-22.0
East Asia	4.99	6.4	13.5	213.5	-7.4
South East Asia	4.41	4.9	49.5	316.1	-2.9
South Asia	4.12	1.2	71.3	1281.5	-4.2
West Asia	3.77	5.3	20.3	35.9	8.1

Given the state of present food insecurity in the region and the potential increase in population by 2050, soil quality plays a very significant role. Over the past five

40. FAO, IFAD, UNICEF, WFP and WHO. (2021). The State of Food Security and Nutrition in the World 2021: Transforming food systems for food security, improved nutrition and affordable healthy diets for all.

decades, crop yields in Asia have increased,[41] but the rate of increase in grain production has not kept pace with the rapid population growth, especially in South Asia, where soils are prone to degradation by erosion, nutrient mining, soil organic matter depletion, salinization, decline in soil structure, and industrial pollution.[42]

Soil quality significantly affects crop yields and agronomic productivity. Fertilizers and soil amendments may not be available to farmers, and even if they are, their effectiveness will not achieve maximum potential in degraded soils. Various studies have observed that agricultural practices that improve soil quality through increase in SOC and natural nitrogen amendment result in improvement in yields.[43] The corollary has also been studied: crop yields from poor quality soils (due to erosion) show a yield reduction of 30–90%.[44] Therefore, working on soil health – especially increasing SOM – becomes paramount as it leads to improvement in the soil quality, which has a direct bearing on crop yields, improving nutrition levels and ensuring food security.

Water Stress

Asia is home to 60% of the world's population today. The per capita fresh water availability in Asia today is 47% of the global per capita availability. Among the three major uses of freshwater – agriculture, industry and potable use – agriculture is the biggest consumer. Agricultural consumption of freshwater in the world is generally at least 70% of the total freshwater use.[45] In Asia, agriculture accounts for 80–90%[46] of freshwater use. If this pattern of water consumption continues, the per capita water availability will fall drastically, pushing the entire region from water stress to physical water scarcity (per capita availability less than 500 m^3).

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41. *Asia's Journey to Prosperity: Policy, Market, and Technology over 50 Years: Manila.* Asian Development Bank. (2020). http://dx.doi.org/10.22617/TCS190290

42. Lal, R. (2018). Soil Quality and Food Security: The Global Perspective. In: *Soil Quality and Soil Erosion.* CRC Press.

43. Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science, 304*(5677), 1623–7. https://doi.org/10.1126/science.1097396

44. Mbagwu, J. S. C., Lal, R., & Scott, T. W. (1984). Effects of desurfacing of Alfisols and Ultisols in Southern Nigeria: I. Crop performance. *Soil Science Society of America Journal, 48*, 828–833. https://doi.org/10.2136/sssaj1984.03615995004800040026x

45. *Water in agriculture*. World Bank. https://www.worldbank.org/en/topic/water-in-agriculture#1

46. *Agriculture water use in North and Central Asia*. ESCAP. https://www.unescap.org/blog/agriculture-water-use-north-and-central-asia

Present agricultural practices have led to poor soil structure, adversely affecting the soil's ability to hold water. Therefore, agriculture practiced on these poor soils demands more water than healthy soils.

It is proven that SOM has a net positive impact on increasing the Available Water Capacity (AWC) of farmland,[47] thereby reducing the irrigation requirement. SOM reduces bulk density and improves soil structure, thus allowing rainfall to infiltrate in a sustained manner into groundwater aquifers.[48] SOM is therefore a critical factor in ensuring water security for the region.

Agrarian Poverty

For a farmer to be successful in agricultural enterprise, the basic requirements are quality soil, adequate water and access to promising markets and fair price for their commodity. Especially for small landholders, the success of agricultural enterprise is extremely important as their entire livelihood depends on it. South, South East and East Asian countries have a large number of small land holders. With poor quality soil and climate shock events (e.g. droughts and floods) leading to repeated failed crops, many of the small holder farmers are in desperate times. They either sink into poverty or are submerged in debts, and in extreme cases, turn to suicide. For example, since 2005, more than 100,000 farmers in India have committed suicide as they could not cope with the challenges of farming.

Farming has become increasingly unattractive. Young people are searching for urban jobs that pay better, require less heavy labor, and are considered more dignified or prestigious.[49] With the younger generation not willing to enter into agriculture, the average age of farmers has risen – it is now 54 years in Thailand, 57 in the Philippines, and 66 in Japan.

To make farming attractive once again, it is important to ensure the basic requirements are taken care of. SOM plays a key role in improving soil quality

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47. Bronick, C. J., & Lal, R. (2005). Soil Structure and Management: A review. *Geoderma 124*(1–2), 3–22. https://doi.org/10.1016/j.geoderma.2004.03.005

48. Owuor, S. O., Butterbach-Bahl, K., Guzha, A. C., Rufino, M. C., Pelster, D. E., Díaz-Pinés, E., & Breuer, L. (2016). Groundwater recharge rates and surface runoff response to land use and land cover changes in semi-arid environments. *Ecological Processes*, *5*(16). https://doi.org/10.1186/s13717-016-0060-6

49. Siddiqi, Y. (2015). Who's Growing Tomorrow's Food? *Asian Development Blog*. https://blogs.adb.org/blog/whos-growing-tomorrows-food

and making soil resilient to climate change shocks,[50] thus meeting two of the fundamental requirements for successful agriculture.

Present Policy Ecosystem in Asia

In this section we look at the historical context of present-day agriculture in Asia and the regional initiatives of groups of countries, including ASEAN[51] for South East Asian countries, SAARC[52] for South Asian countries, CAREC[53] for Central Asian countries, and East Asian nations.

Historical Context of Agriculture in Asia

Immediately after World War II, newly independent states in Asia wanted to become economically independent and therefore wanted to establish heavy industries. The existing economy in Asia was however agrarian and per capita food availability by the end of the 1950s was still lower than pre-war, colonial production.[54] Several Asian countries therefore introduced various policy interventions to become food secure. These interventions have moved Asian countries from being net food importers to net food exporters in the last five decades.

Land Tenure and Food Imports in the 1950s

Land reforms allowed agriculture to lay the foundation for economic wellbeing across Asian countries. As lack of access to land tenure is a consistent bottleneck to ensuring agriculture is done sustainably in Middle-Income Countries (MIC) and LDC countries across the world, post-independence land reforms were initiated in various countries

50. Lal, R. (2013). Climate–resilient agriculture and soil organic carbon. *Indian Journal of Agronomy*, *58*(4), 440-450. https://www.researchgate.net/publication/280028239_Climate-resilient_agriculture_and_soil_organic_carbon

51. ASEAN – Association of Southeast Asian Nations. Member countries: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam.

52. SAARC – South Asian Association for Regional Cooperation. Member countries: Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka.

53. CAREC – Central Asia Regional Economic Cooperation Program. Member countries: Afghanistan, Azerbaijan, People's Republic of China, Georgia, Kazakhstan, Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan.

54. The ECAFE region in 1964. *Economic and Social Survey of Asia and the Far East 1964.* https://doi.org/10.18356/675ede91-en

starting from the 1950s,[55] to redistribute lands to small and landless farmers who were farming those lands. In Japan, 33% of arable land was redistributed to some 61% of rural households. Similarly, 27% of arable land was redistributed to 63% of rural households in Taipei.[56] The pace of reform rollout varied across countries.

Land reforms improved the agricultural sector by empowering small, landless farmers. However, these reforms were not sufficient to solve the issue of food import dependency. Food imports in Asia went up by 40% from 4.2 million tons to 5.9 million tons, between 1952–54 and 1961–63.[57] This consistently exposed Asian countries to the risk of food shortage, and in fact, terrible food shortages hit some of the South Asian countries such as India in the 1960s.

To change the “ship-to-mouth” situation, governments had to put in a more concerted effort towards increasing agricultural production. The regional leadership understood that they needed to invest in the agricultural sector and rural areas to wean their countries away from food imports. There was a call to make traditional agricultural practices more efficient by making use of modern technology and machine-driven farming in order to produce enough food for the population.

The Green Revolution in the 1960s

The technological revolution to transform traditional agriculture came to be known as the Green Revolution, and it began in South East Asia. It boosted grain productivity, and shifted Asia from being a food importer to a food exporter, which it is even today. The Green Revolution was essentially a package of high-yielding seeds along with application of modern inputs (inorganic fertilizers) and improved irrigation. Concerted action was taken to bring the Green Revolution to every farmer in Asia and make agriculture profitable, including:

- Development of modern wheat and rice strains that were responsive to fertilizers, short-statured and suitable for modern climate and tropical weather

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55. *Asia’s Journey to Prosperity: Policy, Market, and Technology over 50 Years: Manila.* Asian Development Bank. (2020). http://dx.doi.org/10.22617/TCS190290

56. Deininger, K. (2003). Land Policies for Growth and Poverty Reduction. *World Bank Policy Research Report.*

57. *Asia’s Journey to Prosperity: Policy, Market, and Technology over 50 Years: Manila.* Asian Development Bank. (2020). http://dx.doi.org/10.22617/TCS190290

- Establishment of research institutions specific to rice and wheat, such as the International Rice Research Institute (IRRI) and International Maize and Wheat Improvement Center (CIMMYT), in the second half of the 1960s.
- Investments in the rural food production ecosystem, such as access to modern machinery
- Strengthening last mile connectivity of farmer support services

The efforts yielded significant results across Asia. For example, the rice yields increased from 2 t/ha in the early 1960s to about 7 t/ha in East Asia and 4 t/ha in South Asia and South East Asia in 2015. Wheat yields also increased from 1 t/ha in the early 1960s to over 5 t/ha in East Asia and 3 t/ha in South Asia in 2015.[58]

The increase in crop yields and the increase in total land area brought under agriculture caused an upward trend of food production for a few decades. Thus, less focus was given to investment and agricultural research in the early 1990s.[59] After that, unsustainable land use began to take its toll and the soil health began to deteriorate. The result of this was apparent in the food crisis the world faced in 2008, especially in developing nations.[60]

Soil-Specific Policies Across Asia

Policies for sustainable soil management (SSM) vary across Asia, from rudimentary to comprehensive. It is evident that more developed economies have more clear and detailed policies for soils under agricultural use.

Soil-Specific Policies in ASEAN Countries

ASEAN countries have a strategic plan of cooperation in Food, Agriculture and Forestry for the period of 2016–2025.[61] One of the goals is to increase the resilience of food systems and mitigate and adapt to climate change.

58. *Asia's Journey to Prosperity: Policy, Market, and Technology over 50 Years: Manila.* Asian Development Bank. (2020). http://dx.doi.org/10.22617/TCS190290

59. Pingali, P. L., Hossain, M., & Gerpacio, R. V. (1997). Asian Rice Bowls: The Returning Crisis?. *International Rice Research Institute and Center for Agriculture and Bioscience International.* http://books.irri.org/0851991629_content.pdf

60. *World Development Report 2008: Agriculture for Development.* World Bank Group. (2013). https://doi.org/10.1596/978-0-8213-6807-7

61. *Vision and Strategic Plan for ASEAN Cooperation in Food, Agriculture and Forestry (2016-2025).* ASEAN-CRN. (2015). https://asean-crn.org/vision-and-strategic-plan-for-asean-cooperation-in-food-agriculture-and-forestry-2016-2025/

In 2017, the regional consortium published a clear guideline (in collaboration with the BMZ – Ministry for Economic Cooperation and Development department of Germany) to educate the small farmers of this region in managing their soil and nutrient inputs sustainably.[62] The document lists all the components that are needed for sustainable soil management:

- **Technology package:** To inventorize regional maps, degraded soils, and protocols to improve these soils
- **Decision support:** A support system in which soil doctors help farmers through last mile connectivity and give them access to technical experts.
- **Delivery system:** Soil doctors help farmers by setting up IT and communication systems which provide farmer-friendly information.
- **Regulatory functions:** To examine the ecosystem of labs and QQ/ QC facilities to measure the quality and nutrient content of soils.

Soil-Specific Policies in SAARC Countries

South Asia is home to 25% (1.8 billion people) of the global population. Over 67% of South Asia's population lives in rural areas, and almost half of its workforce (42%) is employed in agriculture. Thus, agriculture plays a very prominent role in the economy of South Asia.

The countries within the region are pursuing SSM through their own national policies, but all of them are at a very nascent stage of development and/or implementation. In 2019, agricultural ministers of SAARC (South Asian Association for Regional Cooperation) countries met to discuss cooperation in agriculture under the Technical Committee on Agriculture and Rural Development (TCARD).

TCARD has also conducted various meetings and workshops in collaboration with the International Fund for Agricultural Development (IFAD) and FAO to intensify food production sustainably. As an outcome of its collaboration with IFAD, SAARC came up with two policy recommendations and a logical framework, "SAARC Partnership Action Plan (2017-2025) on Land & Soil Management and Water Use Efficiency for

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62. Thandar, N. *et al.* (2017). ASEAN Guidelines on Soil and Nutrient Management. ASEAN Sustainable Agrifood Systems. https://www.asean-agrifood.org/download/asean-guidelines-on-soil-and-nutrient-management-final-draft/

Sustainable Intensification of Agriculture in South Asia (2017–2025)," which is a 7-year action plan to manage soil and water resources of the region sustainably.[63]

Soil-Specific Policies in Central Asian and South-Caucasus Countries[64]

Central Asian and South Caucasus countries share a similar agricultural policy framework, which was heavily influenced by the USSR. Since the fall of the USSR, there have been waves of reforms in the agriculture sector, such as land reforms, price liberalization, and dismantling of collective farming. A one-time push in agricultural productivity by land reforms and restructuring of the agricultural sector saw a surge in yields.

The land and labor productivity of the region is still far below the world averages for various crops. The regional policies aim to diversify produce, reduce the region's dependence on food imports, improve trade access to farmers and increase value addition capacity. The nations are also strategizing to address the land and water constraints unique to the region.

The focus of policies across the region has been to help nations become self-sufficient in terms of food, and to eradicate hunger. Recently, the focus in Central Asian nations has slowly shifted towards sustainable use of land under agriculture.

All the Central Asian countries have a version of the National Agriculture Development Framework under which desired outcomes and related policies are detailed. The focus of the policies in the region is (i) achieving food security and safety, (ii) increasing farmers' income, (iii) enhancing agricultural competitiveness, and (iv) promoting sustainable agricultural development.[65]

Soil Specific Policies in East Asia

There is no formal grouping of East Asian nations which can reflect the policy regime of the region. The three countries which make up most of East Asia are China, Japan

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63. *Agriculture and Rural Development*. SAARC. (2020). https://www.saarc-sec.org/index.php/areas-of-cooperation/agriculture-rural-development

64. South-Caucasus Countries: Armenia, Georgia, and Azerbaijan

65. Asian Development Bank. (2020). *Agriculture development in the Central Asia Regional Economic Cooperation Program member countries: Review of trends, challenges, and opportunities*. https://www.adb.org/publications/trends-agricultural-development-carec-countries

and South Korea. We will look at the present policy regimes in these nations to understand the policy ecosystem in the region.

The soil management policy and implementation regime of Japan[66] is robust, and has a detailed map and assessment of the soils across the nation. It prioritizes sustainability of soil fertility management, assessment systems to measure soil contamination and SOC, and a system to disseminate information to farmers to safeguard food security. They have digitized all the cultivated soils (1:50,000 ratio), set up 20,000 soil monitoring sites and a system to analyze soil health indicators (soil erodibility, soil carbon stock, available water content, soil nitrogen map and soil temperature).

Alongside this, a research ecosystem conducts long-term and short-term experiments to understand the effect of agricultural practices on the soil. All this information is eventually used to formulate an advisory that guides farmers about judicious use of specific fertilizers on their farms.

South Korea also has crafted policies for soil. “The Act on the Promotion of Environment-Friendly Agriculture and Fisheries and the Management of and Support for Organic Foods” which promotes sustainable agriculture was initially crafted in 2012 and has since been amended favorably for both the wellbeing of soils and farmers.[67]

China launched the National Strategy on Rural Revitalization (2018–2022) in 2018 to support agricultural and rural development and poverty reduction. The strategy pledged support for family and smallholder farms[68] and emphasized the importance of sustainability, inclusive growth, and environmental sustainability in agricultural development.[69]

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66. Yagi, K. (2012). Status and priorities of soil management in Japan. *Managing Soils Workshop, FAO, Rome, Italy.* https://www.slideshare.net/FAOoftheUN/status-and-priorities-of-soil-management-in-japan-kazuyuki-yagi

67. *Act on the Promotion of Environment-Friendly Agriculture and Fisheries and the Management of and Support for Organic Foods, Etc.* FAO. http://extwprlegs1.fao.org/docs/pdf/kor166959.pdf

68. China Statistical Yearbook 2018. *National Bureau of Statistics China. China Statistics Press.* http://www.stats.gov.cn/tjsj/ndsj/2018/indexeh.htm

69. Huang, J., & Rozelle, S. (2018). China’s 40 Years of Agricultural Development and Reform. In: Ross, G., Ligang, S., & Cai, F. (Eds.). *China’s 40 Years of Reform and Development: 1978–2018.* Social Sciences and Academic Press (China). ANU Press. pp. 487–506.

Country-Specific Policies from SOILEX

The existing legal instruments on soil protection and prevention of soil degradation vary greatly in Asian countries. The FAO SOILEX[70] lists parameters of soil conservation, soil erosion, soil restoration, soil monitoring, soil quality, nutrient imbalance, soil pollution, waterlogging, soil biodiversity loss, soil acidification, soil compaction, and SOC loss. Some countries have planned extensively, laying out the necessary measures to achieve their sustainable development goals. Others have not updated laws and regulations after the 20th century and are only striving to restrict further decline in soil health rather than rigorously articulate and pursue solutions towards regenerating soil.

Central and West Asia

In the Central and West Asia group, Georgia stands out for setting high standards and consistently updating its environmental acts, including several laws pertaining to soil protection and soil conservation. It has eight separate laws / resolutions / orders under the Soil Conservation category alone and several National Action Plans (NAP) like the Second National Action Program to Combat Desertification 2014–2022.

Having a plan for financing and collaborations is key to achieving targets and building the ecosystem to deliver action on the ground. The Law of Georgia on Soil Conservation and Restoration-Improvement of Soil Fertility (No. 2260-IIS of 2003) goes particularly into the financing of soil conservation and restoration-improvement of soil fertility; state control and supervision of soil conservation and restoration-improvement of soil fertility, and international cooperation for soil conservation and restoration/improvement of soil fertility.

Moldova, Azerbaijan and Kazakhstan also have notably progressive plans in place. Tajikistan created their one and only law “On Soil Protection” in 2010, accurately highlighting “careful soil management, soil conservation and improvement of soil fertility.”

Armenia, Belarus, Kyrgyzstan, Turkmenistan and Uzbekistan could further improve their existing laws and frameworks to be more aligned to soil regeneration and provide relevant solutions for the same.

70. SoiLEX is a global database that aims to facilitate access to information on existing legal instruments on soil protection and prevention of soil degradation.

East Asia

Mongolia has the most comprehensive laws in place from the East Asia group of countries. As an example, Article 8 of the Soil Protection and Desertification Prevention Law made in 2012 establishes incentives for soil protection and desertification prevention measures. Article 9 is about assessment and analysis of soil erosion, degradation, pollution and desertification. Article 10 recognizes the need to set up a database of soil protection and desertification prevention measures.

China has over 20 different laws in the SOILEX portal. Some laws have been well created as focused solutions to fix particular land use categories such as the Grassland Law of the People's Republic of China 2002 (Order of the President No. 82). This national law, originally enacted in 1985, ensures stock carrying capacity is not exceeded on grasslands, as overgrazing is a major cause of land degradation. It further suggests appropriate methods of managed grazing, including regional rotation grazing and rational distribution of herds for the balanced use of grasslands.

Similar to Russia, China has several laws targeting soil conservation in particular provinces / regions to tackle the unique problems of those areas; this is an ideal approach in countries with large land areas or vast agroecological zones.

South East Asia

In the South East Asia group, Indonesia has strong policies laid out especially for peatlands, as it is home to 70% of the peatlands in South East Asia.[71] Cambodia, Lao People's Democratic Republic, Myanmar, Vietnam, and Timor Leste also have in place more recent (post-2000) and therefore more scientifically up-to-date action plans that contain the FAO SOILEX soil protection categories.

South Asia

In the South Asia group of countries, Nepal and Bangladesh are the only countries with a 10-year framework for soil health. Nepal has a Priority Framework for Action Climate Change Adaptation and Disaster Risk Management in Agriculture. Rightly so, it includes implementing technical options in agriculture and livestock sectors that include SSM practices like organic farming, community biodiversity management

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71. *Peatlands in Southeast Asia*. ASEAN Specialised Meteorological Centre. https://www.mss-int.sg/vfsp-was/about/peatlands-in-southeast-asia

and integrated nutrient management to enhance soil health. India and the rest of the South Asian countries' soil laws are not progressive, either because they have not yet paid attention to mature and update them or because they are simply not aligned with SSM or soil improvement directly.

Policy Recommendations for Asia

South, South East and East Asian countries have made huge strides towards reducing poverty and hunger over the past seven decades. This has come at the cost of degradation of soils from unsustainable land use. The soils of Asia today face various anthropogenically induced threats. For a densely populated continent like Asia to be food secure — now and in the future – and have ample water to meet the needs of a growing population, the health of the soils has to be revitalized. As mentioned earlier, bringing back a minimum of 3–6% SOM in agricultural lands is one simple aspect that can address all other aspects that are ailing the soils of Asia.

Nations like Japan have set up comprehensive soil health management and farmer assistance systems, while other nations like China and India are in the process of setting up these systems. Some others are only beginning to articulate soil policies. Japan has set up a very thorough knowledge generation system that is tied closely to its farmer support ecosystem and monitoring and learning systems, and can serve as a model for LDC and MIC countries in the region. Hence, there is a huge opportunity for intra-regional collaboration to accelerate the process of setting up ecosystems to manage soils sustainably.

This collaboration can draw on and modify ASEAN's "ASEAN Guidelines on Sustainable Soil and Nutrient Management" policy document, such that it covers the whole of Asia.

Knowledge Systems

Asia is spread over many agroecological zones, a wide range of latitudes from temperate arid to tropical lowlands. There are centers of excellence for these various agroecological zones and specific crop types. These centers are run by UN entities and international think tanks, such as the International Center for Agricultural Research in the Dry Areas (ICARDA) whose work is relevant to Central and West Asia, and IRRI which is relevant to the entire South, South East and East Asian regions who produce most of the rice consumed globally.

Asian Soil Information Systems

The work done by research institutions like ICARDA, IRRI, governments and aided projects, in the past and future, should be cataloged and documented into a simple Package of Practices (PoP). The PoPs for Asian countries should take into consideration the geographical context of the farmers, such as rainfall and temperature patterns. They should also be specific to crop type based on its specific nutritional requirement, and across various soil types of that nation or region. The nutritional requirements and means of production for these crops should be precisely articulated to avoid problems that arise due to excess usage of inputs or application of the wrong inputs – both organic and inorganic. Implementing this will ensure the pollution and contamination of soils from excess use of agrochemicals does not occur. One such database was put together by the Global Soil Partnership in its Regional Implementation Plan (2016), which sought to establish Asian Soil information systems to set up a knowledge system.[72]

Experts Within the Region

According to an IFPRI report, within the developing part of the world (MENA, Latin America, Asia and Africa), the rate of return on research in agriculture is highest in Asia.[73] Another analysis done by Organization for Economic Co-operation and Development (OECD) suggests that for countries within South East Asia, compared with other countries at a similar level of development, there is significant scope to increase investments in R&D and innovation systems to help safeguard future levels of productivity growth and mitigate some of the expected negative effects of climate change [74]

Asia, unlike Africa, also has a reasonable agricultural research infrastructure. Asia does not suffer a dearth of research institutions. Agricultural policies of the Central Asian countries have also sought to fill research and extension gaps created during the region's transformation to a smallholder-dominated production system. Policies

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72. *Report of the Third Asian Soil Partnership Workshop: Towards a Regional Implementation Plan for Asia.* FAO, Rome. (2016). https://www.fao.org/3/br396e/br396e.pdf

73. Hazell, P. (2009). Transforming agriculture: The Green Revolution in Asia. *IFPRI. Discussion Paper 00911.* https://www.researchgate.net/publication/292797700_Transforming_agriculture_The_Green_Revolution_in_Asia

74. *OECD-FAO Agricultural Outlook 2017–2026*. Food and Agriculture Organization of the United Nations (FAO). https://stats.oecd.org/Index.aspx?DataSetCode=HIGH_AGLINK_2017

included support for research, development, and technology adoption. In countries such as Kazakhstan, Tajikistan, and Uzbekistan,[75] supporting domestic research and development has been written into the nations' strategies. Thus, continuing their agricultural research activities can pay off in a big way for Asian nations.

Farmer Support Ecosystem

The farmer ecosystem is lacking in Central and West, South and South East Asia. Given the expanse of the countries and the number of farmers, this pillar of intervention requires a lot of attention and work. Specifically, the following are the recommendations for Asia:

Access to Training: For farmers to transition to SSM practices, they need hands-on training on their land. There has to be access to training material and experts round the clock, as on-farm emergencies like a pest attack cannot afford a delay in response.

Soil Doctors: The concept of soil doctors has been developed and adopted in certain African countries. They are grassroots farmers who are trained to address specific local issues of farmers. Soil doctors must be developed and nurtured to support farmers in their region. The soil doctors to farmers ratio should be such that it ensures effective extension work to farmers.

Reward Farmers: Farmers must be incentivized and rewarded for putting SOM back into soil by measuring SOC. Carbon credit markets can pay farmers for sequestration in their lands. However, pricing must be fair, transparent and just. Middle men and evaluators should not earn more than 10% as a commission or administrative fee.[76]

Reward Monitoring of SOM: Farmers must be rewarded for ecosystem services provided by their SSM practices. This can be achieved by monitoring SOM, other soil biology parameters, and terrestrial biodiversity on their land.[77]

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75. Asian Development Bank. (2020). Agriculture development in the Central Asia Regional Economic Cooperation Program member countries: Review of trends, challenges, and opportunities. https://www.adb.org/publications/trends-agricultural-development-carec-countries

76. A Food Systems Approach to Transforming Africa's Soil Health: Policy, Science, Implementation and Impact. *IFDC.* (2021). https://ifdc.org/2021/10/25/a-food-systems-approach-to-transforming-africas-soil-health-policy-science-implementation-and-impact/

77. Lal, R. (2022). *Soil Organic Carbon and Feeding the Future: Basic Soil Processes*. CRC Press.

Incentives and Resource Support During Transition: Farmers should be supported in the transition to SSM practices with access to free seeds, and with incentives to follow specific practices such as cover cropping and similar interventions. The transition to SSM will need a change in equipment to be used on the land. The government can set up equipment lending for groups of farmers.

Legal Provisions

In terms of legal provisions, Japan and South Korea are leading the way in Asia for SSM. All other nations have an intent to sustainably manage their agricultural lands but do not have the complete ecosystem to deliver it.

It will be prudent to enshrine in law or define by policy what constitutes healthy soil. *The definition of healthy agricultural soil should ask for SOM to be a minimum of 3–6%*. The law should also articulate the responsibility of the custodians of soil, and the incentives and disincentives regarding agricultural practices.

It is necessary to also articulate explicitly the permissible limits of contaminants in soil. The levels of pollution in the soil should be adjusted to factor in biomagnification of contaminants. Biomagnification[78] in food happens in two stages. Contaminants enter irrigation water, where some of them go through a chemical reaction and transform into a more harmful version. The plant then absorbs this contaminant into its system. In the process, the contaminant becomes more concentrated as it enters the plant, and later human beings, when it is consumed.

This aspect of potential biomagnification is addressed, for example, by the Japanese in their Agricultural Land Soil Pollution Prevention Law. The maximum allowable limit of cadmium in paddy fields is set in terms of the cadmium concentration in rice grains produced in the contaminated field because the concentration of cadmium in rice will always be higher than that in soil.[79] This is because the amount of bioavailable cadmium in soil is affected dramatically by water management practices used for rice cultivation.

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78. *Biomagnification*: The term food web biomagnification is used to describe trophic enrichment of contaminants within food webs and refers to the progressive increase in chemical concentrations with increasing animal trophic status.

79. Asami, T. (1981). Maximum allowable limits of heavy metals in rice and soil. In: Kitagawa, K., Yamane, I. (Eds.). *Heavy Metal Pollution in Soils of Japan*, pp. 257–274. Tokyo, Japan Scientific Societies Press.

Monitoring and Learning Systems

Standardize indicators to assess soil health: Japan has set up clear indicators that it is measuring over 20,000 testing spots across the nation to understand the state of soil health. The list of indicators measured do not include soil biological activity or SOM levels. If both these indicators are added to the existing list, Japan's soil health assessment will be near complete.

A similar list of indicators can be put together for the rest of the Asian countries based on the Japanese model, as well as FAO suggested indicators that can be measured to assess soil quality improvement through adaptation of SSM practices.[80]

Soil testing: Soil testing laboratories should also be equipped to conduct tests for biological properties of soil, along with the physical and chemical properties of soil. The testing facilities should be made nominal and accessible to farmers. In Europe, for example, the French government has a free soil-sampling scheme[81] to encourage farmers to test their soil and, accordingly, carry out interventions on their land. This will provide farmers with evidence of their soil's health and bring about a change in their behavior towards managing their soils sustainably. A farmer's decisions on use of nutrition (organic/inorganic) and its quantity, and choice of SSM practice (cover crop species / intercrop mix, etc.) will be guided by their soil report and the nutritional needs of the crop(s) they intend to grow on their farm. This testing will also help soil doctors and farmers decide which type of SSM practice will increase productivity on their land and decrease input cost.

80. *Protocol for the assessment of Sustainable Soil Management now available!* Global Soil Partnership. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/global-soil-partnership/resources/highlights/detail/fr/c/1370578/

81. *Base de Données d'Analyses des Terres – BDAT*. Gis Sol. https://www.gissol.fr/le-gis/programmes/base-de-donnees-danalyses-des-terres-bdat-62

3.4 Policies for Europe

European countries can be broadly classified as European Union (EU) countries and EU partner countries[1] whose policies mirror EU policies (like Switzerland and Norway), and countries with their own specific policies. There are two parts to this section. In the first part, we will look in depth at the EU policy ecosystem. This analysis will also largely apply to EU partner countries. The second analysis looks at a few major non-EU countries with a large area under agriculture: Russia, the United Kingdom and Ukraine.

3.4.1 European Union

1. EU partner countries are either European Economic Area (EEA) countries or European Free Trade Association (EFTA) countries. EEA member countries that are not in EU are Iceland, Liechtenstein and Norway. EFTA countries are Iceland, Liechtenstein, Norway And Switzerland.

Member Nations of the European Union (EU): Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden.

European Union Statistics

Total Population: 447.7 million

GDP: USD 15.3 trillion (Dec 2020)

GDP Per Capita: USD 34,149.3 (2020)[2]

Total Landmass Area: 3,999,622.5 km²

Landmass under Agriculture: 1,637,507.3 km² (2018)[3]

Population Dependent on Agriculture as a Percentage of Total Employment: 17% (40 million people)[4]

Average Farm Size: 11 ha

Executive Summary

At the outset, we find that there is substantial progress that has happened in setting up knowledge systems to support farmers to transition to sustainable soil management practices. These policies are in line with Conscious Planet's recommendations on soil health. With the recent proposal from the European Commission to its MEPs and Parliament to have a Soil Health Law legislation, we think the legal provision to manage soil sustainably will be in place. Even without the Soil Health Law, the present EU Green Deal and its strong effect on the reformed CAP presents a strong case for increasing Soil Organic Matter (SOM). However, there are specific areas where we think the EU can strengthen its intervention to achieve its aspirations for healthy soil. These areas are the Farmer Support Ecosystem and the Monitoring and Learning Systems.

Before we articulate the recommendations, in this policy brief we outline the current state of soil in the EU, existing policies or policies being proposed that affect soil

2. Based on World Bank data. IMF figure is USD 42,120.998 (2020)

3. *Agricultural land (sq. km) – European Union*. The World Bank. https://data.worldbank.org/indicator/AG.LND.AGRI.K2?locations=EU

4. *The common agricultural policy at a glance*. European Commission. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en

health, and provide recommendations to strengthen the policy ecosystem to help revitalize soil health. Our recommendation to the EU is to implement interventions in a timely manner through focused and clear policies to achieve a goal of increasing SOM to a minimum of 3–6%. The following is a summary of the specific recommendations under the four pillars of Conscious Planet's recommendations for soil health:

- *Under knowledge systems, establish knowledge systems with last-mile connectivity to farmers.*
- *Under Farmer Support Ecosystems, the EU can provide free access to education and the knowledge systems to help farmers adopt SSM practices. The EU can also provide assistance for equipment specific to regenerative agriculture practices.*
- *Legally, the EU can add the requirement of a minimum SOM of 3–6% to the definition of healthy agricultural soils in the new Soil Health Law.*
- *Under Monitoring and Learning Systems, soil health measurements should involve testing of biological properties along with chemical and physical properties of the soil.*

By working on improvement of SOM in agricultural lands, the EU will be able to see increased productivity from the agriculture sector and also reduction in expenditure for fertilizers. Land and soil degradation costs the EU an enormous sum of €50 billion per year.[5] Furthermore, soil erosion reduces annual agricultural productivity by €1.25 billion. Bringing back SOM to 3–6% will help cut down on these costs, and current trends can be reversed.

The State of Agricultural Soil in the European Union

The technical report on Soil Threats to Europe[6] by the Joint Research Centre (JRC) of the European Union very clearly articulates the problems faced by the soils of Europe. The list includes: deterioration of SOM, soil erosion, soil biodiversity loss, soil compaction, soil contamination, salinization, sealed soils and desertification. The following sections quantify the gravity of some of the fundamental issues.

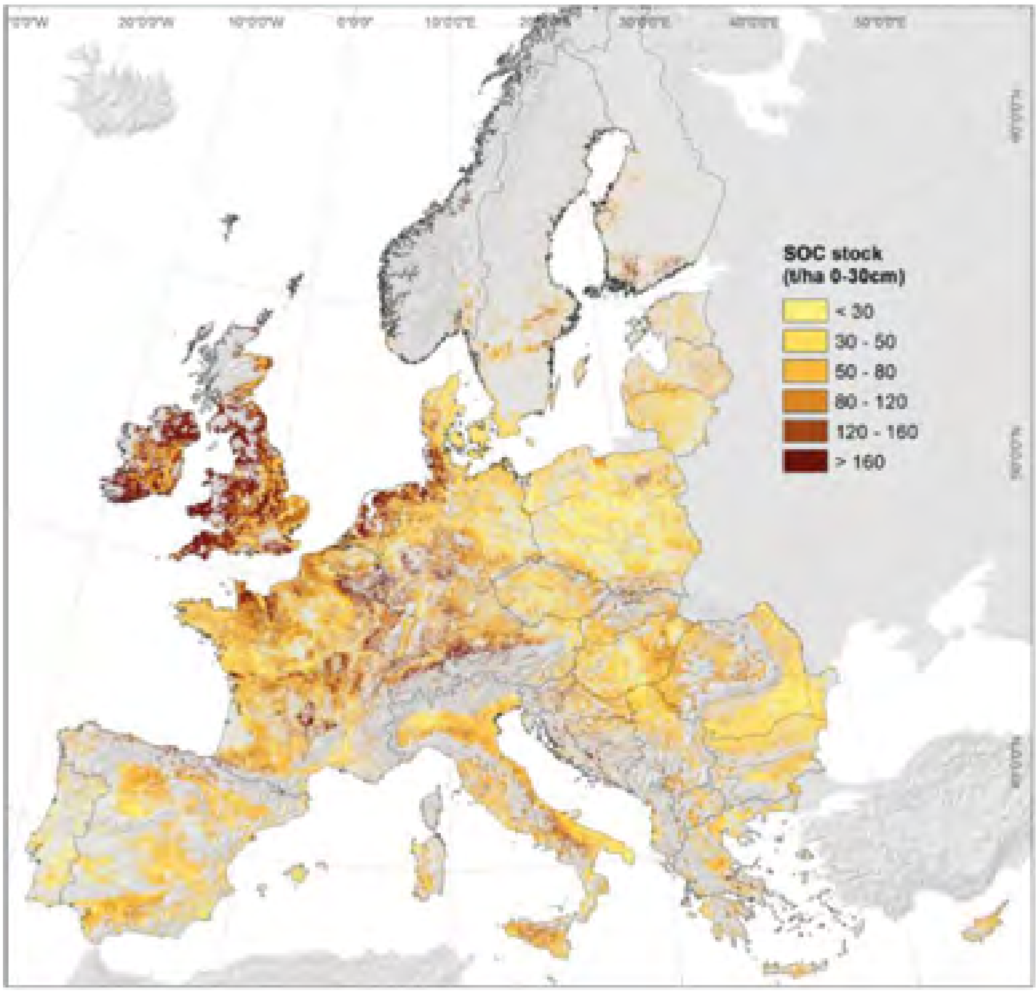
5. *Questions and Answers on the EU Soil Strategy*. European Commission. (2021). https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_5917

6. Stolte, J., Tesfai, M., Oygarden, L., Kvaerno, S., Keizer, J., Verheijen, F., Panagos, P., Ballabio, C., & Hessel, R. (2016). Soil threats in Europe: status, methods, drivers and effects on ecosystem services: deliverable 2.1 RECARE project. *JRC Technical Reports, European Commission.*

Declining Soil Organic Carbon

In a working paper that details the rationale and reasons for the key areas of focus for soil threats, it is estimated that around 75% of all EU croplands are below 2% Soil Organic Carbon (SOC).[7] This approximately translates into Soil Organic Matter (SOM) being less than 3%.

Map 1: Soil Organic Carbon stock in agricultural topsoils of the EU.[8]



7. Stolte, J., Tesfai, M., Oygarden, L., Kvaerno, S., Keizer, J., Verheijen, F., Panagos, P., Ballabio, C., & Hessel, R. (2016). Soil threats in Europe: status, methods, drivers and effects on ecosystem services: deliverable 2.1 RECARE project. *JRC Technical Reports, European Commission.*

8. Lugato, E., Panagos, P., Bampa, F., Jones, A., & Montanarella, L. (2013) A new baseline of organic carbon stock in European agricultural soils using a modelling approach. *Global Change Biology.* doi.org/10.1111/gcb.12292. In *CAP Specific Objectives – Efficient Soil Management.* European Commission. (2018). https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/cap-specific-objectives-brief-5-soil_en.pdf

Soil Erosion

Erosion affects three regions within the EU with different intensities: a southern zone with severe risk, a loess zone with moderate risk, and an eastern zone comprising areas with both moderate and severe erosion.

Approximately 11.4% of the EU's territory is estimated to be affected by moderate (up to 5 tonnes per hectare per year) to severe water erosion (more than 5 tonnes per hectare per year).[9] Over 24% of EU lands and almost a third of agricultural areas have erosion higher than sustainable rates (2 tonnes per hectare per year). Thus, 35% of EU lands are losing soil to erosion. Moreover, 24% of EU lands and almost a third of agricultural areas have erosion higher than sustainable rates (2 tonnes per hectare per year). Erosion rates today have reduced compared to what was observed between 2000–2010. For example, erosion has decreased by 20% in arable lands in Western and Central Europe because of erosion control activities.[10, 11]

A recent quantitative estimate of wind erosion shows that around 7% of the EU's arable lands have rates higher than 2 tonnes per hectare per year. The regions most affected by wind erosion are large parts of arable land in Denmark, Netherlands, the northern part of Germany and the Iberian Peninsula.[12]

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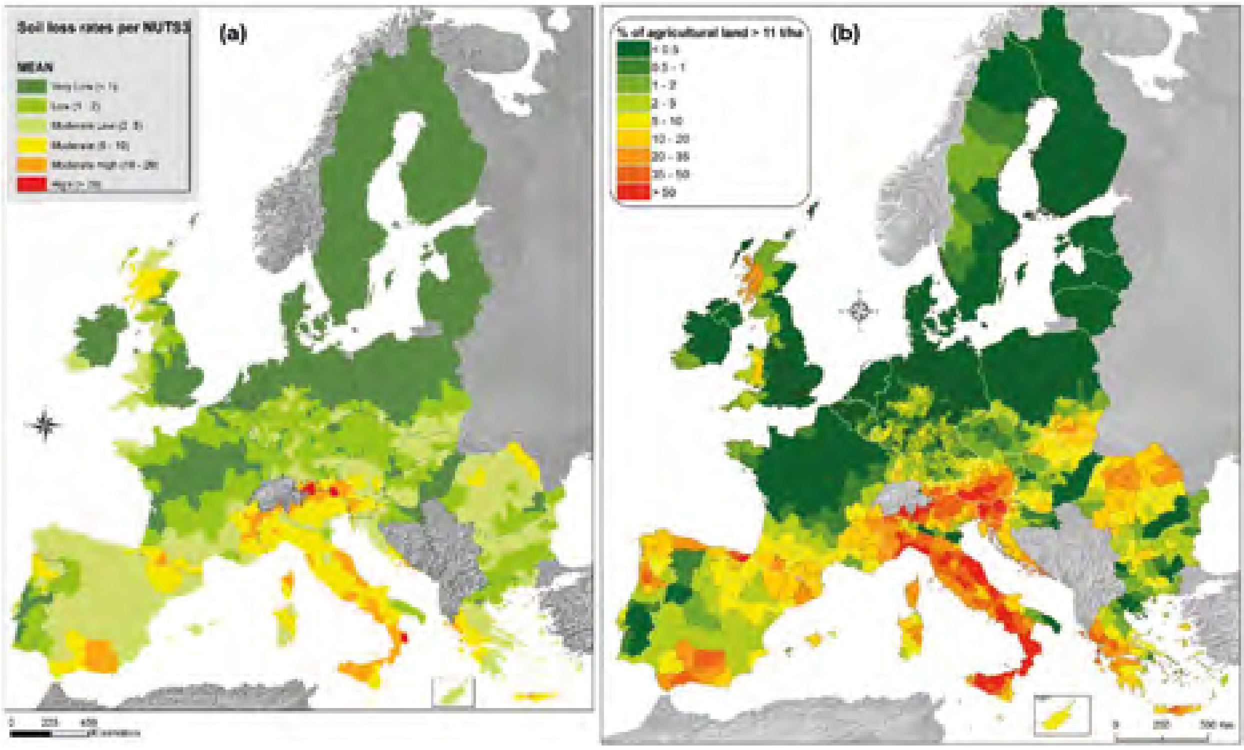
9. Panagos, P., Borrelli, P., Poesen, J., Meusburger, K., Lugato, E., Montanarella, L., & Alewell, C. (2015). The new assessment of soil loss by water erosion in Europe. *Environmental Science & Policy, 54*, 438–447.

10. *Summary for Policymakers of the Regional Assessment Report on Biodiversity and Ecosystem Services for Europe and Central Asia*. IPBES. (2018).

11. Panagos, P., Borrelli, P., Meusburger, K., Alewell, C., Lugato, E., & Montanarella, L. (2015). Estimating the soil erosion cover-management factor at the European scale. *Land Use Policy, 48*, 38–50.

12. Borrelli, P., Lugato, E., Montanarella, L., & Panagos, P. (2017). A New Assessment of Soil Loss Due to Wind Erosion in European Agricultural Soils Using a Quantitative Spatially Distributed Modelling Approach. *Land Degradation & Development, 28*, 335–344. https://doi.org/10.1002/ldr.2588

Map 2: (a) Soil erosion by water (tonnes per ha per year), 2010, EU-28, NUTS 3 (left) and (b) Severe soil erosion in agricultural lands (right) - % of agricultural land with >11t/annually.[13]



Soil Biodiversity Loss

The problem with quantification of soil biodiversity is that there is no comprehensive knowledge of what existed in the soil in the first place. This has been overcome by the European Atlas of Soil Biodiversity.[14] Based on various factors that lead to reduction in soil biodiversity – soil sealing, erosion, loss of soil organic matter, salinity, compaction etc.[15] – and according to the Land Use / Land Cover survey of 2018 and DNA extraction techniques, the potential risk to soil biodiversity is mapped and shown in Map 3 for

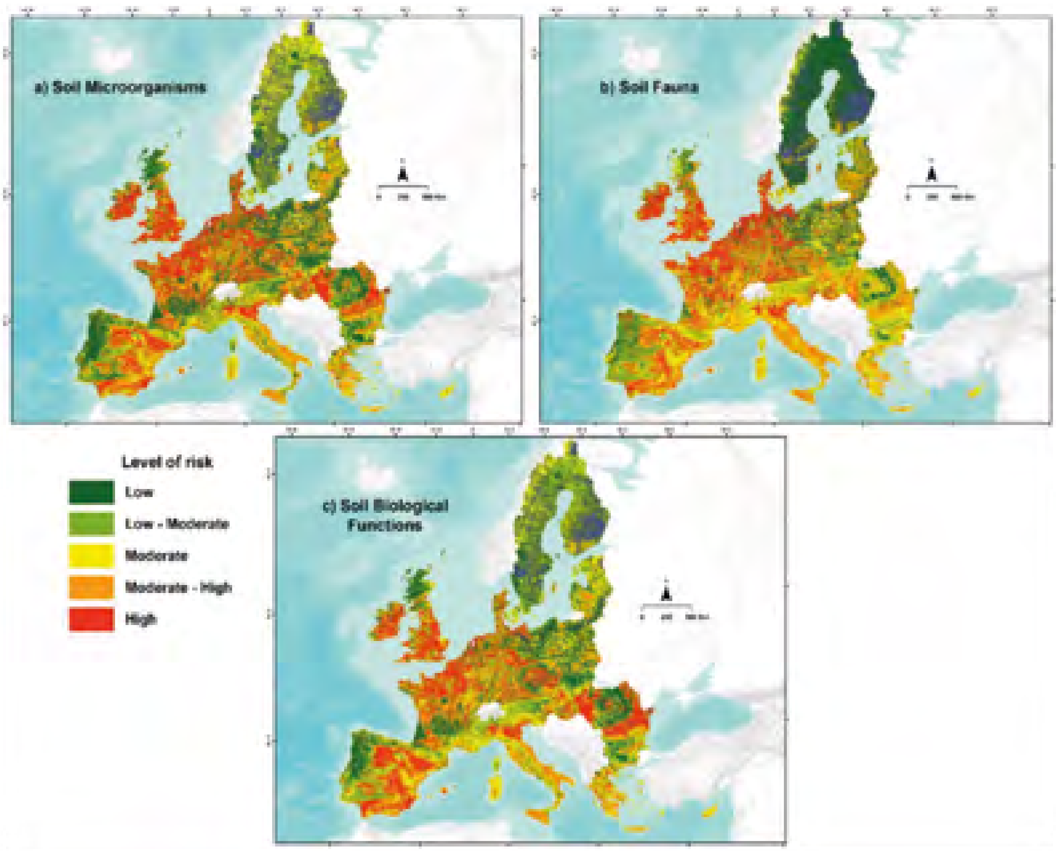
13. *CAP Specific Objectives – Efficient Soil Management*. European Commission. (2018). https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/cap-specific-objectives-brief-5-soil_en.pdf

14. Jeffery, S., Gardi, C., Jones, A., Montanarella, L., Marmo, L., Miko, L., Ritz, K., Peres, G., Römbke, J., van der Putten, W. H. (eds.). (2010). European Atlas of Soil Biodiversity. *Publications Office of the European Union.* https://doi.org/10.2788/94222

15. Stolte, J., Tesfai, M., Oygarden, L., Kvaerno, S., Keizer, J., Verheijen, F., Panagos, P., Ballabio, C., & Hessel, R. (2016). Soil threats in Europe: status, methods, drivers and effects on ecosystem services: deliverable 2.1 RECARE project. *JRC Technical Reports, European Commission.*

microorganisms, flora, and soil biological functions. The maps showcase the intensity of biodiversity loss across microorganisms, soil fauna and soil biological function. The color spectrum denotes green regions having low loss of diversity, and red regions at the other extreme with high loss of biodiversity.

Map 3: Distribution of the potential threats to (a) soil microorganisms, (b) soil fauna and (c) soil biological functions predicted for 27 European countries (spatial resolution 500 m).[16]

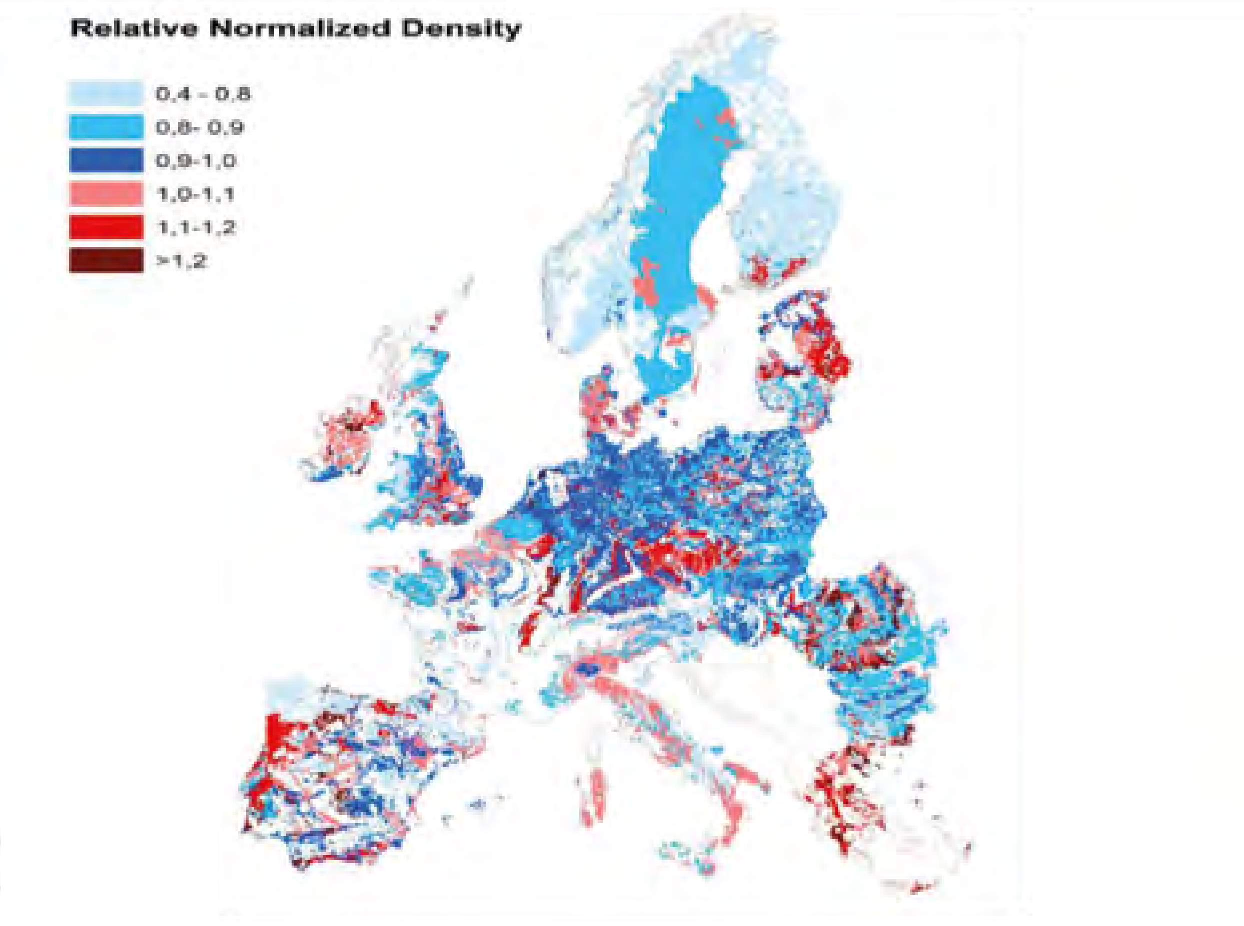


Soil Compaction

Based on a study conducted across various soils, it was found that around 23% of soils are at critical high densities, densities (i.e., they are heavily compacted) (Map 4). This status of soils can be partly explained by the increased use of heavy machinery since the 1960s, resulting in high stress on soils, in particular in the subsoil below the plough layer.

16. *CAP Specific Objectives – Efficient Soil Management*. European Commission. (2018). https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/cap-specific-objectives-brief-5-soil_en.pdf

Map 4: Relative normalized density (RND) for European subsoil horizons covering the depth of 0.25–0.7 m as calculated by Eqs. 3ab based on the SPADE8 database. RND>1 may be considered a dense soil.[17]



Present Policy Ecosystem in the European Union

Soil has become part of the larger sustainable initiatives of the EU. Research on the state of soil has been conducted in the EU since the early 2000s. The policy ecosystem largely comprises three main policies: The EU Soil Strategy for 2030; Common Agriculture Policy (CAP); and the European Green Deal. The first is primarily focused towards strategy; the second is a program under which budgets are allocated for soil regeneration activities; and the third is an aspirational document listing green targets. In this section, we read all three of these policies together to understand the overall policy ecosystem in the EU.

17. *CAP Specific Objectives – Efficient Soil Management*. European Commission. (2018). https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/cap-specific-objectives-brief-5-soil_en.pdf

The EU Soil Strategy for 2030

The EU Soil Strategy document for 2030 sets up a collective goal to make the soils of the EU healthy. It also acknowledges the significance of decisions to be made in this decade and their ramifications for the soils of Europe.

The Vision Statement

By 2050, all EU soil ecosystems are in healthy condition and are thus more resilient, which will require very decisive changes in this decade.

By then, protection, sustainable use and restoration of soil has become the norm. As a key solution, healthy soils contribute to addressing our big challenges of achieving climate neutrality and becoming resilient to climate change, developing a clean and circular (bio)economy, reversing biodiversity loss, safeguarding human health, halting desertification and reversing land degradation.

The medium-term goals and long-term goals are also outlined in this document.

Medium-term Objectives by 2030

1. Combat desertification, restore degraded land and soil (including land affected by desertification, drought and floods), and strive to achieve a land degradation-neutral world (Sustainable Development Goal 15.3).
2. Significant areas of degraded and carbon-rich ecosystems, including soils, are restored.
3. Achieve an EU net greenhouse gas removal of 310 million tonnes CO_2 equivalent per year for the land use, land use change and forestry (LULUCF) sector.
4. Reach good ecological and chemical status in surface waters and good chemical and quantitative status in groundwater by 2027 as defined by the EU's Water Framework Directive 2000/60/EC.
5. Reduce nutrient losses by at least 50%, the overall use and risk of chemical pesticides by 50% and the use of more hazardous pesticides by 50% by 2030.
6. Make significant progress in the remediation of contaminated sites.

Long-term Objectives by 2050:

1. Reach no net land take.[18, 19]
2. Soil pollution should be reduced to levels no longer considered harmful to human health and natural ecosystems, and should respect the boundaries our planet can cope with, thus creating a toxic-free environment.
3. Achieve a climate-neutral Europe and, as the first step, aim to achieve land-based climate neutrality in the EU by 2035.
4. Achieve a climate-resilient society for EU, fully adapted to the unavoidable impacts of climate change by 2050.

The strategy goes into detailing actions needed for these medium-term and long-term goals to be reached.

Common Agricultural Policy (2021–27)

The Common Agricultural Policy (CAP) is a policy that all EU nations must implement with regards to agricultural activity. Every few years, the CAP is reformed after consultation with member states, to ensure it stays relevant to the needs of farmers and society in a changing world. The objectives of the CAP (2021–27) are:

1. **To ensure a fair income to farmers:** Support viable farm income and resilience across the EU to enhance food security.
2. **To increase competitiveness of EU farmers:** Increase competitiveness and agricultural productivity in a sustainable way to meet the challenges of higher demand in a resource-constrained and climate uncertain world.
3. **To rebalance the power in the food chain:** Improve farmers' position in the value chain.
4. **Climate change action:** Contribute to climate change mitigation and adaptation, as well as sustainable energy.
5. **Environmental care / Efficient soil management:** Foster sustainable development and efficient management of natural resources such as water, soil and air; with special focus on soil.

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18. Land take is the loss of agricultural, forest and other semi-natural and natural land to urban and other artificial land development.

19. Geneletti, D., Biasiolli, A., & Morrison-Saunders, A. (2017). Land take and the effectiveness of project screening in Environmental Impact Assessment: Findings from an empirical study. *Environmental Impact Assessment Review* 67, 117–123. https://doi.org/10.1016/j.eiar.2017.08.008

6. **To preserve landscapes and biodiversity:** Contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes.
7. **To support generational renewal:** Modernize the agricultural sector by attracting young people and improving their business development.
8. **Vibrant rural areas:** Promote employment, growth, social inclusion and local development in rural areas, including bio-economy and sustainable forestry
9. **To protect food and health quality:** Improve the response of EU agriculture to societal demands on food and health, including safe, nutritious and sustainable food, reducing food waste, and enhancing animal welfare.
10. **To foster knowledge and innovation:** Modernize agriculture by increasing cooperation and knowledge sharing, and improving agricultural training.

A thorough reading of all the working papers on the key objectives reflects a very strong intent to make agriculture in the EU nations sustainable and green. Analysis of the budgets under the two major pillars of the CAP only makes the intent firmer.

Figure 1: 10 Key Objectives of the CAP (2021–27)[20]

20. *Key policy objectives of the new CAP*. European Commission. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/new-cap-2023-27/key-policy-objectives-new-cap_en

CAP has two major verticals through which it ensures farmer welfare:

Pillar I:[21] direct payments and market measures

Pillar II:[22] focuses on well-rounded rural development

The overall budget for CAP for the period of 2021–27 is €387 billion. Compared to previous iterations of the CAP, the current policy is better equipped to ensure on-ground implementation of policy objectives. Several mechanisms have been incorporated into CAP for this purpose, including environment and climate action targets that increase with each programming period, prevention of backsliding by nations on these targets, and stronger mandatory requirements for beneficiaries to receive payments.

There are also enhanced minimum budget allocations towards climate, biodiversity and environment-related aspects. For example, 40% of the CAP (2021–27) budget will have to be climate relevant; in the fruits and vegetables sector, operational programs will allocate at least 15% of their expenditure towards environment; at least 25% of the budget for direct payments will be allocated for eco-schemes.

European Green Deal (2021)

The European Green Deal is a set of policies aimed at making the EU's economy circular, carbon neutral and sustainable by 2050. Agriculture has been rightfully recognized as an important component in fulfilling the European Green Deal. The European Green Deal will transform the EU into a modern, resource-efficient and competitive economy, ensuring:

- No net emissions of greenhouse gases by 2050
- Economic growth decoupled from resource use
- No person and no place left behind

21. Pillar 1: Direct payments are made annually to farmers to help stabilize their farm revenue and face risks associated with market volatility and market measures to tackle specific market situations and to support trade promotion.

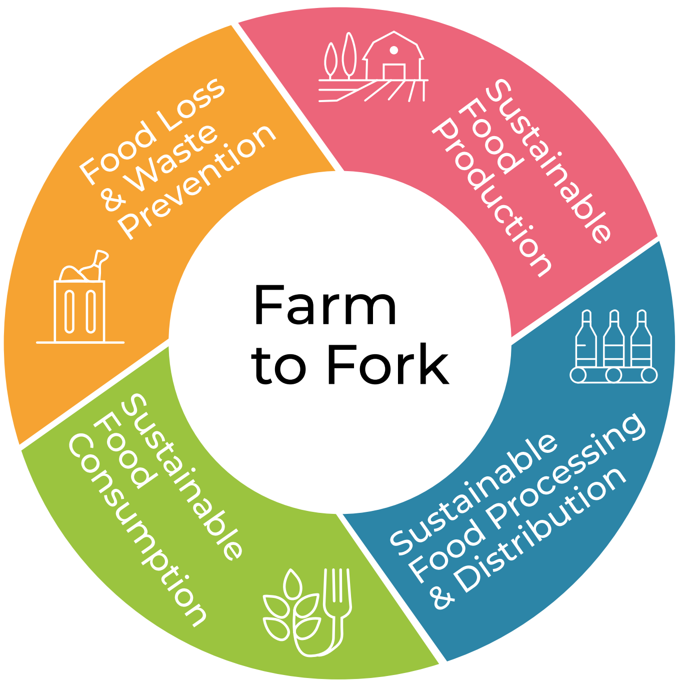
22. Pillar 2: Rural development – Objective of this pillar is to have balanced development in rural areas like provision of access to internet, sustaining a farming sector that is environmentally sound, as well as promoting competitiveness and innovation

The Green Deal aspires to reduce the greenhouse gas (GHG) emissions of Europe by at least 55% by 2030, compared to 1990 levels. The various areas of action under the Green Deal are: Climate, Energy, Agriculture, Industry, Environment and Oceans, Transport, Finance & Regional Development and, last but not least, Research & Innovation. By acting on these areas, the Green Deal intends to provide for and improve the wellbeing of citizens now and in the future through seven objectives. The two that are directly related to soil are: fresh air, clean water, healthy soil and biodiversity; and healthy and affordable food. The other five objectives will be affected positively by working on soil health.

As a part of the Green Deal, there are two major strategy documents to guide the interventions. The one specific to agriculture (the entire supply chain from production to processing to the dining table) is the Farm to Fork strategy document. The second one pertaining to biodiversity is called the Biodiversity Strategy for 2030.

The strategies listed under the Farm to Fork strategy document, especially pertaining to the production aspect of it, go in depth into SSM.

Figure 2: EU Farm to Fork Strategy[23]



23. *Farm to Fork Strategy*. European Commission. https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en

The strategy seeks to have a legislative framework for sustainable food systems, through which the EU wants to support and lead the world into sustainable agri-food systems through its trade policies and international cooperation instruments.

The overall budget for the Green Deal amounts to €1.8 trillion, part of which comes from CAP (2021–27) funding. CAP receives exceptional budgetary support – one-third of the EU's budget goes towards CAP[24] – and CAP will therefore play a major part in ensuring the Green Deal is fulfilled.

CAP Tied Tightly to the European Green Deal

The reformed CAP (2021–27) will have the payments to farmers tied to a set of mandatory environment conditionalities (rules).

Strong and Well-defined Conditionalities for Spending (Pillar I) – Direct Payments

All beneficiaries of the new CAP (2021–27) will continue to have their payments linked to a set of mandatory rules (known as "conditionality" in the new CAP), comprising of statutory management requirements (SMRs)[25] and good agricultural and environment conditions (GAECs).[26, 27] In the new CAP, the most effective aspects of these practices will be incorporated into new conditionality rules. For example:

- ***GAEC on soil protection and quality****: Crop rotation will be required on all farms of at least 10 hectares. Crop diversification (the current obligation) will only be permitted when this practice contributes to the objective of preserving the soil potential. There are exemptions for farms with a lot of grassland, and organic farms are considered as fulfilling the obligation.*

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24. *The common agricultural policy at a glance*. European Commission. vvhttps://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en

25. SMRs include rules on public, animal and plant health and animal welfare and the environment

26. GAEC standards are designed to:
    - prevent soil erosion by defining minimum soil cover and minimum land management practices;
    - maintain soil organic matter and soil structures;
    - maintain permanent grasslands;
    - protect biodiversity and ensure the retention of landscape features through, for example, a ban on cutting hedges and trees during the bird breeding and rearing season;
    - protect and manage water through the establishment of buffer strips along water courses, authorization on water for irrigation and protection of groundwater from pollution.

27. *Cross-compliance: Good agricultural and environmental conditions.* European Commission. https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/cross-compliance_en#gaec

- ***GAEC on biodiversity and landscape:*** *Four percent of land will be devoted to non-productive elements and areas, including fallow land, on all farms of at least 10 hectares. This is more than under the current "greening" system. The obligatory minimum for such non-productive features will be 3% where farmers "top up" that total to 7% through an eco-scheme, or where farmers devote significant additional land to catch crops or nitrogen-fixing crops (cultivated without plant protection products in each case).*

Eco-schemes (Pillar I)

Twenty-five percent of payments made from CAP (2021–27) Pillar I (direct farmer payments) will be allocated for eco-schemes mandatorily, thus incentivizing climate- and environment-friendly farming practices, and tying together CAP and Green Deal objectives. These practices/actions will be listed and defined by the European Commission. These funds can also be used to support organic farming, agro-ecological practices, precision farming, agro-forestry or carbon farming, as well as animal welfare improvements.

Eco-schemes will be mandatory for EU countries to include in their plans, but voluntary for farmers. There is a 2-year learning period for countries to get on the eco-scheme bandwagon by 2023. In this period, countries may spend less than 25% of the budget. But by 2027 the average spending of 25% should be towards these eco-schemes.

Rural Development (Pillar II)

Rural development, the so-called "second pillar" of the CAP (2021–27), also ties into Green Deal objectives by dedicating a higher share ("**ring-fence**") of its resources to interventions relating to climate and the environment. In this "ring-fenced" fund, at least 35% of the rural development budget (earlier it was 30%) will be allocated to support environment, climate and animal welfare. Natura2000 (network of core breeding and resting sites for rare and threatened species) and Water Framework Directive payments, environmental and climate investments, and animal welfare are some of the schemes which are eligible under the ring-fenced budget. In areas with constraints, the mandatory ring-fenced expenditure on specific items will be 50% of the total allocation. Whereas in areas without constraints, it is mandatory to spend all the ring-fenced allocations for activities allowed under that category.

Higher Green Ambitions in Some Sector-Specific Interventions

Expenditures for specific sectoral interventions that are targeted towards production of fruits and vegetables will also have to go towards meeting specific objectives of environment / efficient soil management and climate / carbon sequestration efforts on agricultural lands. Moreover, the reform introduces several new types of intervention serving the same environmental and climate objectives (e.g. EU countries will have to dedicate at least 5% of financial allocations for the wine sector to meet these objectives).

Climate Tracking

What gets measured gets done. Following this principle, the new CAP (2021–27) will incorporate climate tracking to ensure that contribution to climate change mitigation from agricultural interventions is counted. The European Commission will propose an improved methodology through which climate tracking will be done with rigorous collection of data on specific indicators after 2025.

Policy Recommendations for the European Union

Soil degradation or soil extinction (the extreme form of degradation) has ramifications on food security, production of nutritious food that affects human and animal health, water scarcity, biodiversity, climate change and, therefore, the overall harmony of society. Also, soil degradation, like water scarcity, has transboundary effects outside of the states where degradation happens.

There is a clear awareness on the state of soil and what needs to be done on the soil, so that it is no longer a problem, but a solution for various developmental aspirations of the Union, like food security, food safety, climate mitigation, water, and biodiversity. The EU Soil Strategy for 2030 document, the CAP (2021–27), the European Green Deal, and the Farm to Fork strategy documentations cover various bases of what is needed to sustainably manage soil. CAP, the primary policy framework through which agricultural soils will be regenerated in this edition, has moved from a social policy to one that intends to deliver results for the environment as well as for human beings. But it will be good to make some adjustments to ensure this policy is rolled out effectively.

Ensuring soil health is an urgent need of the hour: The timelines set for CAP (2021–27) and the European Green Deal are of the order of 4–5 years. This duration may be too long for the agenda of soil regeneration and SSM, due to the urgency of the situation. There is a 2-year adaptation window given to all EU nations for new policies. It may be worthwhile to think of reducing these adaptation timelines to shorten the roll out.

After the analysis of the present policy ecosystem, Conscious Planet's Save Soil Movement gives policy recommendations under the four pillars of:

- Knowledge Systems
- Farmer Support Ecosystem
- Legal Provisions
- Monitoring and Learning Systems

Knowledge Systems

- **Simplified soil mandate for agricultural lands:** The present agriculture knowledge systems can be focused towards soil regeneration when catering to farmers. The existing system is quite nuanced and substantial studies have been conducted to develop a PoP for various agroecological conditions of the EU. All of this can be organized with a focused outcome to help achieve a minimum of 3–6% SOM in agricultural lands.

  All recommendations from soil scientists and practitioners of regenerative/conservation and smart agriculture to regenerate soil, amount to increasing SOM. The practices mentioned are crop rotation, no or reduced till farming, having leguminous crops in rotation to fix nitrogen naturally, cover crops for summer, cover crops for winter, managed grazing, composting, green manure, introducing animal waste back into land, silvo-pasture, and a few other practices. If knowledge generation and cataloging specific to agricultural lands were focused on a single mandate of increasing SOM to a minimum range of 3–6% soil management mandate, the communication and training of farmers will yield better results.

Farmer Support Ecosystem

- **Easy and free access to education and knowledge systems to facilitate transition:** The role of advisory services in the form of training, exposure visits, and engagement with progressive farmers are essential in assisting land users in transitioning from conventional farming practices to regenerative practices. This is crucial as there is a possibility of reduction in yields, and crop failures during the transition period. For agricultural soils, local action must be closely nurtured and fostered with sufficient support from the farm advisory services and the **Agricultural Knowledge and Innovation Systems (AKIS)** of the CAP (2021–27) strategic plans. The Farm to Fork strategy document again talks about research, innovation, technology and investments. Access to fast broadband internet will also enable data driven advisory and decision-making for farmers.
- **Assistance for equipment specific to regenerative agriculture practices:** Eco-scheme (Pillar I) and/or ring-fenced rural development funds can be allowed to assist farmers in equipping themselves with machinery (e.g. seed drills used to lodge seeds into the soil on no-till farms), that will be needed to transition from conventional to regenerative farming practices.

Legal Provisions

- **Need for a simple and focused Soil Health Law:** The process to bring soil back to being "healthy soil" seems to be split across various strategies and policies. It has been consistently observed that when a particular natural resource base (like water or air) gets sharp, focused attention, there is a clear direction to improve the quality of this resource, and the targets for various programs that use this resource get aligned to that mandate.

  There is a clear Water Legislation for Europe that ensures all types of water use is regulated and monitored. There is an EU policy for coastal areas and oceans. There is an EU and international air pollution policy to ensure clean air. But there are no policies that underline the need for a legal framework that grants similar protection to soil as water, marine environment, and air. While the MEPs of all EU nations are debating a need for a specific Soil Health Law, we feel that there is no question that a dedicated Soil Health Law is the need of the hour. This is because of the multifaceted effect healthy soil has on food, nutrition, water, biodiversity and climate change. This need for a resource-specific policy for soil has been pointed out by the EU Soil Strategy for 2030 document too. A soil certificate for farmers has been proposed in the Soil Health Law. The soil certificate *"should ensure the soil's SOM is also measured alongside physical and chemical properties of the soil."*

- **Define healthy soil:** Similar to what is mentioned in the EU Soil Strategy document, it will bring clarity on what healthy soil is if the EU defines the threshold beyond which soil cannot be considered healthy. This will aid in designing country-specific CAP (2021–27) strategic plans. In this definition of healthy agricultural soil, one of the criteria should be that SOM should be at least 3–6%. These ranges set by the Commission should then be achieved at an accelerated pace by 2030.

Monitoring and Learning Systems

- **Digital systems for data collection and monitoring:** Provisions to measure indicators of progress on various aspects of the soil, especially the change in SOM and soil biology, should be in place. This can help remote monitoring, knowledge exchange among farmers and also between farmers, experts and other stakeholders.
- **Implementation framework:** We acknowledge that EU's new CAP (2021–27) policies and the Green Deal and Soil Strategy are only a few months old. So we suggest the 2-year period allocated for member states to learn be spent on building a clear implementation framework with definitions of clear Key Performance Indicators (KPIs) across various soil specific schemes for landowners. Some of the specific KPIs that can ensure nations stay on track are:
    - Change in SOM
    - Change in water holding capacity of lands
    - Change in quantum of fertilizer use
    - Change in yields
    - Change in LULUC (change in cropping patterns, etc.)

It is recommended to have regular, annual assessments on these KPIs at local and aggregate levels. The results should be made available to farmers, and AKIS should support in addressing any lack of progress within the member states.

Implementation of the above-mentioned recommendations will yield significant results towards the following CAP (2021–27) key objectives:

- **Increasing competitiveness of EU farmers:** It has been observed that regenerative farm practices have given rise to increased yields of produce in any type of soil. They also lead to reduced input needs of fertilizers, water, etc. as the soil's natural ability to provide nutrients gets established with improved soil microbial biodiversity. Thus, the cost of production also goes down. Also, the quality of the produce goes up, and with the new labelling protocols that the EU is taking up, this may fetch the farmers better prices for their produce as well.

- **Climate change action:** Regenerative practices lead to increase in SOM, which translates to an increase in SOC. It has been observed that in grasslands and forests of the EU, SOC is 10% and sometimes up to 20%. The EU's agricultural lands at present mostly have less than 2% SOC.[28] The difference between grasslands and agricultural lands is the carbon sequestration potential of soils.
- **Environmental care / efficient soil management:** Improving SOM was suggested in order to meet this key objective of CAP (2021–27). An increase in SOM will lead to reduction in unsustainable soil erosion found in 35% of Europe's lands, reduced fertilizer runoffs and improved carbon sequestration.
- **To preserve landscapes and biodiversity:** Regenerative farming principles lead to increase of SOM. This happens through the revival of all life in soil and the overall soil food web.
- **To support generational renewal:** The activities to bring back SOM will require a detailed implementation framework starting from a clear training ecosystem involving experts, scientists, progressive farmers, and last-mile outreach to the farmers in rural areas. This will also involve using digital technologies which is an area that the younger generation is comfortable with. While some of them can engage with farming directly, other rural youth can be engaged in facilitation of:
    - Farmer-to-Farmer network based learning
    - Handholding farmers through helplines: phone-based, computer-based and in-person assistance
    - Facilitating access to the expertise of various stakeholders for farmers
- **To protect food and health quality:** Adopting regenerative agricultural practices will lead to reduced need for fertilizers, pesticides and other chemical inputs, and better animal husbandry and animal feed management within the farm. This leads to less chemical residues in the produce and healthier food.

Increasing SOM will also contribute towards the European Green Deal's aspiration to provide its citizens with fresh air, clean water, healthy soil and biodiversity, healthy and affordable food, recycled and re-used crop residue, globally competitive and resilient industry, and future-proof jobs and skills training for the transition.

28. FAO. (2015). World fertilizer trends and outlook to 2018. *Food and Agriculture Organization of the United Nations.* https://pdf.usaid.gov/pdf_docs/PA00XT7Z.pdf

3.4.2 Russian Federation

Russian Federation Statistics

Total Population: 145,912,000

GDP: USD 1.69 trillion

GDP per Capita: USD 11,605.6

Total Landmass Area: 17,098,246 km^2

Landmass under Agriculture: 2,154,940 km^2

Population Dependent on Agriculture as a Percentage of Total Employment: 5.6%

Average Farm Size: 150 ha[29]

The State of Agricultural Soil in the Russian Federation

The state of Russian soils vary dramatically due to the vast expanse of area and the many agro-climatic conditions of the nation. Fourteen percent of agricultural land suffers water erosion, 24% is affected by wind erosion, 31% suffers from swamping, 14% suffers water logging and 1.41% is affected by desertification. Radioactive contamination, a problem unique to Russia, also affects around 8% of agricultural soil.[30] The cost of land degradation that led to low soil productivity alone was calculated to be around USD 189 billion for the period between 2001–2009. The total economic value of ecosystem goods and services is estimated to be around USD 3700 billion, which is three times the GDP.[31] Also, in Russia, the costs of action against land degradation are lower than the costs of inaction by 5–6 times over a 30-year horizon.

Present Policy Ecosystem in the Russian Federation

Land Tenure Change (1990s): Agriculture reforms in Russia in the 1990s saw land ownership of over 85% of lands move from the state to individuals. This led to

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29. Qamar, M. K. (2014). Russia. *GFRAS*. https://www.g-fras.org/en/world-wide-extension-study/europe/eastern-europe/russia.html

30. Vandysheva, N. M., & Gurov, A. F. (2011). Predominant negative processes on agricultural lands. In S. A. Shoba (Ed.), *National Atlas of Soils in Russian Federation*, 266–267.

31. Bao Le, Q., Nkonya, E., & Mirzabaev, A. (2014). Biomass productivity-based mapping of global land degradation hotspots. *ZEF—Discussion Papers on Development Policy No. 193, 1-57. Report on the state and use of agricultural lands.* (2011). Ministry of Agriculture of the Russian Federation.

reduction of loss-making agriculture enterprises from 88% in 1998 to 28% in 2010.[32] This had an impact on land use efficiency and overall land productivity.

Environmental Quality Standards (2003): Soil quality is covered as one of the parameters of the environment under the environmental quality standards in Russia. By 2003, the maximum allowed concentrations (MAC) for various chemical elements in soil and food stuffs was clearly demarcated.

Soil Use License: Under the larger natural resource licensing / permit system, there is clear articulation of what entails "soil protection". This license, though, leans towards protection of soil from contamination and pollution and does not dwell much on the biological activity of soil. This license is as applicable to a farmer as industries which use the soil.

The Federal Service for Environmental Use: This is a regulatory body entrusted with monitoring, control and supervision of land use and protection of biodiversity and other natural resources.

Land Code of the Russian Federation of 2006:[33] According to this code, the land title holder is responsible to ensure the following:

- *to carry out production of agricultural products in ways that exclude or limit the adverse impact of such activities on the environment*
- *to comply with the norms and rules in the field of ensuring the fertility of agricultural land*
- *to submit information on the use of pesticides and agrochemicals to the relevant executive authorities in accordance with the established procedure*
- *to promote agrochemical, soil, phytosanitary and ecological-toxicological surveys of agricultural lands*
- *to inform the relevant executive authorities about the facts of degradation of agricultural land and soil pollution on land plots in their possession or use, among others.*

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32. *Agriculture, hunting and forestry.* Entrepreneurship, Official Statistics, Federal State Statistics Service. (2014). http://www.gks.ru/. (in Russian).

33. Saenko, A., & Shiposha, S. (2022). The Environment and Climate Change Law Review: Russia. *The Law Reviews*. https://thelawreviews.co.uk/title/the-environment-and-climate-change-law-review/russia

State Program for Agriculture (SPA) (2019) 15th Edition:[34] The reformed state agriculture scheme, SPA, focused on farmer support with respect to pricing of farm produce, payment for outputs, access to credit, etc. The SPA document aims to also create favorable conditions for efficient land use. The Ministry of Agriculture also promotes climate smart practices for farming systems, which will encourage sustainable use of water, air and nutrition regime. SPA strongly focuses on digitalization of agricultural data.

Federal Law On Soil Protection (No. 83334-3) Bill (2002): This is the legal provision that was brought to protect soil as a resource like water and air. But it never gained a strong foothold due to its drafting not being "quite correct in its formulation" from a legal point of view.[35]

Policy Recommendations for the Russian Federation

The overall policy regime in Russia at present is focused largely on contamination of soil and other natural resources. There exist policies regarding climate adaptation but focused on the contribution of industries. Agriculture as a sector receives focus in terms of improving productivity and ensuring the land is not polluted from agricultural use. Given this situation, soil biology and SSM is yet to come into focus in Russia.

Knowledge Systems

Russian agriculture is diverse. Agriculture as a sector, in terms of sustainable agricultural practices, is spread across various departments. There are universities conducting research, government institutions rolling out government schemes, etc. To ensure that Russia's food security is not jeopardized by climate change, all these institutions should work in tandem rather than in silos. There has to be a concerted effort to build knowledge systems (by pooling together the work done by all the various institutions) in one place. These knowledge databases should be accessible to farmers with varied education backgrounds from across the country.

34. *Russian Federation*. Agricultural Policy Monitoring and Evaluation 2021: Addressing the Challenges Facing Food Systems. OECD. (2021). https://www.oecd-ilibrary.org/sites/ed982f42-en/index.html?itemId=/content/component/ed982f42-en

35. Chukov, S. N., & Yakovlev, A. S. (2019). Soil and land categories in the modern legislation of Russia. *Eurasian Soil Science, 52*(7), 865-870.

- **Create/collate agroecological zone based information:** To start with, clear SSM recommendations for various agroecological zones and soil types should be published and made available to farmers across the country.
- **Conduct farm equipment R&D domestically:** At present there is a heavy reliance on imported technology for agriculture equipment. If the R&D around SSM practices is done domestically, farmers may be able to access the equipment at affordable prices.[36]
- **Increase the number of agriculture experts/staff to handhold farmers:** There may be a lack of enough trained agriculture experts who can handhold farmers in transitioning to SSM practices.[37]

Farmer Support Ecosystem

SSM techniques in agriculture will involve change in cropping types, nutrient regimes, and agriculture techniques and equipment.

The bottleneck for farmers to adopt climate smart / precision farming in Russia[38] is the lack of regulatory support from the government. SSM practices also suffer from the same bottleneck.

The farmer support ecosystem should have last-mile access to assistance. A contextual farmer-to-farmer learning network, like that of soil doctors suggested by the Global Soil Partnership, will help farmer transition to be quick and effective.

- **Access carbon credit for farmers:** Russia is clearly on track to meet its commitments at Paris COP15. Agriculture in Russia can play a huge role in meeting the nationally declared commitment at COP. The carbon credit benefits from SSM can be a way to incentivize farmers to transition to SSM practices.
- **Access to SSM-specific farm equipment:** When farmers transition to SSM practices, there will be a change in the farm equipment used. This capital expenditure may not be possible for all farmers. Either incentives should be designed to pay for this equipment, or some form of low cost rental/leasing should be facilitated by the regional governments.

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36. Kulyasov, N. S., Novik, N. N., Klyukin, N. D., & Charyyarova, G. D. (2020). Precision agriculture in the Russian Federation: Problems and directions in development. *IOP Conference Series: Earth and Environmental Science*, *548*(2), 022090.

37. *ibid.*

38. *ibid.*

Legal Provisions

The present legal definition of soil is vague and uncertain. The only federal law on soil protection that was drafted did not take off in Russia. There should be clear legal provision for soil to be treated as an independent natural resource just like air and water. Just like there is a federal law on the protection of atmospheric air, there should be one for soil protection, too. The law should delve into the details of the various functions of soil – physical, chemical and biological. Most importantly, the biological function of soil must incorporate the requirement that SOM should be at least 3–6%, along with definitions of soil bulk density and soil biological parameters as mentioned by the FAO, (in 3.1 Policies for the World).

Monitoring and Learning Systems

Soil quality is presently monitored by regional regulatory bodies. The aspects that are monitored should include biological parameters like soil biological activity, SOM, soil productivity, and physical properties like bulk density. This data should be ideally collected at the farm level.

The information gathered at the farm level can also be used to guide farmers through the soil doctor last-mile connectivity network. For larger regional level mapping, the Global Soil Partnership's GSOCmap mapping teams and their models can be adapted to Russia. Strategic and statistically relevant monitoring centers can be established to collect data on soil health.[39]

Consistently, if interventions are undertaken with a single point focus to improve SOM to a minimum of 3–6%, it will help improve the soil health in Russia in a time-bound manner.

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39. *The GSOCmap, a stepping stone in our knowledge of soils.* Global Soil Partnership. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/global-soil-partnership/pillars-action/4-information-and-data-new/global-soil-organic-carbon-gsoc-map/en/

3.4.3 United Kingdom

United Kingdom Statistics

Total Population: 68,207,000

GDP: USD 2.82 trillion

GDP per Capita: USD 41,854.5

Total Landmass Area: 242,495 km²

Landmass under Agriculture: 175,212.961 km²

Population Dependent on Agriculture as a Percentage of Total Employment: 1%

Average Farm Size: 87 hectares[40]

The State of Agricultural Soil in the United Kingdom

Over 70% of land in the United Kingdom (UK) is under agriculture, which contributed £10.4 billion to the UK economy in 2019. Fifty-five percent of the food produced was consumed domestically.[41]

As with many parts of Europe, UK's soils under agriculture are degraded. Over 2.9 million tonnes of topsoil in the UK (England and Wales) are eroded by wind and water.[42] About 3.9 million ha are under the risk of compaction.[43] Contamination of soil due to poor sewage sludge application, microfiber and micro-plastic is also a concern. Contamination of soil adversely affects beneficial soil organisms like earthworms.[44] Soil nutrient balance had reduced between 2000 and 2019. Nitrogen had reduced by 24%, and phosphate by 46%.[45]

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40. Dodds, S. (2019) What size is the average farm? *MHA MacIntyre Hudson.* https://www.macintyrehudson.co.uk/insights/article/what-size-is-the-average-farm

41. *Agriculture in the United Kingdom.* DEFRA. (2020). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1056618/AUK2020_22feb22.pdf

42. Environment Agency. (2019). The State of the Environment: Soil. *GOV.UK.* https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/805926/State_of_the_environment_soil_report.pdf

43. *Technical Report.* UK Climate Risk. https://www.ukclimaterisk.org/independent-assessment-ccra3/technical-report/

44. Prendergast-Miller, M. T., Katsiamides, A., Abbass, M., Sturzenbaum, S. R., Thorpe, K. L., & Hodson, M. E. (2019). Polyester-derived microfibre impacts on the soil-dwelling earthworm Lumbricus terrestris. *Environmental Pollution, 251,* 453-459.

45. *Agriculture in the United Kingdom.* DEFRA. (2020). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1056618/AUK2020_22feb22.pdf

Present Policy Ecosystem in the United Kingdom

The present policy ecosystem around soil is quite strong. Concerted efforts to save soils began in 2009. The timeline of policy interventions since 2009 is as follows:

Safeguarding Our Soils (2009): Countrywide strategy document[46]

Protecting Our Water, Soil and Air (2009): A good-practice guide for land management[47]

The Natural Choice – Securing the Value of Nature (2011): A white paper valuing nature and assisting the nation to make choices that are sustainable. This looked at the value of soil along with other ecosystem services provided by nature.

The Environmental Audit Committee (2016):[48] Articulates the state of soil degradation in the UK, and how soil health can potentially address various issues of climate change, water scarcity, farm yields, etc. It also mentions the lack of a monitoring system to measure trends in soil health. It recommends the following:

- *Establish a scheme to monitor the uptake of soil conservation measures, with enforcement where soils are not being appropriately managed; and Include specific proposals to reverse the ongoing loss of lowland peat soils*

The 25-Year Environment Plan (2018):[49] Reiterated all the previous soil management goals, and sought dedicated allocation of £200,000 for setting up monitoring systems at national and farm-scale levels and developing matrices for soil health.

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46. *Safeguarding Our Soils – A Strategy for England.* DEFRA. (2009). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69261/pb13297-soil-strategy-090910.pdf

47. *Protecting Our Water, Soil and Air – A code of good agriculture practice for farmers, growers and land managers.* DEFRA. (2009). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/268691/pb13558-cogap-131223.pdf

48. *Environmental Audit Committee – Inquiry into Soil Health.* Committee on Climate Change. (2016). https://www.theccc.org.uk/wp-content/uploads/2016/01/CCC-Written-Submission-to-Environmental-Audit-Committee-Inquiry-into-Soil-Health.pdf

49. *A Green Future: Our 25 Year Plan to Improve the Environment.* DEFRA. (2018). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf

Agriculture Act 2020:[50] In this act, the incentives for the farmer to improve soil health are articulated. Farmers will be compensated for protecting and improving soil health through Environment Land Management (ELM) schemes. Under the ELM scheme, Sustainable Farming Incentive (SFI) will be specifically brought in to replace certain payments made to farmers under the CAP regime of the EU.

Environment Act 2021: Under this new strategy, the Soil Health Action Plan for England (SHAPE) was announced to restore soil health through SFI.

The 2022 Sustainable Farming Incentive: Through this scheme, the UK government will pay farmers to produce public goods such as water quality, biodiversity, animal health and welfare, and climate change mitigation, alongside food production.

SFI payments are designed around 4 principles[51] that are inclusive and encourage widespread participation of farmers. These are: fair and effective payments to farmers; allow delivery through a range of activities; allow for existing natural assets to be managed in continuity; and allow for farmers to also earn from private sector sources.

A payment regime is articulated under this scheme, with details of introductory, intermediate and advanced levels of intervention in farmlands, with the payments being commensurate to the level of intervention.[52] The scheme also elaborates on creating more detailed standards which will be implemented from 2023. The payment regime for sustainable animal rearing, in line with the Annual Health and Welfare Review, is also outlined in the scheme.[53]

Innovations in Soil Monitoring Technology:[54] Innovations could simplify national- and farm-scale soil monitoring, reporting and verification. In a recent publication

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50. *Agriculture Act 2020.* UK Public General Acts. https://www.legislation.gov.uk/ukpga/2020/21/contents/enacted/data.htm

51. *Annex A: Early roll out of Sustainable Farming Incentive – coherence with payment principles.* DEFRA (2021). https://www.gov.uk/government/publications/sustainable-farming-incentive-how-the-scheme-will-work-in-2022/annex-a-early-roll-out-of-sustainable-farming-incentive-coherence-with-payment-principles

52. *Sustainable Farming Incentive: How the scheme will work in 2022.* DEFRA. (2021). https://www.gov.uk/government/publications/sustainable-farming-incentive-how-the-scheme-will-work-in-2022/sustainable-farming-incentive-how-the-scheme-will-work-in-2022

53. *Introducing the Annual Health and Welfare Review.* Future Farming. DEFRA. (2021). https://defrafarming.blog.gov.uk/2021/10/05/introducing-the-annual-health-and-welfare-review

54. *Restoring Agricultural Soils.* UK Parliament Post. Post Note. (2022). https://researchbriefings.files.parliament.uk/documents/POST-PN-0662/POST-PN-0662.pdf

on measurement/monitoring, reporting and verification (MRV) systems for SOC, a concerted effort to understand the challenges in measuring SOC and development of models to measure SOC has been made.[55]

Policy Recommendations for the United Kingdom

The policy ecosystem that is being crafted to improve soil health in the UK is in congruence with all the recommendations of Conscious Planet. The work that has happened over a decade in the UK accounts for strengthening all pillars of intervention needed to improve soil health, namely:

Knowledge Systems

The good-practice guide effort that started in 2009 has set a strong foundation for the knowledge systems that are needed to transition to sustainable agriculture.

Farmer Support Ecosystem

The Sustainable Farming Incentive policy of 2022 is a promising start to encourage farmers to transition to sustainable agricultural practices to improve soil health. The incentives are clear and measurable. The farmer support ecosystems present now can be bolstered with a farmer-to-farmer learning platform like the Global Soil Doctors Programme run by the FAO.[56]

Additionally, the carbon credit rates in the last year have tripled as the European Commission moved towards tighter targets.[57] After the COP26 at Glasgow, a global protocol for trading carbon credits and offsets was arrived at consensually. The carbon credits market is now more accessible to both farmers and corporates/industries and financial investors. These markets can also be leveraged to accelerate the process of transitioning farmers to SSM practices.

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55. Smith, P., Soussana, J. F., Angers, D., Schipper, L., Chenu, C., Rasse, D. P., ... & Klumpp, K. (2020). How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. *Global Change Biology, 26*(1), 219-241.

56. *Global Soil Partnership.* Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/global-soil-partnership/pillars-action/2-awareness-raising/soil-doctor/en/

57. Mellow, C. (2022) Carbon Trading 2.0: The effect of the Glasgow COP26 meeting continues to grow and is now propelling the carbon-trading market. *Global Finance Magazine.* https://www.gfmag.com/magazine/february-2022/carbon-trading-20

Farmers will also incur capital expenditure related to the change in farm equipment, when they move towards SSM practices. The farmer support ecosystem should have explicit assistance in the form of low interest loans or rentals to assist with these expenditures.

Legal Provisions

Under the Cross Compliance in England rules set up by DEFRA in 2015,[58] the process to be followed for soil standard enforcement and associated payments to farmers based on the results of soil inspection is clearly articulated. The definitions of soil health, soil quality, soil security and soil resilience have been covered under the recent UK Parliamentary Post of January 2022 – Restoring Agriculture Soils. It will be best if the definitions for all these aspects are further elaborated and enshrined in law. At present, these feature only in the strategy document for safeguarding the soils of England.[59] **The definition of healthy soil under agriculture should also mention the need for a minimum SOM of 3–6%.**

Monitoring and Learning Systems

A clear need for MRV has been mentioned in the Parliamentary Post of January 2022. The work has begun to arrive at methods and models based on which SOC can be measured across the country scientifically. There exist simple field level testing kits (mentioned in Chapter 2) that can help farmers assess the change in their soil biological parameters, including SOM. Although such testing kits may not be as accurate as spectrometry tests, they will provide farmers with the information they need to understand the trends of how their soil is changing.

58. *Cross compliance in England: Soil protection standards.* DEFRA. (2015). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/397046/CCSoilPS_2015_v1_WEB.pdf

59. *Safeguarding Our Soils – A Strategy for England.* DEFRA. (2009). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69261/pb13297-soil-strategy-090910.pdf

3.4.4 Ukraine

Ukraine Statistics

Total Population: 43,467,000

GDP: USD 153 billion

GDP per Capita: USD 3,495.5

Total Landmass Area: 603,500 km²

Landmass under Agriculture: 413,110 km²

Population Dependent on Agriculture as a Percentage of Total Employment: 14.1%

Average Farm Size: 100 ha[60]

The State of Agricultural Soil in Ukraine

Ukraine, rightfully known as the breadbasket of Europe, has one of the largest areas of agricultural land in Europe – 41 million ha. Its geographic location also provides access to key agricultural markets in Europe, the Middle East, North Africa, and Asia.[61] Having exceptionally fertile soil and favorable weather conditions for crop production, Ukraine has enormous potential for sustainable agriculture development.

Ukraine has one-third of the world's endowment of black soil, which is among the most fertile soils in the world. This soil, under the right conditions, can produce high yields and incomes. However, it is estimated that Ukraine's arable land loses over 500 million tonnes of soil to erosion annually, resulting in loss of soil fertility across 32.5 million ha. The loss of nutrients has a financial impact of approximately USD 5 billion.[62]

Water logging amounts to 12% of land degradation, while acidification, salinization and alkalinization together affect over 18% of the soil.[63] However, the primary causes

60. Mark, O. (2014). What it's like to farm in the Ukraine. *Farmers Weekly.* https://www.fwi.co.uk/machinery/like-farm-ukraine

61. *Productivity of agricultural land in the context of state policy.* Food and Agriculture Organization of the United Nations (FAO). (2021). https://www.fao.org/fileadmin/user_upload/GSP/WSD21/Concept_note_for_WSD_event_2021.pdf

62. Fileccia, T., Guadagni, M., Hovhera, V., & Bernoux, M. (2014). Ukraine: Soil fertility to strengthen climate resilience. *FAO Investment Centre.* https://www.fao.org/3/i3905e/i3905e.pdf

63. *ibid.*

of soil degradation are wind and water erosion. Twenty million hectares are affected by dust storms and 19 million ha are exposed to the harmful effects of water and wind erosion.[64] The value of eroded soil each year is around a third of the agricultural GDP.

Present Policy Ecosystem in Ukraine

The following are some of the policies that are relevant to soil health in Ukraine.

On Land Protection (2003):[65] This statute directly pertains to soil health. The law mandates protection of soil as a national wealth, prioritization of environmental protection of soil as it is a basic means of food production, compensation for damages caused to land by infringing upon the land protection legislation, designing economic incentives and ensuring legal responsibility of stakeholders with respect to land protection; and finally, it details the role of public participation and mandates transparency in the sphere of land protection.

Ministry of Agrarian Policy and Food Validating the Regulation (Order No. 536) (2011):[66] This order mandates all state government hands to have an agrochemical certificate. The certificate captures characteristics of the soil, the level of contamination and toxic substances. Agrochemical certification of arable land is carried out once in 5 years, and for hayfields, pastures and perennial plantations once in 5–10 years, and it is mandatory for all landowners and land tenants.

National Action Plan (NAP) to Combat Land Degradation and Desertification (2014):[67] In 2014, the Cabinet of Ministers of Ukraine resolved and approved the concept to combat land degradation and desertification. This concept was then elaborated and adopted in a resolution in March 2016. Implementation of the respective programs will mainly be aimed at decreasing land degradation in agricultural areas and achieving Land Degradation Neutrality (LDN).

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64. *Ukraine: Soil degradation.* Agroberichten Buitenland. (2021). https://www.agroberichtenbuitenland.nl/documenten/publicaties/2021/06/17/ukraine-soil-degradation

65. *Ukraine: Law No. 1877-IV on land* protection. FAOLEX Database. (2003). https://www.fao.org/faolex/results/details/en/c/LEX-FAOC045747/

66. *Ukraine: Order No. 536 of the Ministry of Agrarian Policy and Food validating the Regulation on the procedure for managing of agrochemical certificate of a field and a land plot*. FAOLEX Database. (2011). https://www.fao.org/faolex/results/details/en/c/LEX-FAOC171839/

67. *National Target Setting to Achieve Land Degradation* Neutrality *in Ukraine.* LDN TSP, The Global Mechanism of the UNCCD. (2018). https://knowledge.unccd.int/sites/default/files/ldn_targets/2019-06/Ukraine%20LDN%20TSP%20Country%20Report.pdf

Ukraine 2050 Low Emission Development Strategy (2017):[68] Low Emission Development Strategy (LEDS) has determined that economic and social growth does not necessitate an increase Greenhouse Gas emissions (GHG). One of the emission reduction goals is to use land as a carbon sink. It is articulated as the objective "Increase in the volumes of carbon absorption and uptake with the help of best climate change mitigation practices in agriculture and forestry."

A Formal Coordination Council Was Established for the NAP (2017): Two workshops with key stakeholders on LDN issues were held in Kyiv and the targets were further tied with the implementation of SDGs in Ukraine. The experts produced two publications for stakeholders including: "Combating Land Degradation and Desertification: Key Political Documents" and "Monitoring and Indicators of Land Degradation Neutrality in Ukraine (Collection of Articles)".

Main Principles (Strategy) of the State Environmental Policy of Ukraine for the Period upto 2030 (2019): A multisectoral policy document related to protection of natural resources – air, water, soil – from the impact of climate change. This strategy mandates bringing back ecological balance in ecosystems of Ukraine.

National Land Degradation Neutrality (LDN) Target Setting Programme (2018): National Scientific Center and the Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences established a baseline for soil organic carbon national data gathered by experts from across the country. Proposals for national LDN targets were discussed, and the agreed upon target included the stabilization of soil organic carbon in agricultural lands.

Ukrainian Soil Partnership (USP) (2019): Under the umbrella of the Global Soil Partnership the USP was established in May 2019. This collaboration is for a period of 4 years between the Ukraine government and FAO to guide the country in achieving the national LDN targets. The protection of fertile land and the integrated management of natural resources is a national priority and it will play a major role in advocating for and coordinating initiatives to LDN targets by 2030.[69]

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68. *Ukraine 2050 Low Emission Development Strategy*. FAOLEX Database. (2017). https://www.fao.org/faolex/results/details/en/c/LEX-FAOC181201/

69. *Launch of the Ukrainian Soil Partnership*. Global Soil Partnership. Food and Agriculture Organization of the United Nations (FAO). (2019). https://www.fao.org/global-soil-partnership/resources/events/detail/es/c/1196362/

Table 1: SOM-specific LDN Target[70]

LDN Voluntary Target	Target Baselines	Time of Implementation	Indicators of Implementation
Stabilization of SOC content in agricultural lands	The content of soil organic carbon (humus) in agricultural lands as of 2010: 3.14% on average in Ukraine, including as it relates to these zones: Polissya – 2.24%; Forest Steppe – 3.19%; Steppe – 3.40%	**By 2030, increase the content of soil organic carbon (humus) in agricultural land by not less than 0.1%**, including as it relates to these zones: Polissya – by 0.10–0.16% Forest Steppe and Steppe – by 0.08–0.10%.	1. Percent humus content in agricultural soil 2. Percent soil organic carbon content (0–30 cm) 3. Remote sensing data on agricultural productivity

Policy Recommendations for Ukraine

The World Bank along with the FAO carried out a study to quantify the benefits of large-scale adoption of specific sustainable agriculture practices, such as Conservation Agriculture in Ukraine.[71] The study made an assessment of potential benefits at farm, national and global levels. The benefits that will accrue were assessed to be USD 136 per ha at the farm level and USD 4.4 billion nationally. Conservation Agriculture will also reduce the USD 5 billion loss due to soil erosion. There are other benefits from Conservation Agriculture for the nation and world which, when quantified, will exceed the above benefits. In our recommendations, we encourage SSM practices like Conservation Agriculture.

The Ukraine Soil Partnership initiative in collaboration with FAO has objectives for soil health which are in line with sustainable soil management, namely: Strengthen monitoring systems, build transparency in monitoring systems, and strengthen the country's capacity to generate public interest around soil issues. Much needed is a step towards accelerating policies for healthy soil in Ukraine. The USP plays a major role in

70. *National Target Setting to Achieve Land Degradation Neutrality in Ukraine.* LDN TSP, The Global Mechanism of the UNCCD. (2018). https://knowledge.unccd.int/sites/default/files/ldn_targets/2019-06/Ukraine%20LDN%20TSP%20Country%20Report.pdf

71. Fileccia, T., Guadagni, M., Hovhera, V., & Bernoux, M. (2014). Ukraine: Soil fertility to strengthen climate resilience. *FAO Investment Centre.* https://www.fao.org/3/i3905e/i3905e.pdf

the process to achieve the national target of neutral land degradation by 2030.[72] This is also in line with recommendations of Conscious Planet's Save Soil Movement.

The four-year partnership with Global Soil Partnership and FAO can be leveraged to set up all the four pillars required for soil health.

Knowledge Systems

Advancement in policies for soil health in Ukraine have been hindered by a lack of adequate institutional structures and updated research in the field of soil health.73 Given that Ukraine has been favorably endowed with one-third of the world's black soil, research in the country should be conducted in line with its natural endowments and challenges. The national and subregional agriculture research organizations can start by cataloging credible databases of FAO and WOCAT, etc.

There has to be a crop-specific sustainable soil package of practices (PoP), along with models of intercropping, cover crop, leguminous rotation crops, etc., developed specific to Ukrainian farmers. The PoP should cover specific nutritional application protocols for every crop.

The partnership will act as a united national platform to facilitate dialogue and cooperation among ministries, leading institutions, existing research schools and laboratories on land resources, and relevant stakeholders.[74]

- **Centralized and Customized Information Systems:** A knowledge exchange platform to monitor the soil has been launched in Ukraine – "Healthy Soil."75 All of the information gathered and new research generated should be cataloged and organized in a database. This information should be available to all in the entire chain starting from knowledge producers (researchers, academics, pioneer farmers) and knowledge users (farmers and last-mile extension officers who will handhold farmers).

72. *Launch of the Ukrainian Soil Partnership*. Global Soil Partnership. Food and Agriculture Organization of the United Nations (FAO). (2019). https://www.fao.org/global-soil-partnership/resources/events/detail/es/c/1196362/

73. *ibid.*

74. *Ukraine, FAO unit to save healthy soil*. Global Soil Partnership. Food and Agriculture Organization of the United Nations. https://www.fao.org/global-soil-partnership/resources/highlights/detail/fr/c/1195674/

75. A knowledge exchange platform to monitor the soil in Ukraine, "Healthy Soil" is being populated with articles on topics directly linked to the project operations and recent developments or events of the project. https://healthy-soils.org.ua

Farmer Support Ecosystem

- **Creation of Farmer-friendly Information:** The research work done under the knowledge systems have to be made available to farmers in a farmer-friendly format, through various mediums of print, video and other formats that farmers prefer.
- **Training:** Training sessions on sustainable soil management, regenerative agricultural practices, and PoPs for specific crops must be conducted for farmers. Agricultural research institutions should also arrange for model farm plots that demonstrate the benefits of such practices, such as improvement in crop yield. It should be noted that such training sessions have maximum impact when conducted by fellow progressive farmers whose livelihoods depend on agriculture. Under the USP partnership with FAO there are training programs for farmers of Ukraine for specific Steppe regions of the country.[76] The FAO team in Ukraine is working on developing an online course on conservation agriculture practices in collaboration with national and regional agriculture universities of Ukraine, based on the Farmer Field School program.[77]
- **Soil Doctors:** Farmers will need last-mile support, in the form of extension officers, or soil doctors. Soil doctors could be reputed farmers who are trusted amongst the farming community, and have implemented SSM practices. A high ratio of trained soil doctors to farmers will ensure they can do justice to the number of farmers allocated to them.
- **Incentives for Farmers:** Strengthen incentives for adopting technologies to maintain soil fertility and reduce the volatility of agricultural production, through practices like Conservation Agriculture with no-till. These incentives can be leveraged from international carbon credits and environmental protection budgets.
- **Transitional Budgets:** The country should invest in helping farmers transition to SSM practices by either subsidizing equipment or offering financial instruments (rents, leases).

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76. *Healthy soils in Ukraine: Integrated Natural Resources Management in Degraded Landscapes in the Forest-Steppe and Steppe Zones of Ukraine*. Food and Agriculture Organization of the United Nations (FAO). (2019). http://old.belal.by/elib/fao/1178.pdf

77. *ibid.*

Legal Provisions

In order to optimize the legal support to the protection of land and soil, adopting the draft law "On Protection of Soil and Its Fertility" (drafted in 2013) would be important.[78] This proposed law should define healthy soil and its parameters. The parameters to measure healthy soil should include biological factors as mentioned in Conscious Planet's recommendations for the world's soil. The definition should include a minimum of 3–6% SOM. The law should provide for clear monitoring of soil biological parameters.

Monitoring and Learning Systems

Ukraine has recently begun to set up soil monitoring infrastructure as part of the USP in 2019.[79] In addition, soil monitoring indicators were formulated and implemented by the Ministry of Energy and Environmental Protection with technical assistance from the FAO through the USP program. The "Healthy Soil" platform of the Ukraine government can also host monitoring information along with information on good practices. The "Healthy Soil" platform will support the formation of a monitoring base of land cover, land productivity and carbon stocks.[80]

It will be best if this platform is used to collect and monitor information at the granularity of every farm. And this monitoring information can be used to assist and handhold farmers through the Farmer Support Ecosystem. As mentioned in the Legal Provisions, the information collected at farm level should mandatorily have biological parameters, SOM, bulk density, biological activity, soil respiratory rate, etc.

78. Khominets, S. (2021). Legal Support to the Protection of Land and Soil in Light of New Regulations of Ukraine. *Journal of Environmental Law & Policy, 1*, 35.

79. *Launch of the Ukrainian Soil Partnership*. Global Soil Partnership. Food and Agriculture Organization of the United Nations (FAO). (2019). https://www.fao.org/global-soil-partnership/resources/events/detail/es/c/1196362/

80. *"Healthy Soil" knowledge platform*. https://healthy-soils.org.ua

3.5 Policies for Latin America and the Caribbean

Latin America and the Caribbean (LAC) Countries: Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Bolivia (Plurinational State of), Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela (Bolivarian Republic).

LAC Statistics

Total Population: 652,276,325

GDP: 4.726 trillion USD[1]

GDP per Capita: USD 7,244[2] (ranges from USD 1178 – 32,290[3])

Total Landmass Area:[4] 20.5 million km²

Landmass under Agriculture:[5] 7.12 million km²

Population Dependent on Agriculture as a Percentage of Total Employment: 13.5%[6] (ranges from 0.09–31%[7])

Average Farm Size: 54 hectares (ha)[8]

Executive Summary

The Latin American and Caribbean (LAC) region occupies a wide latitudinal span across the equator, with most of its land in the tropical zone. Its biodiverse ecoregions include tropical and subtropical broadleaf forests, tropical and subtropical grasslands, savannas and shrublands, deserts and xeric shrublands, temperate grasslands, and mangroves. Forests are home to roughly half of the

1. *Latin America & Caribbean*. World Bank Open Data. https://data.worldbank.org/region/latin-america-and-caribbean
2. *GDP per capita (current US$) – Latin America & Caribbean*. World Bank Open Data. https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=ZJ
3. *Gross domestic product (GDP) per capita in Latin America and the Caribbean in 2020, by country (in U.S. dollars)*. Statista. https://www.statista.com/statistics/802613/gross-domestic-product-gdp-per-capita-latin-america-caribbean/#statisticContainer
4. *Land area (sq. km) - Latin America & Caribbean*. World Bank Open Data. https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=ZJ&view=chart
5. *Agricultural land (sq. km) - Latin America & Caribbean*. Wold Bank Open Data. https://data.worldbank.org/indicator/AG.LND.AGRI.K2?locations=ZJ
6. *Employment in agriculture (% of total employment) (modeled ILO estimate) - Latin America & Caribbean*. World Bank Open Data. https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=ZJ
7. The population dependent on agriculture ranges widely in the region. https://www.statista.com/statistics/1082252/latin-america-caribbean-share-employment-agriculture-country/
8. Lowder, S. K., Skoet, J., & Raney, T. (2016). The number, size, and distribution of farms, smallholder farms, and family farms worldwide. *World Development*, *87*, 16–29. https://doi.org/10.1016/j.worlddev.2015.10.041

world's terrestrial species, and seven biodiversity hotspots.[9] The LAC region is also known for sustainable agricultural practices like milpa, which has preserved land fertility even after 5000–6000 years of agriculture.[10]

Unlike MENA or Asia, Latin America holds some of the richest natural resources in the world. With only 8% of the global population, it has 23% of global arable land, 12% of global cultivated land, 46% of global tropical forests and 31% of global freshwater.[11] However, despite being well-endowed in natural resources, the region still faces food insecurity, degradation of arable lands, and the challenges of climate change.

This policy recommendation will highlight the state of soils due to land use practices, the ramifications of the same for the people of the region, an analysis of present soil-specific policies, and finally, recommendations to reverse current trends of soil management, and the ramifications of this.

The State of Agricultural Soil in LAC

Threats to soil health in the LAC countries include a reduction in Soil Organic Carbon (SOC), water and wind erosion, soil contamination, acidification, salinization and sodification, loss of soil biodiversity, waterlogging, nutrient imbalance, compaction, and soil sealing. Among these, soil erosion, changes in SOC and soil salinization are the major threats discussed in detail in this section.

Erosion

Soils in the LAC region are mostly prone to water erosion, though soils in arid and semi-arid regions are more prone to wind erosion. A high proportion of terrains in

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9. United Nations Environment Programme (UNEP). (2010). State of biodiversity in Latin America and the Caribbean; Gibbs, H. K., Brown, S., Niles, J. O., & Foley, J. A. (2007). Monitoring and estimating tropical forest carbon stocks: Making Redd a reality. *Environmental Research Letters, 2*(4), 045023; Werth, D., & Avissar, R. 2003. The regional evapotranspiration of the Amazon. *Journal of Hydrometeorology 5*, 100–109; Myers, N., Mittermeier, C. G., Mittermeier, R. A., da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature 403*(6772), 853–58. In: Ardila, J., Arieira, J., Bauch, S. C., Bezerra, T., Blackman, A., David, O., ... & Warren, M. (2020). Latin American and Caribbean Forests in the 2020s: Trends, Challenges, and Opportunities. http://dx.doi.org/10.18235/0003019.

10. Oudman, T., & Mann, C. (2020). The future of agriculture lies in the past. *The Correspondent.* https://thecorrespondent.com/835/the-future-of-agriculture-lies-in-the-past

11. Garret, L.J. (1997). Challenges for the year 2020 in Latin America: Nutrition and Agriculture Since 1970. *Instituto internacional de investigaciones sobre políticas alimentarias. IFPRI. Washington, DC.* [in Spanish]

LAC are slopes and steps susceptible to soil loss by water erosion. Agricultural lands see widespread loss of soil through erosion on slopes. Fast-growing population, deforestation, overgrazing, and unsustainable agricultural practices in both subsistence and large-scale, high input commercial farms have led to the acceleration of soil erosion.[12]

In drier areas of Mexico and Argentina, wind erosion is the primary cause of soil erosion. Most assessments of erosion in the region are imprecise or not objective. Therefore, the causes of erosion are not clearly ascertained.[13] However, according to some estimates, half of agriculture lands of the region are negatively affected to the tune of 15–25%.[14, 15]

Reduction in SOC/SOM

Large-scale land use change, such as deforestation for livestock rearing and food production, has caused loss of SOC in the region. Forest cover loss in tropical rainforests accounts for 32% of all global forest cover loss. Half of this tropical forest loss is in South America, which has some of the best soils in the world (e.g., in the Pampas). These soils are rich in organic matter and very fertile. But continuous cropping has increased mineralization and reduced SOC. In both cases, soils are becoming less productive, limiting their ecological services.[16]

A long-term study was conducted on loss of SOM in Paraguay, Uruguay, Argentina, and southern Brazil with land use change from conversion of native forests (tropical/savannah) to agricultural lands. In the region of study, there was large-scale adoption

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12. Pla, I. (1996). Degradación de suelos en zonas de ladera de América Latina. In: Bertsch, F., & Monreal, C. (Eds.). *El Uso Sostenible del Suelo en Zonas de Ladera: El Papel Esencial de los Sistemas de Labranza Conservacionista*, pp. 28-49. Costa Rica, San Jose, FAO-MAG.

13. Pla, I. (1992). La Erodabilidad de los Andisoles en Latino América. *Suelos Ecuatoriales, 22*(1), 33–43.

14. Oldeman, L. R., Hakkeling, R. T. A., & Sombroek, W. G. (Eds.). World Map of the Status of Human-induced Soil Degradation: An Explanatory Note, pp. 27–33. *Wageningen, International Soil Reference and Information Centre & Nairobi, United Nations Environment Programme.* https://digitallibrary.un.org/record/220140?ln=en. In: Oldeman, L. R., van Engelen, V.W.P. & Pulles, J.H.M. (1991). *The extent of human-induced soil degradation.*

15. Oldeman, L., Hakkeling, R., & Sombroek, W. (1991) World Map of the Status of Human-induced Soil Degradation. *Wageningen, GLASOD-ISRIC.* https://www.isric.org/documents/document-type/isric-report-199007-world-map-status-human-induced-soil-degradation

16. Lavado, R. S., & Taboada, M.A. (2009). The Argentinean Pampas: A key region with a negative nutrient balance and soil degradation needs better nutrient management and conservation programs to sustain its future viability as a world agroresource. *Journal of Soil and Water Conservation, 65*, 150–153. https://doi.org/10.2489/jswc.64.5.150A

of no-till farming, but there was also large-scale monocropping. Reduction in SOM was one of various types of soil degradation observed. Studies indicated that cropping system changes, which have generally included removal of pasture from crop rotations, decreased crop diversity with the increased frequency of soybean, and conversion of marginal land into cropland, are threatening soil quality.

A study in Argentina comparing native pristine soils to agricultural soils shows a reduction in SOM. SOM in soils cultivated for less than 10 years was only 83% of that of pristine soils, and SOM in soils cultivated for 10–20 years was only 64% of that of pristine soils.[17] If such a reduction in SOM is observed in the soils of a no-till monoculture system, the reduction in SOM will be even greater in a monoculture system with tillage.

Figure 1: Organic carbon stock (or density) in soils of Latin America and the Caribbean, expressed in Gigagrams per hectare.[18]

17. Wingeyer, A. B., Amado, T. J., Pérez-Bidegain, M., Studdert, G. A., Varela, C. H. P., Garcia, F. O., & Karlen, D. L. (2015). Soil quality impacts of current South American agricultural practices. *Sustainability*, 7(2), 2213-2242. https://doi.org/10.3390/su7022213

18. Gardi, C., Angelini, M., Barceló, S., Comerma, J., Cruz Gaistardo, C., Encina Rojas, A., Jones, A., Krasilnikov, P., Mendonça-Santos, M.L., Montanarella, L., Muniz Ugarte, O., Schad, P., Vara Rodríguez, M. I., & Vargas, R. (Eds.). (2014). Atlas de suelos de América Latina y el Caribe. *Luxembourg, Comisión Europea, Oficina de Publicaciones de la Unión Europea, L-2995,* pp. 176.

Salinization

Seventy-one Mha in Central and South America is affected by salinity.[19] Many of the large plains of the continent are naturally saline, but land use changes and overgrazing have caused topsoil salinization. Salinity is also introduced from groundwater in humid and sub-humid climates of the country. In many countries, such as Peru, irrigation projects have caused increased drainage and salinity problems – often due to a lack of complete feasibility studies prior to implementing these projects.[20]

Salinity has led to reduced yields in many regions, such as the semi-arid parts of Brazil,[21] and even abandonment of farms, such as in Venezuela's Falcón state[22] – once a major vegetable producing region.

Ramifications of the State of Soil in LAC

Soil degradation has led to increased vulnerability to climate change, food insecurity and increase in poverty. These issues and their connection to soil are discussed in more detail in this section.

Vulnerability to Climate Change

Due to unsustainable agricultural practices, the LAC region has seen large-scale land degradation and deforestation in the search for better soils. Because no effort is being made to regenerate degraded soils, newly converted arable lands eventually degrade as well, which drives further deforestation in a vicious cycle.

According to the United Nations Convention to Combat Desertification (UNCCD), subsistence farming, commercial farming, logging of wood, and firewood have

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19. Akhtar, M. S. (2019). *Salt Stress, Microbes, and Plant Interactions: Causes and Solution: Volume 1.* Germany: Springer Singapore.

20. Cornejo, A. (1970). Resources of Arid South America. In Dregne, H.E. (Ed.). Arid Lands in Transition, pp. 345–380. *AAAS*.

21. Heinze, B. C. L. B. (2002). A IMPORTÂNCIA DA AGRICULTURA IRRIGADA PARA O DESENVOLVIMENTO DA REGIÃO NORDESTE DO BRASIL. *Silo of Research Documents.* https://silo.tips/queue/a-importancia-da-agricultura-irrigada-para-o-desenvolvimento-da-regiao-nordeste?&queue_id=-1&v=1649610739&u=MjQwOTo0MDYzOjRlOTg6Y2I4ZTpjMTk1Ojk4MGI6NTgyZDplMzgw

22. Villafañe, R. (1995). Detección de suelos afectados por sales en áreas bajo riego de los estados Portuguesa, Barinas y Lara, Venezuela. *Agronomía Tropical, 54*(3), 445–456. http://www.sian.inia.gob.ve/revistas_ci/Agronomia%20Tropical/at4503/arti/villafane_r.htm

caused 48%, 32%, 14% and 5% of deforestation, respectively. Forty percent of LAC's native forests have been lost, which has contributed to accelerating climate change, and also increased vulnerability to the consequences of climate change[23] such as floods, droughts, El Niño, etc.

Amazon's hydrological engine plays a major role in maintaining global and regional climates. This engine is already failing and is on the brink of irreversible transition.[24] The repercussions are already apparent in the changing precipitation patterns and climate extremes. The 2015/2016 El Niño event was one of the strongest of the past century. Fifty-three million people were affected by the resulting drought, 42 million by flood and 34 million by storms.[25]

Climate change will also lead to high-intensity rains in short spells, and since degraded soils have poor water absorption and infiltration ability, this will lead to more floods.

Climate shock disasters also cause failed crops or reduced yields. The five major LAC export crops – beans, maize, rice, soybean, and wheat – have suffered a reduction in average crop yields, overall output and arable land area. This has caused a trade deficit and increased food insecurity in many nations.[26] Climate change also affects the quantity and quality of feedstock in the livestock sector,[27] as well as animal health and milk production.[28]

23. Zeigler, M., & Truitt Nakata, G. (2014). The Next Global Breadbasket: How Latin America can feed the world: A call to action for addressing challenges & developing solutions. *Inter-American Development Bank*. https://publications.iadb.org/en/next-global-breadbasket-how-latin-america-can-feed-world-call-action-addressing-challenges

24. Xu, X., *et al.* (2022). Deforestation triggering irreversible transition in Amazon hydrological cycle. *Environmental Research Letters*, *17*, 034037. https://iopscience.iop.org/article/10.1088/1748-9326/ac4c1d/pdf

25. OCHA. (2019). Natural disasters in Latin America and the Caribbean: 2000–2019. https://reliefweb.int/sites/reliefweb.int/files/resources/20191203-ocha-desastres_naturales.pdf

26. Prager, S., Rios, A. R., Schiek, B., Almeida, J., & Gonzalez, C. E. (2020). Vulnerability to Climate Change and Economic Impacts in the Agriculture Sector in Latin America and the Caribbean. *Inter-American Development Bank (IDB)*. http://dx.doi.org/10.18235/0002580

27. Hristov, A. N., Harper, M., Meinen, R., Day, R., Lopes, J., Ott, T., Venkatesh, A., & Randles, C. A. (2017). Discrepancies and Uncertainties in Bottom-up Gridded Inventories of Livestock Methane Emissions for the Contiguous United States. *Environmental Science & Technology, 51*(23), 13668–77. https://doi.org/10.1021/acs.est.7b03332

28. Johnson, J. S. (2018). Heat Stress: Impact on Livestock Well-Being and Productivity and Mitigation Strategies to Alleviate the Negative Effects. *Animal Production Science, 58*(8), 1404–13. https://doi.org/10.1071/an17725

Adopting sustainable soil management (SSM) practices that increase SOM will improve agricultural output and soil fertility, which will almost eliminate deforestation, and therefore reduce climate change. Healthy soil is also a powerful carbon sink, and can therefore further mitigate global warming.

In a tropical tree-based intervention, both soil and vegetation act as sinks for atmospheric carbon.[29] The quantum of sequestration can be gauged from the fact that accumulation in aboveground biomass alone, can reach upto 8.7 petagrams of carbon per year. The resultant increase in SOC will also significantly increase water availability and crop yields, which will improve nutrition levels, and thus address food security and poverty.

Table 1: Carbon Accumulation in Aboveground Biomass in Tropical Biomes[30]

Land management practice	Typical biomes (Pg C per year)
Forestation	1.3
Agroforestry	2.1
Land rehabilitation	0.1
Conservation agriculture	2.4
End deforestation and desertification	2.8
Total	8.7

Food Insecurity

In 2020, due to the COVID-19 pandemic, LAC saw an increase of 14 million in the number of people affected by hunger.[31] Currently, 60 million people are affected by malnourishment,[32] while food insecurity affects 267 million people.[33] In LAC, climate extremes are the main driver of undernourishment prevalence. As seen in the "Vulnerability to Climate Change" section, climate change impacts on food security will intensify if soils are not managed sustainably in a timely manner.

29. Lal, R., & Cerri, C. (Eds.). (2006). *Carbon sequestration in soils of Latin America*. CRC Press.

30. Lal, R., Cerri, C. C., Bernoux, M., Etchevers, J., & Cerri, E. (2006). *Carbon Sequestration in Soils of Latin America*. Food Product Press.

31. UNICEF. (2021). The State of Food Security and Nutrition in the World 2021. https://data.unicef.org/resources/sofi-2021/

32. *ibid.*

33. *ibid.*

Increasing SOM improves soil quality, water retention capacity, nutrient availability for plant roots, and several other factors that improve crop yields. Therefore, the food situation of LAC nations will benefit greatly if there is a focus on improving SOM.

Table 2: Number of People Experiencing Food Insecurity 2014–2020.[34]

	Number of severely food insecure people (millions)							Number of moderately or severely food insecure people (millions)						
	2014	2015	2016	2017	2018	2019	2020	2014	2015	2016	2017	2018	2019	2020
LATIN AMERICA AND THE CARIBBEAN	47.6	46.6	56.6	63.6	61.7	65.3	92.8	153.8	171.8	197.0	211.2	203.3	207.0	267.2
Caribbean	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	17.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	31.0
Latin America	33.1	32.3	42.0	48.3	45.4	49.7	75.8	126.5	145.0	169.2	183.6	174.7	178.8	236.1
Central America	10.9	11.3	10.5	10.9	12.1	13.0	20.2	50.3	51.2	47.0	48.3	47.9	50.0	67.4
South America	22.2	21.0	31.5	37.3	33.3	36.7	55.6	76.2	93.8	122.2	135.3	126.8	128.8	168.7

Note: Severity level is based on the Food Insecurity Experience Scale. Estimates for 2014 to 2019 include Caribbean countries whose combined populations represent only 30% of the population of that subregion, while the 2020 estimates include countries whose combined populations represent around 60% of the population.[35]

Reduced Contribution of Agriculture to GDP and Employment

Agriculture contributes 5–18% of GDP in 20 LAC countries.[36] The sector employs up to 30% of the population in poorer countries like Guatemala.[37] Soil degradation is a significant driver of crop yield reduction, and thus agricultural incomes and employment. Examples include the soybean mono-cropping system in the Pampean

34. UNICEF. (2021). The State of Food Security and Nutrition in the World 2021. https://data.unicef.org/resources/sofi-2021/

35. *ibid.*

36. World Bank Group. (2020). Agriculture and Food Systems in Latin America and the Caribbean poised for transformational changes. *World Bank*. https://www.worldbank.org/en/news/press-release/2020/11/12/agriculture-food-systems-latin-america-caribbean-changes

37. Trenda, E. (2022). Latin America: Share of employment in agriculture 2020, by country. *Statista*. https://www.statista.com/statistics/1082252/latin-america-caribbean-share-employment-agriculture-country/

and Chaco regions of Argentina, which promoted unfavorable topsoil physical conditions such as laminar and massive aggregation, shallow compaction and decreased infiltration rates. These structural forms were found to decrease soybean yields under rainfed conditions.[38]

Abandonment of farmland in Venezuela's Falcón, driven by soil salinization, has already been noted. Similar issues prevail in Ecuadorian highlands, where irrigation with poor quality water and excess use of fertilizers led to soil degradation and thus a reduction in crop yields.[39]

Climate change in LAC, which as we have seen is a consequence mainly of soil degradation, is another driver of agricultural stress, and the issues that result from it have already been detailed in the earlier section.

As explained previously, both soil degradation and climate change can be significantly influenced by increasing SOM. Thus, increasing SOM should be a single-point focus to mitigate all the ramifications of soil degradation in LAC.

SOM As a Single-Point Focus to Resolve Issues of Soil Degradation in LCA

Restoring food security, building resilience to climate change and strengthening agricultural contribution to the economy and employment of the region will need multi-pronged interventions. However, reaching a SOM content of 3–6% is an important – possibly the most important – intervention that governments and people can invest in.

Increasing SOM in cultivated soils, particularly in the case of the LAC region, can be achieved through SSM and climate resilient food systems. These interventions will also restore degraded soils, and are based on the principles of conservation

38. Bacigaluppo, S., Bodrero, M. L., Balzarini, M., Gerster, G. R., Andriani, J. M., Enrico, J. M. & Dardanelli, J. L. (2011). Main edaphic and climatic variables explaining soybean yield in Argiudolls under no-tilled systems. *European Journal of Agronomy, 35*(4), 247–254. https://doi.org/10.1016/j.eja.2011.07.001

39. Jaramillo, V., Arahana, V., & Torres, M. (2014). Determination of the level of tolerance to salinity in in vitro conditions of the plants of tomate de árbol (Solanum betaceum) from different localities of the ecuatorian highlands. *ACI Avances en Ciencias e Ingenierías, 6*(1). http://dx.doi.org/10.18272/aci.v6i1.158

agriculture, tree-based agriculture such as agroforestry and silvopasture,[40] low carbon agriculture,[41] and integrated crop-livestock and forest systems.

The new cropping systems will lead to higher soil water retention which will lead to increased AWC for plants. These SSM practices will lead to reduced loss of soil from erosion – as the root systems of trees in an agroforestry system will hold the soil together and prevent erosion. In a study conducted by CGIAR's Research Program on Water, Land and Ecosystem, there was a clear difference in the runoff and erosion of sediments in the land before and after Soil and Water Conservation activities were taken up in the land. Though the study was conducted in Ethiopia, the results and learnings from this study are applicable to the LAC regions as well, due to many parallels with Africa.[42]

Table 3: Effects of SWC Measures in Reducing Runoff and Sediment Yield in the Debre-Mawi Watershed in Northwestern Ethiopia[43]

	AVERAGE RUNOFF (mm)			AVERAGE SEDIMENT YIELD (t ha^{-1})		
	BEFORE SWC	AFTER SWC	% REDUCTION	BEFORE SWC	AFTER SWC	% REDUCTION
Weir 1	95	71	26	3.3	1.8	45
Weir 2	242	155	36	16.1	6.3	61
Weir 3	110	74	32	6.6	2.6	61
Weir 4	160	101	37	16.0	3.9	76
Weir 5	272	78	71	62.1	11.6	81

Thus, increasing SOM content to 3–6% in the region's soil through sustainable soil management and conservation agriculture practices in tree-based agriculture will address all three major ramifications LAC faces from degraded agriculture soils.

40. *What's in the soil, stays in the soil: Conserving carbon in our soils to transform food systems*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). (2020). https://www.cgiar.org/news-events/news/whats-in-the-soil-stays-in-the-soil-conserving-carbon-in-our-soils-to-transform-food-systems/

41. Brakarz, B. (2020). Low-carbon farming in Brazil can benefit farmers and curb climate change. *Climate Home News*. https://www.climatechangenews.com/2020/04/09/low-carbon-farming-brazil-can-benefit-farmers-curb-climate-change/

42. CGIAR Research Program on Water, Land and Ecosystems (WLE). (2017). Healthy soils for productive and resilient agricultural landscapes. *Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Program on Water, Land and Ecosystems (WLE)*. 12p. (WLE Towards Sustainable Intensification: Insights and Solutions Brief 2). https://doi.org/10.5337/2017.211

43. *ibid*.

Present Policy Ecosystem in LAC

The current SSM policy ecosystem has been shaped by historic land use and land tenure policies in the region. In this section, we look at this as well as analyze the present soil management policies in the LAC region, drawing heavily from the policies cataloged in the FAO SOILEX database.

History of Present Soil/Land Policies in the LAC Region

As far back as the 1950s, policymakers in LAC nations were aware of the need to improve agricultural productivity. Focused efforts began in the 1960s, with a focus to address the inequity prevalent in landholding, where a small percentage of farmers controlled a large percentage of agricultural land. Different national governments with the support of international organizations developed different policies in order to tackle these problems.[44]

1950–1960s: Agricultural research and extension services were developed, and the Green Revolution began. However, promises of improved productivity and yields were only realized by large landholders who had the capital to make the necessary investments.

1960–1970s: Land reforms were unleashed across LAC countries (except Mexico, which undertook these reforms in 1917). The results of land reforms were mixed. Countries (e.g., Bolivia and Mexico) with a broader reform package that included credit schemes and infrastructure improvement, generally succeeded, while those (e.g., Venezuela, Colombia and Brazil) with a focus on land redistribution alone, were less successful.

1970–1980s: Conversion of forest land to agricultural land was encouraged. However, these changes were not well planned, and the people who occupied these new agricultural areas had little knowledge of agriculture. The areas were also fairly isolated. The net effect was large-scale deforestation,[45] which continues to this day, with little improvement in agricultural production.

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44. Zoomers, A. (2002). Rural development policy in Latin America: the future of the countryside. *Social Scientist*, *30*(11–12), 61–84. https://doi.org/10.2307/3518199

45. Kleinpenning, J. M. G., & Zoomers, E. B. (1988). Internal Colonization as a Policy Instrument for Changing a Country's Rural System: The Example of Paraguay. *Tijdschrift voor Economische en Sociale Geografie, 79*(4), 257–265. https://doi.org/10.1111/j.1467-9663.1988.tb01311.x

This period also saw an effort towards Integrated Rural Development (IRD), by international agencies such as the World Bank. IRD was multidimensional, focusing on economic infrastructure, agricultural productivity, marketing channels, service levels and non-farm income opportunities.[46] However, due to the project being too broad, implementation was too complicated, and the project did not yield results.

1980–2000: The debt crisis of the 1980s resulted in the World Bank stepping in and agricultural interventions shifted from being farmer/producer centric to private-sector centric stimuli. International agencies such as the Food and Agriculture Organization (FAO), United Nations Environment Programme (UNEP) and the Organization for Economic Co-operation and Development (OECD) engaged with the region to alleviate poverty and promote sustainable development, and help countries shape their agriculture and soil policies.

Country-Specific Policies from SOILEX

The majority of Latin American countries have existing legal instruments that include soil protection and the prevention of soil degradation. The FAO SOILEX[47] lists parameters of soil conservation, soil erosion, soil restoration, soil monitoring, soil quality, nutrient imbalance, soil pollution, waterlogging, soil biodiversity loss, soil acidification, soil compaction, and SOC loss.

According to this portal, some LAC countries have planned extensively, laying out the necessary measures to achieve their sustainable development goals. Others have not updated laws and regulations after the 20th century. Besides striving to restrict the further decline in soil health, it is observed that a number of Latin American countries have multiple policies dedicated towards specific SSM solutions.

On a much broader level of sustainable development, in 2010, Bolivia passed a first-of-its-kind "Mother Earth Law", essentially viewing the planet as a living entity and granting nature equal rights as humans, while obligating the state and society to guarantee respect for these rights, for the wellbeing of present and future

46. Zoomers, E. B., & Geurten, G. N. (2008). A Decade of Integrated Rural Development Planning: An Assessment of PRODERM Experiences in Cusco, Peru. *Tijdschrift voor Economische en Sociale Geografie 82*(3),195. https://doi.org/10.1111/j.1467-9663.1991.tb00788.x

47. SoiLEX is a global database that aims to facilitate access to information on existing legal instruments on soil protection and prevention of soil degradation.

generations.[48] Bolivia also has progressive national laws in place for soil, including The Environment Protection Law that regulates how agricultural activities should maintain soil productive capacity and avoid soil loss and degradation.[49] There is also a procedure to obtain a ten-year soil use license in which farmers have to plan out how they will care for the land with the local regulatory authority. Another law passed in 2015 establishes the mechanism for the recovery of degraded agricultural land areas of small properties and communities. Additionally, Bolivia created the comprehensive Soil Recovery Program (PRORESU) under the Vice Ministry of Lands for the recovery of degraded agricultural areas.

Brazil formulated a rigorous policy for desertification and drought in 2015, to prevent and combat desertification and recover degraded areas. Brazil's policies also specifically mention improvement and maintenance of SOM, with SSM policies that: sustainably improve productivity; improve product quality; increase agroforestry income; encourage the practice of integrated livestock and forestry systems in deforested areas as alternatives to traditional monoculture; promote the diversification of production systems through the insertion of forestry resources, stimulate alternative to the use of fire in agriculture; aim at the commercial exploitation of timber and non timber products, as well as other forms of systems in order to protect, manage and exploit forestry and silvo-pastoralism resources; and stimulate and disseminate agroforestry systems allied to conservation practices and animal welfare.

Brazil has over twenty Soil Conservation laws and Argentina has over thirty laws. Both countries have laws for particular regions to tackle the unique problems of those areas. This is an ideal approach in large countries with multiple agroecological zones. These efforts are a starting point for directing the future agricultural expansion towards socially acceptable, economically viable, and environmentally sustainable systems. However, improvements can be made to scale them to maximum potential on the ground.[50]

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48. The Mother Earth Law and Integral Development to Live Well, Law No 300. *Bolivia: Laws, Grantham Research Institute on Climate Change and the Environment*. https://www.climate-laws.org/geographies/bolivia/laws/the-mother-earth-law-and-integral-development-to-live-well-law-no-300

49. GSL. Ley de Protección y Conservación de Suelos N° IX-0315–2004; Ministerio del Campo del Gobierno: de la Provincia de San Luis, Argentina. San Luis, Argentina. http://www.campo.sanluis.gov.ar/campoWeb/Contenido/Pagina11/File/Ley Proteccin y Conservacin de Suelo.pdf (accessed on 15 November 2014).

50. Wingeyer, A. B., Amado, T. J., Pérez-Bidegain, M., Studdert, G. A., Varela, C. H. P., Garcia, F. O., & Karlen, D. L. (2015). Soil quality impacts of current South American agricultural practices. *Sustainability*, 7(2), 2213-2242. https://doi.org/10.3390/su7022213

Mexico, Colombia and Peru have notably comprehensive laws for soil conservation. The National Strategy to Combat Desertification and Drought 2016–2030 in Peru considers a planning horizon of 15 years, which is the longest in the LAC region.

A Latin American country just below the top ten in land area, Uruguay stands out for having very practical laws in place for SSM with the 2008 Decree No. 405/008 – Responsible and Sustainable Use of Soils. Land use in Uruguay is intensifying rapidly and this has led to an increase in the risk of erosion and degradation, as well as the loss of fertility and structural characteristics of the soil. In this context and within the framework of what is established by a previous law, the Decree implements harmonized measures that consider components of dissemination, training, control and supervision of soils and crops. The law clearly mentions inappropriate practices in terms of soil and water management and the consequences for specific points such as leaving the soil bare after harvesting the crop, direct seeding, the application of herbicides in the natural drainage of the land and property, and proper tillage.

Furthermore, Uruguay has fixed a solution so that the estimated potential erosion is less than the maximum allowable soil loss threshold for a particular soil type based on soil and landscape characteristics, proposed rotations and technology used on agricultural land. To adhere to this rule, farmers are required to develop a Land Use Management Plan. After the plan is put together with the help of a certified agronomist, it will go through an assessment process to analyze the potential soil erosion and the proposed management plan on each of the farmer's lands. The plans are then approved if they pass the maximum allowable soil loss threshold and other evaluation measures.

Within the group of smaller countries in Latin America, Nicaragua, Honduras, Guatemala, Costa Rica and Cuba all have laws in place that acknowledge the need for soil protection and soil conservation. In Cuba, land degradation is a priority issue that has received attention in the national strategy document: The National Environment Strategy 2007/2010. As a first step, it has defined five main issues in Cuba: land degradation, factors affecting forest coverage, pollution, loss of biological diversity, and water scarcity. The document proposes policies and instruments to tackle the five issues in order to improve environmental protection and the rational use of national resources.[51] Haiti and the Dominican Republic could update their laws to align more with SSM or soil improvement directly.

Lastly, protection of forests is a major challenge and responsibility that many Latin American countries have to take up to conserve their rich soils. Chile has in place, Decreto Nş 82 - Reglamento de suelos, aguas y humedales 2010. This regulation prescribes correct practices for the felling, destruction, elimination, or impairment of native trees and shrubs in native forests, as well as that of trees, shrubs and succulents in xerophytic formations. It aims to protect soils, springs, water bodies and natural watercourses, and wetlands which are declared as priority conservation sites.

Policy Recommendations for LAC

The policy recommendations in this section are based on the challenges facing agricultural soils of the LAC region. These recommendations should be further detailed for each nation in the region, considering its unique context. LAC, given its rich natural endowment and relatively low population pressure, has the ability to become the breadbasket for the world if region-specific SSM is implemented. Managing soil will also lead to reduced climate vulnerability and deforestation.

While there are various projects that have been taken up by both national and international agencies to combat land and soil degradation in the region, policies need to become more concerted, focused and streamlined. The key point in this streamlined policy should be to bring back a minimum of 3–6% SOM. This can be achieved by taking action under the four pillars of SSM:

- Knowledge Systems
- Farmer Support Ecosystem
- Legal Provisions
- Monitoring and Learning Systems

High level policies to combat and reverse land degradation and desertification have been articulated by agencies like the UNCCD and programs like Reducing Emissions from Deforestation and Forest Degradation (REDD). But operationalizing them

51. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy*. https://www.fao.org/3/i5199e/I5199E.pdf

regionally has unique challenges with respect to capacities, institutional setup and resources.[52]

Forests in the LAC region play a very important and significant role in climate stabilization and many other ecosystem services. Thus, there are several studies conducted by reputed organizations like the Inter-American Development Bank (IADB), Economic Commission for Latin America and the Caribbean, and UNEP, on the state of LAC's forests. Studies have looked at how the role of LAC's forests, as a carbon sink (in the form of forests) and as greenhouse gas emitters (when deforested), is the highest among all forests in the world. But no amount of work will be enough to save forests unless the state of agricultural soils is improved and agriculture becomes profitable.

According to a recent IADB report, to protect forests in the region, policies should be addressed along with forest restoration and protection, new technologies for sustainable agriculture, green infrastructure for risk reduction, and better communication between scientists and stakeholders.[53] The same study observes that domestic policies and stringent regulations around forest use can be short-term deterrents in unsustainable use of forests, but in the long run, only positive incentives to sustainably manage agricultural lands will safeguard forests.[54]

Consistent financing is required for interventions across these four pillars to:

1. Create context-specific knowledge systems
2. Establish farmer support systems in the form of extension activities, trainings and incentive payments to practice SSM
3. Facilitate regular monitoring and evaluation of SSM activities and feedback loops

Some of the sources of funding which can be leveraged are listed next, from a World Bank Report.[55]

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52. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy*. https://www.fao.org/3/i5199e/I5199E.pdf

53. Ardila, J., Arieira, J., Bauch, S. C., Bezerra, T., Blackman, A., David, O., ... & Warren, M. (2020). Latin American and Caribbean Forests in the 2020s: Trends, Challenges, and Opportunities. http://dx.doi.org/10.18235/0003019

54. *ibid.*

55. *Sustainable Land Management and Restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

- **Global Environment Facility (GEF)**: The GEF's main focus is grant funding through four modalities: full-sized projects (over USD 2 million); medium-sized projects (up to USD 2 million); enabling activities (under USD 1 million) and programmatic approaches. Non-grant instruments are also available for specific initiatives.

  Projects can be developed and submitted through 18 GEF agencies including UNEP, UNDP, World Bank, Regional Development Banks, WWF, IUCN, and Conservation International. Funding proposals are largely "mainstreamed" in the project preparation cycle of these organizations.

- **Green Climate Fund (GCF):** Low-emission (mitigation) and climate resilient (adaptation) projects and programs developed by the public and private sectors: Risk-based approach depending on funding size for micro (up to USD 10 million), small (USD 10–50 million), medium (USD 50–250 million), and large (over USD 250 million) size projects and programs. GCF provides grants with and without repayment contingency, as well as loans and equity.

  The GCF funds can be directly accessed through accredited subnational, national, or regional implementing Accredited Entities; and International Accredited Entities, including UN agencies, development banks, and NGOs.

- **Climate Investment Funds (CIF):** The USD 8.3 billion Climate Investment Funds is providing 72 developing and middle-income countries with urgently needed resources to manage the challenges of climate change and reduce their Greenhouse Gas emissions. Total CIF pledges are expected to attract an additional USD 58 billion of co-financing for a portfolio of over 300 projects and programs and counting.

  CIF is implemented through five multilateral development banks: World Bank, African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development, and the Inter-American Development Bank.

- **Adaptation Fund:** The Adaptation Fund has piloted direct and regional access and provides grants of up to USD 10 million for concrete adaptation projects in nine thematic focus areas. The projects need to result in outputs that are visible and tangible, which always entails a concrete on-the-ground investment (i.e., pure capacity building or research projects are not eligible).

  Through national, multilateral and regional implementing entities including UN agencies, development banks, NGOs, or directly through national implementing entities, proposals are accepted three times a year for review at annual board meetings and in-between sessions, either as a full proposal or as a concept note.

- **Land Degradation Neutrality (LDN) Fund:** The LDN Fund is focused on direct investment into larger-scale land restoration, rehabilitation, and land degradation avoidance programs that will integrate smallholders and local communities and has a dedicated window for small-scale projects and small- and medium-sized enterprises.

  The Fund will only consider projects that can make a significant contribution to LDN while producing appropriate risk adjusted returns and complying with robust environmental and social standards. Projects should have already successfully completed a pilot/feasibility project and be looking for further investment to support a scale up.

- **International Development Association (IDA):** The International Development Association is part of the World Bank Group and it is the fund for the world's 75 poorest countries. Since its establishment in 1960, IDA has provided USD 312 billion in loans and grants. Annual commitments have averaged about USD 19 billion per year. In its 18th replenishment cycle, IDA has been able to mobilize approximately USD 75 billion for the period from 2017 to 2020.

  IDA resources are made available to IDA eligible countries based on several criteria and approved according to the objectives set in the Country Partnership Framework of the World Bank Group.

- **Multilateral Development Banks (MDBs):** The MDBs provide technical and financial support in the form of credits, concessional loans, and grants, as well as technical assistance for low- and middle-income countries. Resources are allocated for a range of sectors, such as agriculture, environmental and natural resource management, and climate action. Thus, the MDBs play an important role in financing LDN.

  The MDBs have dedicated private sector branches that facilitate private sector investments and public private partnerships, for example, for agriculture or forestry investments. Among these outlets are the World Bank's International Finance Cooperation (IFC) or IDB's Inter-American Investment Cooperation (IIC) that have mobilized financing from the private sector to support sustainable forest management, conservation agriculture, and other projects. In the fiscal year 2016, IFC invested USD 3.4 billion in agribusiness.

Knowledge Systems

The knowledge systems set up in LAC should build on setting up institutions that help farmers have strong forward linkages (to markets and fair prices), for produce from a farming system sustained by SSM practices that also includes tree-based agriculture (or agroforestry).

Creating and cataloging agroecological-specific SSM practices: There have been efforts to bring SSM practices through promotion of agroforestry, low carbon farming and sustainable management of forests, which have been promoted by international organizations such as the IICA, World Agroforestry Alliance, CIAT, IADB, etc. There is also an effort to reforest the region through regeneration, ecological restoration, timber plantation, agroforestry, etc. The FAO's Global Soil partnership initiative has set up the Latin American Soil Information Systems, where these practices and the research conducted by various global organizations can be cataloged.

The information system should provide alternative models tailored to a farmer's current conventional practice, such that they are economically equivalent to the present practice and incorporate any or all needs of crop production, pasture and animal rearing.[56]

Research on major soil threats: Given the various threats and degradation that the soils of the region have seen, it will be best to develop SSM models with economic benefits in the medium and long term. It is observed that with enough education and awareness, farmers are willing to wait out reduced yields in the short term, if they can expect better returns in the medium and long term. Development of models for degraded soils will be of utmost importance to ensure that no further deforestation happens in the region.

Study indigenous practices and catalog them: An understanding of the biophysical and human factors behind indigenous practices might indicate how they can be adopted or adapted to the present socio-economic situation.[57] Archeological studies are beginning to unearth that parts of Amazonia were composed of iron-rich soils

56. Wingeyer, A. B., Amado, T. J., Pérez-Bidegain, M., Studdert, G. A., Varela, C. H. P., Garcia, F. O., & Karlen, D. L. (2015). Soil quality impacts of current South American agricultural practices. *Sustainability*, 7(2), 2213–2242. https://doi.org/10.3390/su7022213

57. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy*. https://www.fao.org/3/i5199e/I5199E.pdf

which were uncultivable. But indigenous farming practices converted these into fertile soils in very short durations (weeks to months). For example, *terra preta – the rich amazonian black soils* that are less prone to nutrient leaching because of a high concentration of charcoal, microbial life and organic matter, were discovered to be manmade.[58] Similarly, there may be other indigenous practices that could revive degraded soils much faster than methods currently known to us.

Realtime market knowledge: If the farmers of the region have to pick up SSM practices outside of what is practiced by them presently, they will have to benefit from these in the market. Market and economic research has to be conducted to ensure the alternative models provided to farmers translate into real markets and not potential markets. It is therefore important for LAC to explore opportunities for new markets, new products, and enhanced productivity. Countries other than Brazil, Chile, and Uruguay, particularly those in Central America, have opportunities to expand timber production in both natural forests and plantations. Global Timber Model projections suggest that LAC forest product output will increase from 2020 through 2040–2050.[59]

Farmer Support Ecosystem

There is strong evidence that farmers embrace new practices if they understand the challenges and benefits. The LAC region has adopted large scale no-till (NT) farming voluntarily, in response to the unsustainable soil erosion observed under tillage. The region's adoption of NT was a huge success, reaching more than 54 Mha (approximately 45% of global NT area) in less than three decades, without direct government financial support.[60] This proves that if farmers have access to farmer-friendly knowledge, they will transition to a new practice.[61]

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58. Orozco-Ortiz, J. M. (2020). Insights into the genesis of Amazonian Anthrosols: the role of ceramic sherds and flies during the early stages of Terra Preta formation. *Institute of Crop Science and Resource Conservation – Soil Science and Soil Ecology. Colombia*.

59. Ardila, J., Arieira, J., Bauch, S. C., Bezerra, T., Blackman, A., David, O., … & Warren, M. (2020). Latin American and Caribbean Forests in the 2020s: Trends, Challenges, and Opportunities. http://dx.doi.org/10.18235/0003019

60. Wingeyer, A. B., Amado, T. J., Pérez-Bidegain, M., Studdert, G. A., Varela, C. H. P., Garcia, F. O., & Karlen, D. L. (2015). Soil quality impacts of current South American agricultural practices. *Sustainability*, 7(2), 2213-2242. https://doi.org/10.3390/su7022213

61. *ibid.*

Incentivize SSM: There have not been policies and well-targeted subsidies or incentives through marketing prices and credits to induce sustainable land management. In addition, agricultural research has been oriented towards increasing productivity through the use of inputs, rather than towards sustainable land use. This has contributed indirectly to growing environmental problems, including soil erosion.[62]

According to soil studies in Latin America, a large proportion of the area under agricultural crops and pasture is actually suitable only for forestry uses.[63] This means agroforestry and tree-based models will yield well here. However, income from agroforestry produce is not certain and as straightforward as selling maize or wheat. If the incentives towards SSM practices were made available and mainstreamed (through certain and straightforward access), the rate of transition to SSM practices will be accelerated. Some sources of incentives are listed in the beginning of this policy recommendation section.

Legal Provisions

Soil to be enshrined in legal systems: Soil should be treated like any other natural resource that is enshrined by the law of the land. Healthy soils and their characteristics must be clearly defined. The "healthy soil" definition should include a clear quantified range for physical, chemical and biological parameters. The biological parameters should ensure that SOM of a healthy soil is a minimum of 3–6%. SSM practices should also be detailed in laws specific to the country's context. These practices can be drawn from FAO's Voluntary Guidelines for Sustainable Soil Management.[64]

Land tenure: It is found that regional economic and land tenure conditions are at odds with practices aimed at long-term soil quality conservation and improvement.

The issue of land tenure in the region should be resolved by the governments at the earliest, as this is a significant bottleneck that deters farmers from adopting SSM

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62. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy*. https://www.fao.org/3/i5199e/I5199E.pdf

63. Kishor, N. M., & Constantino, L. F. (1993). Forest Management and Competing Land Uses: An Economic Analysis for Costa Rica. *LATEN Dissemination Note # 7. The World Bank. Washington, D.C.*

64. Baritz, R., Wiese, L., Verbeke, I., & Vargas, R. (2017). Voluntary guidelines for sustainable soil management: Global action for healthy soils. *International Yearbook of Soil Law and Policy 2017*, 17–36. https://doi.org/10.1007/978-3-319-68885-5_3

practices. The Voluntary Guidelines on Tenure developed by the FAO can assist in this process.[65]

Brazil is a global exception in terms of forest policy change, with a dramatic policy-driven reduction of deforestation in the Amazon Basin.[66] But land tenure in the region should also define forest dwellers / forest dependent people first. However, the heterogeneity of people's interactions with forests makes it difficult to define forest dependence in a standard and meaningful way.[67]

Setting up a structure for community forest management has promise for LAC, as evidence shows it has decreased the rate of deforestation in many locations. If done properly, community forest management and timber concessions are efforts that can help regularize property rights and reduce the illegal exploitation of forests.[68] At the same time, alternatives that also enhance livelihoods such as expanding production of non-timber forest products should be looked at for long-term sustainability of the environment and local communities.[69]

Monitoring and Learning Systems

The prevalent soil monitoring sites in LAC have been selected to address questions related to fertility or taxonomy. To overcome this, Mexico and Brazil are currently conducting national soil surveys designed to quantify SOC, increasing the number of sites within a systematic grid and using state-of-the-art instrumentation.[70] In the case

65. Seufert, P. (2013). The FAO voluntary guidelines on the responsible governance of tenure of land, fisheries and Forests. *Globalizations*, *10*(1), 181–186. https://doi.org/10.1080/14747731.2013.764157

66. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy*. https://www.fao.org/3/i5199e/I5199E.pdf

67. Newton, P., Miller, D. C., Byenkya, M. A. A., & Agrawal, A. (2016). Who are forest-dependent people? A taxonomy to aid livelihood and land use decision-making in forested regions. *Land Use Policy, 57*, 388–395. https://doi.org/10.1016/j.landusepol.2016.05.032

68. Ardila, J., Arieira, J., Bauch, S. C., Bezerra, T., Blackman, A., David, O., … & Warren, M. (2020). Latin American and Caribbean Forests in the 2020s: Trends, Challenges, and Opportunities. http://dx.doi.org/10.18235/0003019

69. *ibid.*

70. Vargas, R., Yepez, E. A., Andrade, J. L., Angeles, G., Arredondo, T., Castellanos, A. E., Delgado-Balbuena, J., Garatuza-Payan, J., Gonzales del Castillo, E., Oechel, W., Rodriguez, J. C., Sanchez-Azofeifa, G. A., Velasco, E., Vivoni, E. R. & Watts, C. (2013). Progress and opportunities for monitoring greenhouse gases fluxes in Mexican ecosystems: the MexFlux network. *Atmosfera, 26*(3), 325–336. https://doi.org/10.1016/S0187-6236(13)71079-8

of Mexico, there are currently 11,000 sites with systematic information on all carbon reservoirs and coordinated programs for re-sampling and continuous monitoring.[71]

National soil information systems: Set up national soil information systems that will capture soil health information using both primary data collection (as much as possible) and secondary data from satellite imagery. The information systems can monitor the threats to soil – salinization, erosion, water scarcity, dust storms, SOM and other crucial parameters. Argentina, Bolivia, Chile, Colombia, Ecuador, Peru and Uruguay have started to develop their national soil information systems to measure SOC, as part of a climate change adaptation and mitigation strategy setup.[72] All this data can be regionally collated under the Latin American Soil Information System.

Digital systems for data collection and monitoring: Provisions to measure indicators of progress on various aspects of the soil, especially the change in SOM and soil biology, should be in place. This can facilitate remote monitoring, knowledge exchange among farmers and also between farmers, experts and other stakeholders.[73]

Soil testing ecosystem: Soil biology should be made a part of soil testing reports, and the testing ecosystem – non-existent at present – should be established and strengthened. Instead of setting up elaborate infrastructure for laboratories like the rest of the world, LAC can try to use field testing kits that are being developed across the world. The soil testing kits can be used extensively to help farmers make scientific decisions on crop inputs. There can also be some physical infrastructure laboratories run by research organizations for a more detailed understanding of what is happening to the soil. The testing kits can also measure SOM, SOC and soil biological parameters mentioned in the global policy recommendation. These measurements can also serve the purpose of paying incentives to farmers for carbon sequestration or ecosystem services that soil provides.

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71. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy*. https://www.fao.org/3/i5199e/I5199E.pdf

72. Seven Latin American countries start developing their National Soil Information Systems. *Global Soil Partnership, FAO.* https://www.fao.org/global-soil-partnership/resources/highlights/detail/en/c/1035210/#:~:text=Areas%20of%20work-,Seven%20Latin%20American%20countries%20start%20developing%20their%20National%20Soil%20Information,change%20adaptation%20and%20mitigation%20strategy

73. Bahn, R. A., Yehya, A. A., & Zurayk, R. (2021). Digitalization for Sustainable Agri-Food Systems: Potential, status, and risks for the MENA region. *Sustainability*, *13*(6), 3223. https://doi.org/10.3390/su13063223

3.5.1 Policies for the Caribbean

Nations: Antigua and Barbuda, Aruba, Bahamas, Belize, Bermuda, Barbados, Cuba, Curaçao, Cayman Islands, Dominica, Dominican Republic, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Maarten, Puerto Rico, Suriname, St. Martin, Turks and Caicos Islands, Trinidad and Tobago, Saint Vincent and the Grenadines, British Virgin Islands, United States Virgin Islands, Guadeloupe, Martinique, Grenada, Caribbean Netherlands, Anguilla, Saint Barthélemy, and Montserrat.

Caribbean Statistics

Total Population: 73.14 million[1]

GDP: USD 884.77 billion[2]

GDP per Capita: USD 11,921[3] (wide range from USD 1,479 (Haiti) to USD 113,023 (Bermuda))

Total Landmass Area:[4] 1.48 million sq. km

Landmass under Agriculture:[5] 343,000 sq km

Population Dependent on Agriculture as a Percentage of Total Employment: 13.05% (wide range from 1.09% (Puerto Rico) to 29.03% (Haiti))[6]

Average Farm Size: 39.05 ha (wide range from 0.98 ha (Saint Vincent and the Grenadines) to 60.02 ha (Bolivarian Republic of Venezuela))[7]

Executive Summary

Although the Caribbean currently faces challenging situations, these can be seen as an opportunity to establish Sustainable Soil Management practices through agricultural interventions. The interventions will need to focus on strengthening the institutional framework and build Knowledge Systems, a Farmer Support Ecosystem, Legal Provisions, and Monitoring and Learning Systems. These efforts will increase the food security of the region, combat water scarcity, build climate resilience and increase agriculture's contribution to GDP and employment. If time-bound action is taken, the Caribbean islands can stand as an example for all small island states across the world.

1. World Bank Open Data 2020. https://data.worldbank.org/
2. World Bank Open Data 2018 (Venezuela, RB 2014). https://data.worldbank.org/
3. *ibid.*
4. World Bank Open Data 2020. https://data.worldbank.org/
5. World Bank Open Data 2017. https://data.worldbank.org/
6. World Bank Open Data 2019. https://data.worldbank.org/
7. Lowder, S. K., Skoet, J., & Raney, T. (2016). The number, size, and distribution of farms, smallholder farms, and Family Farms Worldwide. *World Development, 87*, 16–29. https://doi.org/10.1016/j.worlddev.2015.10.041

In order to assess the efforts that the Caribbean nations have made towards Sustainable Soil Management (SSM), we must first examine the current state of their soils and climate, including the natural constraints that they face. Secondly, we must look at the existing policies that govern agricultural lands.

The State of the Caribbean Islands' Soils

Around 5% of the land area of the Caribbean islands is under agriculture. Rainfed agriculture is the predominant practice. The amount of soil degradation in the region is not yet quantified. The severity of soil degradation depends on the size and topography of the islands, their climate vulnerability (e.g. hurricanes and high rainfall), presence of natural vegetation to combat soil erosion, drought conditions and salinity intrusion.

Topography

Both topography and size of the islands have an impact on soil degradation. Steep landscapes with slopes more than 30–45° result in higher loss of soil due to wind and water erosion. Smaller states are disproportionately dependent on coastal areas as opposed to larger states, and they have fewer resources to cope with the aftermath of natural disasters. Countries broadly fall under three categories of topography: islands with relatively low elevation and few steep slopes; small islands with a high percentage of steep slopes; and large islands with large areas of both flat lands and steep slopes.

Climate Vulnerability

Heavy/torrential rains and hurricanes: Several islands are characterized by steep slopes with a significant amount of land having slopes greater than 30°, and many slopes greater than 45°.[8] The islands receive annual rainfall of 1300–3000 mm on an average. Some islands like Dominica receive torrential rains of 7500–8000 mm.

In general, total rainfall is not only high, but also intense. The intensity ranges between 25–1127 mm per hour. Strong winds frequently accompany these rains, increasing their erosivity.[9] The islands have lost primary vegetation, and the secondary vegetation does not protect soil against erosion to the same extent as primary vegetation.

8. Gumbs, F. (1994), *Farmers and Soil Conservation in the Caribbean*. Commonwealth Secretariat, London. https://doi.org/10.14217/9781848595729-en.

9. *ibid.*

On an average, 13 hurricane storms hit the Caribbean region between June and November every year. Sometimes these disasters amount to USD 3 billion, which is 200% of the annual GDP of the region.[10]

Droughts

The Caribbean region is characterized by alternating wet seasons (with heavy rainfall) and intense dry seasons. Therefore, droughts (soil moisture deficits and strained water resources) occur every year and often lead to a significant number of bushfires. In 2016, Central American nations neighboring the Caribbeans lost around 50–80% of their agricultural produce due to El Niño.[11] Similar losses were seen in the Caribbeans also.

The Caribbean accounts for seven of the world's top 36 water stressed countries. For example, Barbados, Antigua and Barbuda, and St. Kitts and Nevis are water scarce with less than 1000 m^3 freshwater resources per capita.[12]

Salinity Intrusion

It is well established that salinity intrusion into groundwater happens due to a combination of sea-level rise and over-abstraction of groundwater. Sea levels in the Caribbean have risen at a rate of approximately 1 mm/year during the 20th century. Together with a projected decrease in rainfall, these rising sea levels will lead to salinity intrusion into the limited agricultural land and coastal and groundwater aquifers and thus reduce freshwater availability.

Present Policy Ecosystems

The Caribbean islands vary in population, size, income, and ethnic composition, but they all share a common heritage in agriculture. However, in recent decades in many Caribbean states, the tourism and services sectors have become economic forces while agriculture has declined in relative importance, both in terms of contribution to GDP and the share of the labor force. In the early 1900s, the economies were based on cultivation of tobacco and cotton. They later transformed into sugarcane-based economies before turning into tourism-dependent economies.

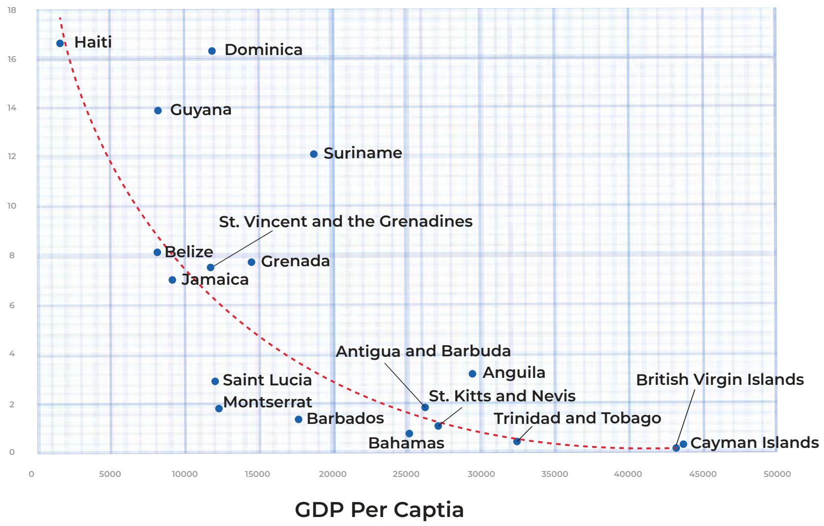
10. *The Caribbean*. World Food Programme. https://www.wfp.org/countries/caribbean

11. *Major crop losses in Central America due to El Niño*. Food and Agriculture Organization of the United Nations (FAO). (2015). https://www.fao.org/emergencies/fao-in-action/stories/stories-detail/en/c/330253/

12. *Drought Characteristics and Management in the Caribbean*. Food and Agriculture Organization of the United Nations (FAO). (2016). https://www.fao.org/3/i5695e/i5695e.pdf

Today, agriculture's contribution to the economy, especially in the small islands, can be as low as 0.7% of GDP.

Figure 1: Agriculture as Percentage of GDP Versus GDP per Capita for Caribbean Nations. (Source: GDP per capita, USD[13])



The Caribbeans spend somewhere between USD 4–10 billion annually on food imports alone.[14]

The CARICOM[15,16] and OECS[17] have acknowledged the need to produce food within the Caribbean region. To become food secure and reduce dependence on food imports, CARICOM came up with a **"25 in 5"** plan in 2020. This plan seeks to reduce food imports by 25% by 2025.[18]

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13. *Current status of agriculture in the Caribbean and implications for agriculture policy and strategy*. 2030 – Food, Agriculture and Rural Development in Latin America and the Caribbean. Food and Agriculture Organization of the United Nations (FAO). (2019).

14. *Reducing CARICOM Food Security Bill Vitally Essential, But Always Potentially Problematic*. St. Lucia News from The Voice. (2022) https://thevoiceslu.com/2022/02/reducing-caricom-food-security-bill-vitally-essential-but-always-potentially-problematic/

15. The Caribbean Community and Common Market (CARICOM) is a grouping of twenty countries: fifteen Member States and five Associate Members.

16. CARICOM Members include Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, and Trinidad and Tobago

17. The OECS is now a nine-member grouping comprising Antigua and Barbuda, Commonwealth of Dominica, Grenada, Montserrat, St Kitts and Nevis, St Lucia and St Vincent and the Grenadines. Anguilla and the British Virgin Islands.

18. Nurse, M. (2020). '25 in 5' plan to tackle CARICOM Food Import Bill. *CARICOM Today*. https://today.caricom.org/2020/07/27/25-in-5-plan-to-tackle-caricom-food-import-bill/

Cheap Imports and Intra-regional Trade

The farmers of the Caribbean region suffer the onslaught of cheap imports that took root when the regional economy oriented itself to tourism as its mainstay. Although CARICOM is pushing for intra-regional trade, consumers cannot be forced to buy local produce until local production becomes economically competitive. Also, there is no resolution or mechanism in place to reduce the cost of transport within the region. Additionally, at present the region does not have an agriculture commodity production plan to ensure that commodities are produced in line with consumption.

Constraints Introduced by Ambiguous Land Tenure

The level of land tenure insecurity is one of the factors that affect the ability of land occupants to mitigate, respond to and recover from natural disasters.[19] A short tenure discourages farmers from investing in long-term methods to regenerate soil.

With respect to land tenure, while the island of St. Vincent has clear ownership titles for over 72% of agricultural lands, in islands like Grenada and St. Kitts, the percentage is only around 30%. Lands without ownership titles are farmed by squatters, renters, short leasers, shared croppers and landless farmers. The outdated agriculture practices followed due to land tenure insecurity are slash and burn and shifting cultivation by squatters, which means whatever is taken out of the soil is not put back, thus leaving the soil undernourished. Especially in the Caribbeans, due to frequent wind and water-based soil erosion, soil is lost in lands with no cover crops or any vegetation – like the plots where slash and burn is practiced.

Small landowners (< 1 ha) farm more than 70% of land holdings in the Caribbean islands. The governments have made efforts to protect small agricultural holdings in many Caribbean countries by making land tenure in the region favorable to small farmers. The tenancy laws do mandate soil conservation activities, however due to lack of access to agriculture extension services and technical support, the conservation activities are not enforced. These tenant laws protect the right of farmers to farm the land, but do not provide for ownership of the land.

19. Griffith-Charles, C., Balfour, S., Bynoe, P., Roberts, D., & Wilson, L. (2015). Land Tenure and Natural Disaster Management in the Caribbean. *Land Tenure Journal*. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/3/I4712T/i4712t.pdf

Aging Agriculture Labor

The average age of farmers in the region is over 50 years, and over 60 in some countries. The drudgery involved in agriculture, combined with the minimal financial reward and rigid traditional methods, has resulted in 30% of the population living in poverty.[20]

Policy Recommendations for the Caribbean Region

Regional coordination among countries is key to ensuring food and nutrition security. As Dr. Mohamed Irfan Ali said in the CARICOM preparatory meeting to the UN Food Summit, larger islands like Belize, Suriname and Guyana can be the bread baskets of the Caribbean region.[21]

The leadership in its preparation for the UN Food Systems summit has expressed[22] the need to have the following interventions within the region:

- Agriculture R&D specific to the Caribbean region with support from expert organizations like the FAO
- Access to innovative processes and technologies to upgrade present agriculture practices in the region
- Agriculture investments from banks, and development of innovative financial products to help farmers move towards climate smart agriculture practices
- Ways to inspire youth to get into agriculture: introduction of sustainable soil management practices; access to loans; innovative communication to get them interested
- Education for farmers
- Crop insurance to cover climate and weather-based risks
- Intra-regional trade

All of the above suggested interventions are very relevant and much needed in the Caribbean context. But to ensure all of this nudges agriculture in a sustainable direction, CARICOM's Agri-Food Task Force and the Agri-Food Systems Strategy can

20. *The Caribbean*. World Food Programme. https://www.wfp.org/countries/caribbean

21. CARICOM Regional Dialogue in Preparation for the United Nations Food Systems Summit. (2021). https://www.youtube.com/watch?v=Q5CCtuvjvv8

22. *ibid*.

have a simple and single-pointed focus towards maintaining a minimum SOM of 3–6% in agricultural lands. While this may look like a simple aspiration, the actions required to achieve this goal will address a gamut of concerns around food security and climate resilience.

Increasing SOM will help in alleviating all the natural constraints mentioned earlier. For example, SOM improves soil structure, which will reduce erosion due to topography and rainfall. SOM also increases the capacity of soil to absorb and store moisture, which is critical to help farmers weather seasons of drought. Salinity intrusion can also be mitigated to some extent. Due to soil's greater water absorption at higher SOM levels, groundwater recharge becomes more effective, which can reduce salinity intrusion into aquifers, and loss of coastal agricultural lands.

Achieving a minimum of 3–6% SOM will need four pillars of intervention:

- Knowledge Systems
- Farmer Support Ecosystem
- Legal Provisions
- Monitoring and Learning Systems

Knowledge Systems

The premier institute of Caribbean Agricultural Research and Development Institute (CARDI) has focused on helping farmers through its four strategic programs – Value Chain Services, Policy and Advocacy, Institutional Strengthening, and Partnerships and Strategic Alliances. But it has not translated into expansion of farmer base or agricultural land in the region. This is to do with limited funding accessible to CARDI.[23] There is a need for funding of regional research, active collaboration with the FAO and establishing an implementation framework that helps farmers in remote areas benefit from work done by local research entities.

23. *Strategic Plan 2018–2022: Building a productive and resilient regional agriculture sector.* CARDI. (2018). http://www.cardi.org/wp-content/uploads/downloads/2018/05/CARDI-Strategic-Plan-2018-to-2022-Final.pdf

Agriculture knowledge systems should address issues specific to the region:

1. **Increased incidence of pests:** Changes in temperature and humidity increase the vulnerability of agrosystems to pests and introduced species.
2. **Low livestock productivity:** Drought, heat stress, and dry pastures reduce the availability of feed, which increases animal mortality and the cost of production.
3. **Climate Smart Agriculture (CSA) practices and farm models:** The FAO developed a "climate resilient practices" handbook for various typologies – cropping systems, livestock systems, fisheries and forest systems[24] in 2021. While the handbook can be a starting point, there are specific CSA practices that can be explored for tropical lowland regions like the Caribbean. Agroforestry is one of the most effective ways to address the issues of drought, agriculture in hilly terrain, windbreaks for heavy hurricane winds, etc. Specific agroforestry and intercropping models can be designed to match the region's unique climate where heavy rainfall is followed by 6 months of drought conditions.

Farmer Support Ecosystem

The present farmer outreach and extension systems are not sufficient. There must be a concerted effort in the region to ensure farmers are supported from sowing to harvest, to help them access markets through centralized information systems, and to build a network of human resources to extend this information to the last mile. By making use of technology, youth can play a very important role here in bringing timely information to farmers and help address advisory needs and farm crisis situations. For example, Antigua and Barbuda has introduced an agri-extension app in collaboration with the Inter-American Institute for Cooperation on Agriculture and the FAO.

Compensating Farmers for Following SSM

Only when farmers are compensated adequately for adopting SSM will it become large-scale. The Caribbean nations can leverage the carbon credit market through various mechanisms like that of REDD++[25] to pay the farmers.

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24. Alvar-Beltrán, J., Elbaroudi, I., Gialletti, A., Heureux, A., Neretin, & L. Soldan, R. (2021). Climate Resilient Practices: Typology and guiding material for climate risk screening. *Food and Agriculture Organization of the United Nations (FAO)*. https://www.fao.org/publications/card/en/c/CB3991EN/

25. *REDD+*. Green Climate Fund. https://www.greenclimate.fund/redd

Legal Provisions

The investments in the agriculture sector from private investment bodies and international entities will materialize only when the legal ecosystem fulfills certain conditions. These conditions are efficient and sustainable agricultural practices by farmers and an assured local market that is accessible to the farmers.

Soil Health Law

It will be prudent for the region to come up with a clear framework for a soil health law. The law for soil health should clearly define the parameters of healthy soil. This definition should include a minimum SOM of 3–6%. The law should involve monitoring the four parameters of SOC, soil biological activity, soil productivity and soil physical properties.

Other Supporting Policies

Resolve Land Tenure Ambiguities: In the Caribbean, many farmers do not have long tenures for the land they farm. For this reason, they are reluctant to take care of the soil and do not adopt medium- or long-term SSM measures such as agroforestry, which may not yield in their tenancy of land.

Crop Risk Insurance to Address Social Vulnerability: Populations and prime agricultural lands are located in coastal areas, vulnerable to sea level rise. Only 16% of farms have crop insurance coverage and 68% of farms have a net household income of less than USD 20,000, making these farmers very vulnerable to climate change. The region needs to devise insurance products to safeguard farmers. These products can be tied to climate smart agriculture practices, thus nudging farmers to become sustainable in land management and also improve their resilience to natural disasters.

Make Intra-regional Trade Affordable: The Caribbean relies heavily on cheap food imports. Intra-regional trade of agricultural commodities has been suggested as a way forward for the region to become food secure. However, the high cost of transport and the logistics involved in intra-regional trade is a well-established problem acknowledged by all the leaders of the Caribbean. A concerted time-bound policy should be crafted and implemented to ensure that intra-regional trade becomes affordable.

Also, governments have to take measures to protect local producers in the interim period before they become competitive against imports. This can be done through import taxations and government procurement of local farmer produce to meet the needs of schools and prisons, etc. These measures have to be carefully crafted to ensure the last mile consumers of the region (most of whom are poor) are not affected by the increased price of basic food items.

Monitoring and Learning Systems

At present, there is no clear source of data that can help one understand the state of soils in the Caribbean. The Global Soil Partnership, an initiative of the FAO, has created the Global Soil Organic Carbon (GSOC) map. It will be supportive to take the help of the regional team of the Intergovernmental Technical Panel on Soils (ITPS) to set up the systems to follow SSM practices and to monitor parameters such as SOC, soil biological activity, soil productivity and soil physical properties.

SSM practices will improve SOM and build a safety wall to reduce vulnerability and increase resilience in communities during droughts, hurricane cycles and other food security shocks created by events like the COVID-19 pandemic. It will also reduce the region's dependency on food imports.

3.6 Policies for the Middle East and North Africa

Middle East and North Africa (MENA) Countries:[1, 2] Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, State of Palestine, Syria, Tunisia, United Arab Emirates, Yemen.

MENA Statistics

Total Population: 457 million

GDP: 3.04 trillion USD[3]

GDP per Capita: USD 1670 – USD 88,000 (Varies significantly across the region)

Total Landmass Area:[4] 11.2 million km²

Landmass under Agriculture:[5] 3.724 million km²

Population Dependent on Agriculture as a Percentage of Total Employment:[6] 18.7%

Average Farm Size:[7] 0.8–16.7 ha
(The land holding size varies drastically across the MENA nations.)

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1. *Near East and North Africa Soil Partnership*. Global Soil Partnership. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/global-soil-partnership/regional-partnerships/nena/en/

2. World Bank's definition of MENA (Middle East and North Africa): A geographical identity and not a political identity. It is also loosely known as WANA – West Asia And North Africa.

3. *GDP (Current US$) - Middle East & North Africa*. World Bank. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=ZQ

4. *Land Area (sq. km) – Middle East & North Africa*. World Bank. https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=ZQ

5. *ibid.*

6. Bertini, R., & Zouache, A. (2021). Agricultural land issues in the Middle East and North Africa. *American Journal of Economics and Sociology*, *80*(2), 549–583. https://doi.org/10.1111/ajes.12391

7. *ibid.*

Executive Summary

The "Fertile Crescent", which includes modern-day Iraq, Lebanon, Palestine, Israel, Syria, Jordan, the northern parts of Egypt and Kuwait, southeastern Turkey and western Iran, has one of the longest histories of agriculture, dating back 11,000 years.[8] *But this once fertile land is now in a state where 40–70% of land and over 25% of arable land is degraded.*[9]

The MENA region is distinct in that it comprises a vast area of land under dry and arid climatic conditions. It is home to some of the largest deserts of the world: the Sahara and its components – the Libyan and Nubian deserts – the Arabian Desert and the Sinai Desert. The soil here has a low concentration of SOM, low inherent fertility and low structural stability or water holding capacity.[10] *Additionally, over the past two decades, this region has lost over 40% of its green cover, further contributing to depletion of organic matter in the soil.*[11] *Large parts of the region are under severe soil degradation due to soil erosion, salinization and nutrient depletion, leading to severe dust storms and active sand dunes.*

The various drivers of this rapid soil degradation and desertification include poor soil parent material, unsustainable agricultural practices, unclear land tenure and rights, and lack of policy focus and push towards sustainable soil management (SSM) in agricultural lands. The region at present is facing high population annual growth rates – 1.91% as compared to the global average of 1.16%.[12] *Other causes for concern are an increase in food deficit, highly variable income levels within and between countries (the GDP per capita ranges from USD 86,853 in Qatar to USD 1327 in*

8. Haviland, W. A., Walrath, D., McBride, B., & L., P. H. E. (2016). *The Essence of Anthropology*. Cengage Learning.

9. Devkota, M., Singh, Y., Yigezu, Y. A., Bashour, I., Mussadek, R., & Mrabet, R. (2022). Conservation agriculture in the drylands of the Middle East and North Africa (MENA) region: Past trend, current opportunities, challenges and future outlook. *Advances in Agronomy*, 253–305. https://doi.org/10.1016/bs.agron.2021.11.001

10. Lal, R. (2013). Climate change and soil quality in the WANA region. In *Climate Change and Food Security in West Asia and North Africa* (pp. 55–74). Springer, Dordrecht.

11. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations.* World Bank. (2019). https://doi.org/10.1596/33037

12. Devkota, M., Singh, Y., Yigezu, Y. A., Bashour, I., Mussadek, R., & Mrabet, R. (2022). Conservation agriculture in the drylands of the Middle East and North Africa (MENA) region: Past trend, current opportunities, challenges and future outlook. *Advances in Agronomy*, *172*, 253–305. https://doi.org/10.1016/bs.agron.2021.11.001

Mauritania[13]), limited and deteriorating arable lands, and extreme water scarcity (11 MENA countries face extreme water stress of 500 m³ per capita water availability).[14]

The economic cost of such degraded soils in the region is USD 9 billion per year,[15] whereas restoring 150 million hectares (ha) of degraded agricultural land could generate USD 85 billion in net benefits to national and local economies, provide USD 30–40 billion a year in extra income for farmers, and provide food for an additional 200 million people.[16]

This policy section for the MENA region will examine the state of agricultural soil of the region; cover the ramifications of the degraded soils on food security, water scarcity, and other aspects that drive conflict in this region; analyze the existing policy ecosystem; and provide policy recommendations which can help reverse the present worrying trends created by degraded soils.

The State of Agricultural Soil in MENA

Changes in soil quality are decided by three fundamental factors – parent material, climatic conditions, and the land-use practices. The MENA region's soils have degraded drastically over the past few decades due to the inherently weak parent material of soil, extreme climatic conditions and unsustainable agricultural land use.

The soils suffer from various degrees of water and wind erosion, salinization (due to flood irrigation and other practices without proper drainage), and loss of soil organic matter, which have accelerated soil degradation. Assessments suggest that upto 70% of MENA's area is degraded. Around 45% of the MENA's agricultural area is exposed to

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13. OECD/FAO (2018). Chapter 2: The Middle East and North Africa: Prospects and Challenges, 67–108. In: *OECD-FAO Agricultural Outlook 2018–2027*. OECD Publishing, Paris/Food and Agriculture Organization of the United Nations, Rome. https://doi.org/10.1787/agr_outlook-2018-en Africa

14. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

15. Caon, L., Watson, J., Gomes da Silva, C., Vargas, R., Khechimi, W., Bottigliero, F., & Verbeke, I. (2019). The multi-faced role of soil in the Near East and North Africa. *Global Soil Partnership Policy Brief No. 1, FAO.* https://www.fao.org/documents/card/en/c/CA3803EN/

16. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

salinity, soil nutrient depletion, and wind-water erosion – including about 68% of the rainfed agricultural land, one-third of the irrigated cropland, and 85% of the rangeland.[17]

To illustrate the intensity of degradation in MENA, a few examples are listed below. A more comprehensive report on degradation across countries is documented by the Global Soil Partnership's policy brief from 2019.[18]

- In Iran, around 50% of agricultural soils face deficiency of more than one essential nutrient. Soil Organic Carbon (SOC) is less than 1% in around 60% of agricultural soils.
- In Egypt, salinization has reduced yield by 25%, and many affected areas have been entirely abandoned.
- In Algeria, water erosion affects 45% of northern regions.
- In Syria, soil has been polluted by heavy metals, petroleum, olive mill wastewater, sewage, etc.

While erosion, salinization and fertility depletion can be directly ascribed to unsustainable agriculture practices, degradation from pollution can be ascribed to industries, agriculture and oil abstraction. These four threats, when not addressed, accelerate threats due to droughts / excess rainfall and climate change.

Parent (Principal) Material of Soil in the Region

The principal soil materials of the MENA region are relatively young and less weathered – comprising Entisols (43.4%), Aridisols (27.0%) and Inceptisols (5.2%). Fertile soils (with fine texture, high SOM concentrations, etc.) are scarce, and include Vertisols (4.3%), Alfisols (3.8%), Mollisols (2.1%), Oxisols (1.1%), Ultisols (0.9%) and Andisols (0.06%). The remaining 12% of land is occupied by shifting sands, rocks and salt crusted soils. The predominant soils of Entisols, Aridisols, Inceptisols have low SOM concentrations, low inherent soil fertility, low structural stability and low available water content (AWC). Thus, these soils are prone to both natural and anthropogenic perturbations, have low resilience, are easily degraded, and are vulnerable to drought stress.[19]

17. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

18. Caon, L., Watson, J., Gomes da Silva, C., Vargas, R., Khechimi, W., Bottigliero, F., & Verbeke, I. (2019). The multi-faced role of soil in the Near East and North Africa. *Global Soil Partnership Policy Brief No. 1, FAO.* https://www.fao.org/documents/card/en/c/CA3803EN/

19. Lal, R. (2013). Climate change and soil quality in the WANA region. In *Climate Change and Food Security in West Asia and North Africa* (pp. 55–74). Springer, Dordrecht.

Climatic Conditions

The MENA region is located within an arid and semi-arid climate with high temperature, low precipitation and variable rainfall patterns.[20] Most countries in MENA are characterized by limited water resources. For example, the region supports 6% of the global population,[21] but has only 0.9% (460 km^3) of the world's annual Renewable Water Resources.[22]

Eleven countries in this region face extreme water stress with just 500 m^3 per capita water availability.[23] The mean annual rainfall in the region ranges from 100–600mm with high variability within and between seasons. Climate projections identify the entire region as a hotspot for temperature changes,[24, 25] which will be amplified by a reduction in rainfall and associated depletion of soil moisture, thereby limiting evaporative cooling.[26]

All countries in the region are either arid or semi-arid, with 60% of the region being hyperarid. Grazing and agriculture are conducted under arid conditions, and cover less than 40% of the region.

20. Namdar, R., Karami, E., & Keshavarz, M. (2021). Climate Change and Vulnerability: the case of MENA countries. *ISPRS International Journal of Geo-Information*, *10*(11), 794. https://doi.org/10.3390/ijgi10110794

21. Devkota, M., Singh, Y., Yigezu, Y. A., Bashour, I., Mussadek, R., & Mrabet, R. (2022). Conservation agriculture in the drylands of the Middle East and North Africa (MENA) region: Past trend, current opportunities, challenges and future outlook. *Advances in Agronomy*, *172*, 253–305. https://doi.org/10.1016/bs.agron.2021.11.001

22. Abou Hadid, A. F. (2009). Impact of Climate Change: Vulnerability and Adaptation Food Production. In: Tolba, M. K., & Saab, N. W. (Eds.). (2009). Arab environment – climate change, impact of climate change on Arab countries. *Arab Forum for Environment and Development (AFED).* Published with Technical Publications and Environment & Development Magazine, Beirut.

23. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

24. Bucchignani, E., Mercogliano, P., Panitz, H.-J., & Montesarchio, M. (2018). Climate change projections for the Middle East–North Africa domain with COSMO-CLM at different spatial resolutions. *Advances in Climate Change Research, 9*(1), 66–80. https://doi.org/10.1016/j.accre.2018.01.004

25. Lange, M. A. (2019). Impacts of Climate Change on the Eastern Mediterranean and the Middle East and North Africa Region and the Water–Energy Nexus. *Atmosphere*, *10*(8),455. https://doi.org/10.3390/atmos10080455

26. Lelieveld, J., Proestos, Y., Hadjinicolaou, P., Tanarhte, M., Tyrlis, E., & Zittis, G. (2016). Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century. *Climate Change, 137*(1–2), 245–260. https://doi.org/10.1007/s10584-016-1665-6

Unsustainable Agricultural Land Use

In most countries in the region, land degradation is caused by water and wind erosion, loss of vegetation cover, salinization, and poor land and water management, which has led to a decline in soil physical properties and available arable land, and resulted in increased water scarcity.[27]

Policies encouraging intensive agriculture have led to the widespread clearing of forests and grasslands for mechanized farming under monocultures, and abandonment of traditional crop rotations and similar SSM practices.[28] Drylands with such cultivation practices will lose SOC and biodiversity – fungi, bacteria, and other organisms – which means fewer nutrients for plants, less water retained in the soil, and ultimately, reduced food production.

These practices also rapidly deplete the already scarce natural freshwater resources in the region. Several countries in the region have encouraged cultivation of water-intensive cereals and cash crops by pumping water from underground aquifers at rates far exceeding their replenishment rates.[29]

Ramifications of the State of Soil in MENA

The ramifications of soil degradation are manifold, but in MENA, food insecurity, water scarcity, agrarian poverty and civil unrest are the most noteworthy. These issues will further intensify as the region is highly vulnerable to climate change, which will lead to accelerated desertification of already poor-quality soils. We discuss these in this section

Food Insecurity

MENA countries are already on the lower end of agricultural productivity, averaging 2.3 t/ha, far below the global average of 4.0 t/ha.[30] Food insecurity also looms large over the region, with the pandemic and conflicts making the situation worse. In 2020,

27. World Bank. (2018). *Beyond Scarcity: Water Security in the Middle East and North Africa.* MENA Development Report, World Bank, Washington, D.C. https://openknowledge.worldbank.org/handle/10986/27659

28. *Sudan: Post-conflict environmental assessment.* UNEP. (2007). https://postconflict.unep.ch/publications/UNEP_Sudan.pdf

29. Devlin, J. C. (2010). Challenges of Economic Development in the Middle East and North Africa Region. *International Economics, 8.* https://doi.org/10.1142/6762

30. *Statistics on Crop Production.* Food and Agricultural Organization of the United Nations (FAO). (2020). http://www.fao.org/faostat/en/#data/QC

MENA's share of the world's acutely food insecure people was 20%, disproportionately high compared to its 6% share of the population. As of September 2021, UN agencies estimated that 55 million[31] of the 457 million people in MENA were undernourished. If the status quo water management scenario continues, and climate change projections come true, crop yields are expected to fall drastically. For example, soy and wheat yields in Egypt could drop by 28% and 14%, respectively, rainfed wheat yield in Iran could drop by 24%, and rainfed wheat and irrigated potato yields in Syria could drop by 39% and 27.5%, respectively.[32] By 2100, a truly terrifying scenario may unfold where food production could decrease by 50%[33] while the population doubles.

Conflict-ridden countries, such as Yemen and Syria, are hit the hardest. The UN estimates 83% of Yemenis – 24 million people – are afflicted by food insecurity[34] in 2021, with 16.2 million needing emergency food. The war in Syria has had devastating consequences: over 12 million[35] Syrians are food insecure, an increase of 4.5 million from 2020. Refugee populations are especially vulnerable.[36]

The Least Developed Countries (LDC) in the region also face widespread poverty – exacerbated by the pandemic, which threatens to push another 16 million into poverty[37] – as well as chronic hunger and related health issues. In 2015, 19.6% and 25.5% of children below five in the Middle East and North Africa respectively, suffered from stunting and wasting.

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31. FAO, IFAD, UNICEF, WFP and WHO. (2020). Regional Overview of Food Security and Nutrition in the Near East and North Africa 2019 – Rethinking food systems for healthy diets and improved nutrition. https://doi.org/10.4060/ca8684en

32. Selvaraju, R. (2013). Implications of climate change for agriculture and food security in the Western Asia and Northern Africa region. In: *Climate change and food security in West Asia and North Africa (pp. 27–51).* Springer, Dordrecht.

33. Devkota, M., Singh, Y., Yigezu, Y. A., Bashour, I., Mussadek, R., & Mrabet, R. (2022). Conservation agriculture in the drylands of the Middle East and North Africa (MENA) region: Past trend, current opportunities, challenges and future outlook. *Advances in Agronomy*, *172*, 253–305. https://doi.org/10.1016/bs.agron.2021.11.001

34.Belhaj, F., & Soliman, A. (2021). MENA Has a Food Security Problem, But There Are Ways to Address It. *World Bank.* https://www.worldbank.org/en/news/opinion/2021/09/24/mena-has-a-food-security-problem-but-there-are-ways-to-address-it

35. *Twelve Million Syrians now in the grip of hunger, worn down by conflict and Soaring Food Prices: World Food Programme*. UN World Food Programme. (2021). https://www.wfp.org/news/twelve-million-syrians-now-grip-hunger-worn-down-conflict-and-soaring-food-prices

36. FSIN and Global Network Against Food Crises. (2021). Global Report on Food Crises 2021. Rome. https://docs.wfp.org/api/documents/WFP-0000127343/download/?_ga=2.255360588.535656598.1630532976-251404490.1626313042

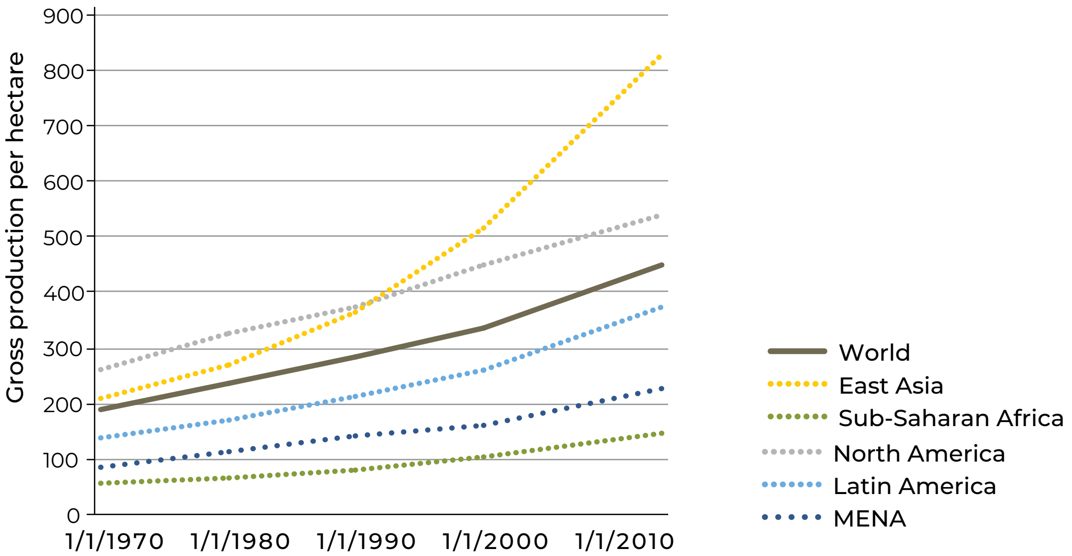
37. Belhaj, F., & Soliman, A. (2021). MENA Has a Food Security Problem, But There Are Ways to Address It. *World Bank.* https://www.worldbank.org/en/news/opinion/2021/09/24/mena-has-a-food-security-problem-but-there-are-ways-to-address-it

Table 1: MENA indicators of overall growth in region, agricultural land, availability of freshwater, and indicators of food security.[38]

	GDP per capita		Agricultural land	Arable land	Renewable internal freshwater resources	Annual freshwater withdrawals
	Current USD*	Growth in % per year, 2000-16	% of total land area (2014)		(2014) billion m^3	
	(1)	(2)	(3)		(4)	
Qatar	86 853		6	1	0.06	0.44
United Arab Emirates	44 450	-2.1	5	0	0.15	4.00
Kuwait	42 996	0.1	9	1	0.0	0.9
Bahrain	24 983	-0.1	11	2	0.0040	0.3574
Saudi Arabia	24 575	1.2	81	2	2	24
Oman	20 458	-0.2	5	0	1.40	1.32
Lebanon	8 537	0.4	64	13	4.8	1.3
Iraq	6 703	2.7	21	12	35	66
Libya	5 603	-2.4	9	1	0.7	5.8
Iran, Islamic Rep.	5 541	2.5	28	9	129	93
Algeria	5 466	2.0	17	3	11	8
Tunisia	4 270	2.3	65	19	4	3
Jordan	4 067	1.1	12	3	0.7	0.9
Egypt, Arab Rep.	3 328	2.2	4	3	2	78
Morocco	3 155	3.0	69	18	29	10
Palestinian Authority	2 961	0.6	50	11	0.81	0.42
Syrian Arab Republic	2 058	2.1	76	25	7	17
Yemen, Rep.	1 647	-2.4	45	2	2	4
Mauritania	1 327	1.4	39	0.4	0.4	1.4

38. OECD/FAO (2018). Chapter 2: The Middle East and North Africa: Prospects and Challenges, 67–108. In: *OECD-FAO Agricultural Outlook 2018–2027*. OECD Publishing, Paris/Food and Agriculture Organization of the United Nations, Rome. https://doi.org/10.1787/agr_outlook-2018-en Africa

Figure 1: Trends of Production per Hectare by Region[39]



Water Scarcity

Water scarcity was already prevalent in the region, and has been made worse by the unsustainable agricultural practices that have depleted SOM. Depleted SOM leads to reduced AWC of soil which in turn increases the irrigation requirement for agriculture. Most countries tap into not just surface freshwater sources, but also underground aquifers, at rates far exceeding replenishment rates.[40] This is evident from the per capita water availability shown in Figure 2. The Sahara and Nubian Aquifers are among the largest fossil aquifers in the region but the rate of exploitation has been such that the Sahara aquifer will be depleted in just another 10 years.[41] Unless current usage trends are reversed, climate change will cause havoc in these countries as water scarcity intensifies due to rising temperatures and falling moisture levels.[42, 43]

39. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

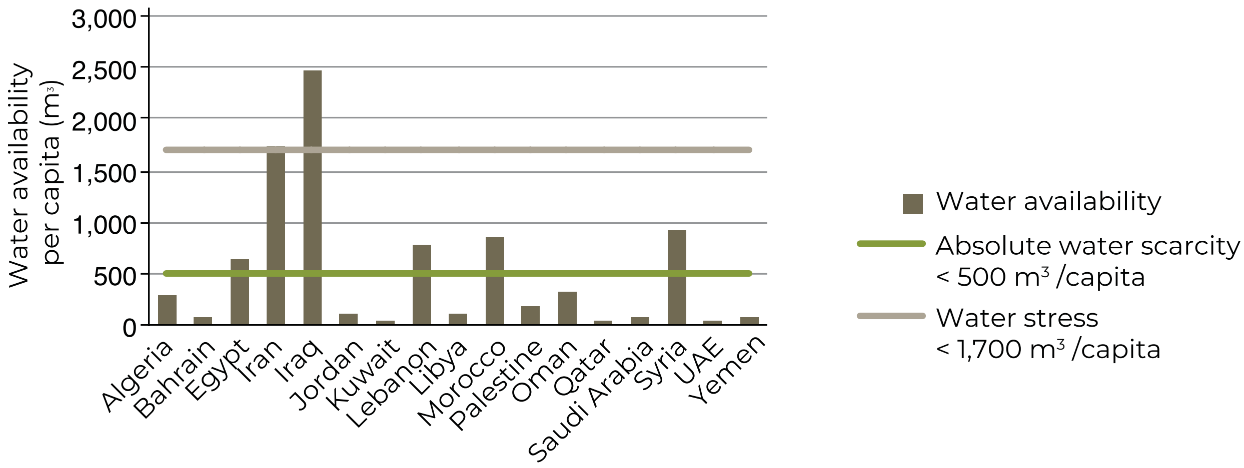
40. *OECD-FAO Agricultural Outlook 2018–2027*. OECD Publishing, Paris/Food and Agriculture Organization of the United Nations, Rome. https://doi.org/10.1787/agr_outlook-2018-en Africa

41. Walton, B. (2015). Groundwater Depletion Stresses Majority of World's Largest Aquifers. *Circle of Blue*. https://www.circleofblue.org/2015/world/groundwater-depletion-stresses-majority-of-worlds-largest-aquifers

42. Bucchignani, E., Mercogliano, P., Panitz, H.-J., & Montesarchio, M. (2018). Climate change projections for the Middle East–North Africa domain with COSMO-CLM at different spatial resolutions. *Advances in Climate Change Research, 9*(1), 66–80. https://doi.org/10.1016/j.accre.2018.01.004

43. Lange, M. A. (2019). Impacts of Climate Change on the Eastern Mediterranean and the Middle East and North Africa Region and the Water–Energy Nexus. *Atmosphere*, *10*(8),455. https://doi.org/10.3390/atmos10080455

Figure 2: Water Availability per Capita in MENA, 2013-2017[44]



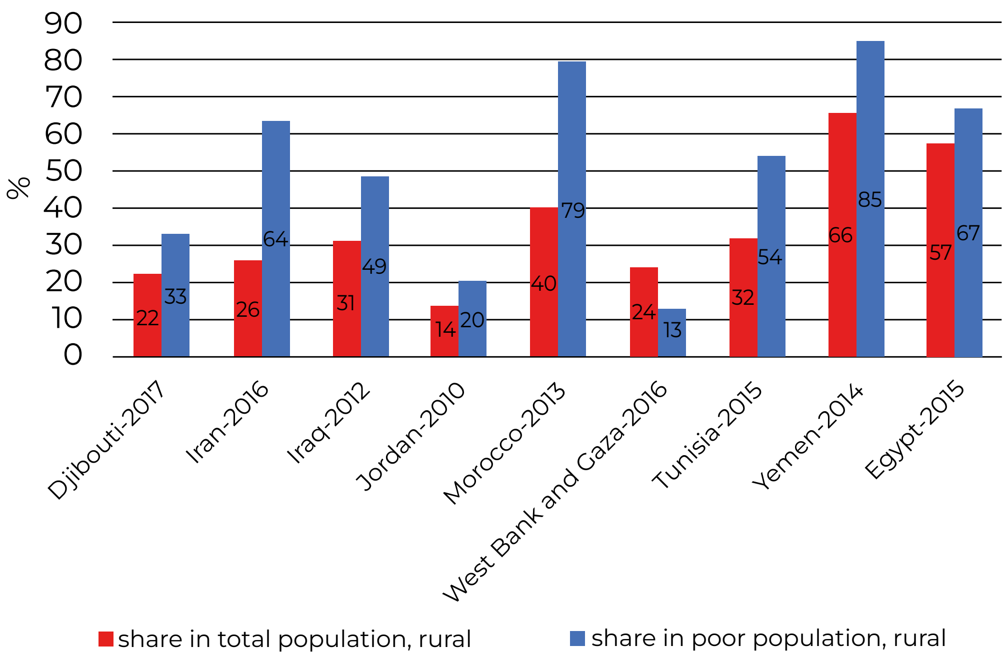
Agrarian Poverty and Civil Unrest

In the LDCs and Middle-Income Countries (MICs) of MENA, over 60% of the population lives in urban areas. At the same time, poor people are disproportionately concentrated in rural areas (as shown in Figure 3). Since most of the rural population are dependent on agriculture, their poverty is partly a result of degraded agricultural soil and low productivity. Hence, most farmers' children in the MENA region do not want to take up agriculture as their profession. This is evident in the fact that although agriculture's share of the GDP was estimated at 14% and remained relatively constant between 1993 and 2003, its share of employment declined modestly from 34% to 28%.[45] With the next generation opting not to enter into agriculture and instead migrating to urban areas, the average age of farmers is rising – for example, it is 53 years in Tunisia. Therefore, agrarian poverty must be addressed in order to prevent the possibility of future food shortages, and also to avoid building stress on basic amenities of food, water, housing, etc. in the already dense urban areas.

44. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

45. Devlin, J. C. (2010). Water Scarcity and Agricultural Policy in the MENA Region. *World Scientific Book Chapters*. In: Challenges Of Economic Development In The Middle East And North Africa Region, (pp. 157–194). *World Scientific Publishing Co. Pte. Ltd.*

Figure 3: Percentage of rural population in the total population and in the poor population.[46]



SOM As a Single-Point Focus to Resolve Social Issues

Restoring food and water security, and ensuring a prosperous, peaceful, conflict-free society will need multi-pronged interventions. However, increasing SOM to 3–6% is an important – and possibly the most important – intervention that governments and people can invest in.

Increasing SOM will significantly increase crop yields, which will improve nutrition levels and reduce poverty. Water retention in soil will also increase, which will improve water availability. Increasing SOM will also lead to greater peace in the region, because once food and water scarcity are addressed, conflict and violence in the region will fall drastically.

While this connection may seem tenuous upon first glance, food and water are two of the most fundamental elements of human survival, and when they are as scarce as they are in the MENA region, conflict is bound to explode if these two resources are not taken care of.

46. Atamanov, A., & Tandon, S. (2019). Rural non-farm activities in the Middle East and North Africa: A path to poverty reduction? *World Bank Blogs.* https://blogs.worldbank.org/arabvoices/rural-non-farm-activities-middle-east-and-north-africa-path-poverty-reduction

For example, in the recent past, the Arab Spring in 2011 was triggered by soaring prices of food and basic commodities.[47] In fact, "bread, freedom and social justice" was one of the main slogans of the movement. Control over the waters of the Jordan River is considered one of the main reasons that led to the 1967 Six-Day War between Israel, Jordan, Syria and Egypt.[48]

Thus, increasing SOM to 3–6% in the region's soil is a sort of cure-all for the major issues that have plagued this region for many decades.

Present Policy Ecosystem in MENA

The policy ecosystem of the MENA region is not organized like that of the African Union or the European Union where model policies and legislations are set up for specific sectors, which are followed by country-level adaptations of these policies. Also, unlike these two unions, MENA has socio-economic characteristics that vary drastically across the region.

Our observations on the existing policy ecosystem for soil in the MENA region draw from two sets of analysis.

1. **Country policy documents from SOILEX:** A review of country-specific soil policies hosted on the FAO's SOILEX database.
2. **Regional initiatives:** An analysis of regional initiatives by multilateral agencies such as the World Bank, specialized UN bodies like the FAO, and international think tanks including the International Food Policy Research Institute (IFPRI), International Water Management Institute (IWMI), and the International Center for Agricultural Research in the Dry Areas (ICARDA).

Country-Specific Policies from SOILEX

The country-specific policies hosted in SOILEX are documented in the country's official languages. The GCC countries (home to 20% of MENA's population[49]) of

47. Lagi, M., Bertrand, K. Z., & Bar-Yam, Y. (2011). The food crises and political instability in North Africa and the Middle East. Available at SSRN 1910031. http://dx.doi.org/10.2139/ssrn.1910031

48. Seliktar, O. (2005). Turning Water into Fire: The Jordan River as the Hidden Factor in the Six-Day War. *Middle East Review of International Affairs, 9*(2). https://ciaotest.cc.columbia.edu/olj/meria/meria_jun05/meria05_seo01.pdf

49. OECD/FAO (2018). Chapter 2: The Middle East and North Africa: Prospects and Challenges, 67–108. In: *OECD-FAO Agricultural Outlook 2018–2027*. OECD Publishing, Paris/Food and Agriculture Organization of the United Nations, Rome. https://doi.org/10.1787/agr_outlook-2018-en Africa

Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates have been working towards managing soils sustainably since the mid-2000s. The focus has been on judicious fertilizer use, sustainable animal rearing and management of pasture lands. The priority has been to improve the soil quality to make it fit for agriculture.

The existing legal instruments on soil protection and prevention of soil degradation vary greatly in MENA countries. Across the parameters of soil conservation, soil erosion, soil restoration, soil monitoring, soil quality, nutrient imbalance and soil pollution, some countries have planned extensively, laying out the necessary measures to achieve their sustainable development goals. At the same time, some countries have not updated laws and regulations after the 20th century.

As a minimum step, all MENA countries, except Libya, have at least one regulation or law that covers an FAO Soilex category. Algeria, Egypt, Iran, Jordan, Tunisia, Saudi Arabia, Syria, and Morocco have taken a step beyond just framing regulations, and have developed national action plans, programmes or strategies regarding soil. A sustainable future can depend on various scenarios, but countries that have taken the preliminary planning steps are better placed to achieve sustainable soil management and productivity targets.

A few MENA countries are actively leading the way in sustainable soil management. For example, Jordan has had a near comprehensive soil conservation, erosion and pollution policy since 2005. The policy is based on SSM practices bolstered by a data-driven approach. Soil conservation and monitoring is clearly elucidated in National Strategy for Agricultural Development 2016–2025, which is the most robust policy among GCC nations, covering five FAO soil categories. Jordan's policy includes monitoring of soil and groundwater pollution as an important part of maintaining the quality of agricultural soil and its productive capacity. It also has had a clear national strategy and action plan to combat desertification since 2015.

Israel is another nation which has been proactive in agricultural innovations. Innovative machines can plow such that soil breakup is minimized, and sowing takes place without preliminary tilling. Farmers also practice conservation agriculture and incorporate practices such as compost covering, which reduces soil loss during rainfall, and bring in extra vegetation that attracts insects that counter pests, thus reducing the need for pesticides.[50] A pioneer in micro-irrigation, it has led the way in judicious and scientific use of agricultural inputs in arid climates. Although Israel imports USD 2.91 billion in raw food products, it exports USD 13.3 billion in FMCG products.[51]

Among the Gulf Cooperation Council Countries (GCC), all countries, except Saudi Arabia, have regulations related to the use of chemical fertilizers and soil conditioners in agriculture, import, production and trade by institutions and companies and the standards they must follow.

On the other hand, Saudi Arabia's Strategy and National Plan for Pastures in the Kingdom of Saudi Arabia until the year 2033 is the most up-to-date plan regarding soil conservation, soil restoration and soil erosion among the GCCs. The plan's long-term vision includes: stopping human activities that have caused deterioration of pastoral habitats, direct technical assistance for the recovery of damaged areas, reducing the amount of sand in the soil, creation of centers for the production of plant seeds suitable for grazing, reduction of plants that require a lot of water, soil preparation, and improvement of the vegetation cover to reduce rainwater runoff.

Land Tenure

A major deterrent to SSM practices in the MENA region is the present land tenure policies.

According to a report by the World Bank, only 10% of rural lands in Africa were registered. One reason for this could be that land registration is both expensive and time-consuming due to inefficient land administration.[52] Property registration in MENA is generally a difficult process.[53] For example, according to a UN report,

50. Rinat, Z. (2016). Nearly Half of Israel's Farmland Threatened by Over-processing, Climate Change. *Haaretz*. https://www.haaretz.com/science-and-health/.premium-what-will-save-israel-s-eroding-farmland-1.5439551

51. *Israel Country Commercial Guide*. (2019). International Trade Administration. https://development.trade.gov/israel-country-commercial-guide

52. Byamugisha, F. F. K. (2013). Securing Africa's land for shared prosperity: A program to scale up reforms and investments. *Africa Development Forum Series. Washington, DC: Agence Française de Développement and the World Bank*. http://hdl.handle.net/10986/13837

53. Kandeel, A. (2020). Let justice be done: Respect for female land rights in the Middle East and North Africa. *MEI@75*. https://www.mei.edu/publications/let-justice-be-done-respect-female-land-rights-middle-east-and-north-africa

registering a property in Egypt entails 217 steps of procedure and, on average, it will take 14 years to achieve ownership.[54]

According to Makhtar Diop, the World Bank Vice President for Africa in 2013, "Improving land governance is vital for achieving rapid economic growth and translating it into significantly less poverty and more opportunity for Africans, including women who make up 70% of Africa's farmers, yet are locked out of land ownership due to customary laws. The status quo is unacceptable and must change so that all Africans can benefit from their land."[55]

Lack of a clear land tenure system leaves very little incentive for farmers of LDC and MIC countries to take up any clear step towards managing soils sustainably. Only with a clear land tenure, are the farmers' rights of land use protected by the law. Then the owner does not have to worry about the possibility of eviction or their land being grabbed by tribes or institutions. Now, the owner can reap the benefits of their efforts on the land, in terms of better yields and economic returns, as well as food security for the family.

However, when the land tenure is precarious, farmers do not want to risk making an effort to improve land health, and so the land is only exploited for short-term returns. Thus, the land quality deteriorates over a period of time. As a consequence, in search of better yielding lands, 40% of forest lands have been deforested in MENA in just two decades.

Regional Initiatives

In this section we review a few initiatives that have been taken up at the regional level by various organizations to combat soil degradation and desertification. The list of projects listed in Table 2 are merely a sample set of existing initiatives. While a few of them are funded by national governments, most of them are funded by international institutions. The projects are implemented either by UN institutions (FAO, IFPRI,

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54. United Nations. Economic Commission for Africa. (2010). Land policy in Africa: North Africa regional assessment. *Addis Ababa: United Nations. Economic Commission for Africa*. https://hdl.handle.net/10855/18733

55. *Africa's land reform policies can boost agricultural productivity, create food security and eradicate poverty*. World Bank. (2013). https://www.worldbank.org/en/region/afr/publication/securing-africas-land-for-shared-prosperity

UNEP, and the Global Environment Facility) or by USAID funded CGIAR[56] agencies (ICARDA and IWMI).

Arab countries have also established institutions such as the Arab Center for the Study of Arid Zones and Dry Lands (ASCAD), which are capable of addressing sustainable management and use of natural resources in arid lands. The Council of Arab Ministers of Environment has prioritized the issues of drylands through the establishment of a workforce of experts who will set frameworks for regional collaborative programs.[57]

Table 2: Land Restoration Initiatives in MENA[58]

Initiative	Implementers	Timeframe	Region / Country
Developing Sustainable Livelihoods of Agropastoral Communities of West Asia and North Africa	ICARDA, IFPRI	1995–ongoing	Mashreq and Maghreb
Enabling Sustainable Dryland Management Through Mobile Pastoral Custodianship	GEF, UNDP	2008–2012	Iran, Morocco (among MENA countries)
SIP: Stimulating Community Initiatives in Sustainable Land Management (SCI-SLM)	GEF, UNEP	2008–2012	Morocco (in MENA)
Rehabilitation of forest landscapes and degraded land with particular attention to saline soils and areas prone to wind erosion	GEF, FAO	2008–2010	Iran
Adapting Conservation Agriculture for Rapid Adoption by Smallholder Farmers in North Africa	ICARDA	2012–2015	Algeria, Morocco, and Tunisia
Enhancing food security across the Arab world	ICARDA, IFPRI	2013–ongoing	Egypt, Tunisia, Morocco, Syria and Jordan (among MENA countries)

56. Consultative Group on International Agricultural Research (CGIAR) is a USAID funded consortium of research organizations.

57. Al-Zu'bi, M. A. (2022). Desertification in MENA – Causes and solutions. *EcoMENA*. https://www.ecomena.org/desertification-mena/

58. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

Initiative	Implementers	Timeframe	Region / Country
Enhancing the resilience of farmers' livelihoods in Area C of Jenin, Nablus, Tubas, and Jericho Governorates through improved water availability and management	FAO, government	2014–2016	West Bank
Identifying biodiversity-related success factors of ecological restoration projects	Saint Joseph University	2017–ongoing	Lebanon
Great Green Wall Initiative	African Union	2007	Algeria, Egypt, Libya, Mauritania (among MENA countries)
Updated rangeland strategy for Jordan	Government	2011	Jordan
Economics of Land Degradation (ELD) Initiative	UNCCD	2011	Global
Lebanon reforestation initiative	USAID	2011	Lebanon
Acacias for All	Acacias for All	2012	Tunisia
Program on Desert Ecosystems and Livelihoods in the Middle East – North Africa region MENA-DELP	World Bank and GEF	2013	Algeria, Egypt, Jordan, Morocco, Tunisia
AFR100 (the African Forest Landscape Restoration Initiative)	Multiple	2015	Africa
Agadir Commitment	Multiple	2017	Algeria, Iran, Lebanon, Morocco (among MENA countries)
Middle East North Africa Water and Livelihoods Initiative (WLI) – Regional	CGIAR	2017	Egypt, Iraq, Jordan, Palestine, Tunisia
Pan-African Action Agenda on Ecosystem Restoration	CBD, Multiple	2019	Africa

Policy Recommendations for MENA

The policy recommendations in this section are based on the challenges facing agricultural soils of the entire MENA region. These recommendations should be further detailed for each nation in the region, considering its unique context. Given the region's inherently degraded soil due to native climatic conditions, it will need a much more concerted effort towards soil revitalization as compared to the other regions of the world.

While there are various projects that have been taken up by both national and international agencies to combat land and soil degradation in the region, the policies need to become more concerted, focused and streamlined. The key point in this streamlined policy should be to bring back a minimum of 3–6% of SOM. This can be achieved by taking action under the four pillars of SSM:

- Knowledge Systems
- Farmer Support Ecosystem
- Legal Provisions
- Monitoring and Learning Systems

Consistent financing is required for interventions across these four pillars. The financing will be needed to:

1. Set up and run MENA context-specific knowledge systems
2. Establish farmer support systems in the form of extension activities, trainings and incentive payments to practice SSM
3. Facilitate regular monitoring and evaluation of SSM activities and feedback loops

Some of the sources of funding which can be leveraged are listed as follows from a World Bank Report:[59]

- **Global Environment Facility (GEF)**: The GEF's main focus is grant funding through four modalities: full-sized projects (over USD 2 million); medium-sized projects (up to USD 2 million); enabling activities (under USD 1 million) and programmatic approaches. Non-grant instruments are also available for specific initiatives.

59. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

Projects can be developed and submitted through 18 GEF agencies including UNEP, UNDP, World Bank, Regional Development Banks, WWF, IUCN, and Conservation International. Funding proposals are largely "mainstreamed" in the project preparation cycle of these organizations.

- **Green Climate Fund (GCF):** Low-emission (mitigation) and climate resilient (adaptation) projects and programs developed by the public and private sectors: Risk-based approach depending on funding size for micro (up to USD 10 million), small (USD 10–50 million), medium (USD 50–250 million), and large (over USD 250 million) size projects and programs. GCF provides grants with and without repayment contingency, as well as loans and equity.

  The GCF funds can be directly accessed through accredited subnational, national, or regional implementing Accredited Entities; and International Accredited Entities, including UN agencies, development banks, and NGOs.

- **Climate Investment Funds (CIF):** The USD 8.3 billion Climate Investment Funds is providing 72 developing and middle-income countries with urgently needed resources to manage the challenges of climate change and reduce their Greenhouse Gas emissions. Total CIF pledges are expected to attract an additional USD 58 billion of co-financing for a portfolio of over 300 projects and programs and counting.

  CIF is implemented through five multilateral development banks: World Bank, African Development Bank, Asian Development Bank, European Bank for Reconstruction and Development, and the Inter-American Development Bank.

- **Adaptation Fund:** The Adaptation Fund has piloted direct and regional access and provides grants of up to USD 10 million for concrete adaptation projects in nine thematic focus areas. The projects need to result in outputs that are visible and tangible, which always entails a concrete on-the-ground investment (i.e., pure capacity building or research projects are not eligible).

  Through national, multilateral and regional implementing entities including UN agencies, development banks, NGOs, or directly through national implementing entities, proposals are accepted three times a year for review at annual board meetings and in-between sessions, either as a full proposal or as a concept note.

- **Land Degradation Neutrality (LDN) Fund:** The LDN Fund is focused on direct investment into larger-scale land restoration, rehabilitation, and land degradation avoidance programs that will integrate smallholders and local communities and has a dedicated window for small-scale projects and small- and medium-sized enterprises.

The Fund will only consider projects that can make a significant contribution to LDN while producing appropriate risk adjusted returns and complying with robust environmental and social standards. Projects should have already successfully completed a pilot/feasibility project and be looking for further investment to support a scale up.

- **International Development Association (IDA):** The International Development Association is part of the World Bank Group and it is the fund for the world's 75 poorest countries. Since its establishment in 1960, IDA has provided USD 312 billion in loans and grants. Annual commitments have averaged about USD 19 billion per year. In its 18th replenishment cycle, IDA has been able to mobilize approximately USD 75 billion for the period from 2017 to 2020.

  IDA resources are made available to IDA eligible countries based on several criteria and approved according to the objectives set in the Country Partnership Framework of the World Bank Group.

- **Multilateral Development Banks (MDBs):** The MDBs provide technical and financial support in the form of credits, concessional loans, and grants, as well as technical assistance for low- and middle-income countries. Resources are allocated for a range of sectors, such as agriculture, environmental and natural resource management, and climate action. Thus, the MDBs play an important role in financing LDN.

  The MDBs have dedicated private sector branches that facilitate private sector investments and public private partnerships, for example, for agriculture or forestry investments. Among these outlets are the World Bank's International Finance Cooperation (IFC) or IDB's Inter-American Investment Cooperation (IIC) that have mobilized financing from the private sector to support sustainable forest management, conservation agriculture, and other projects. In the fiscal year 2016, IFC invested USD 3.4 billion in agribusiness.

- **International Development Finance Club (IDFC):** In 2014, the members of the IDFC had collective commitments of USD 630 billion. Often parts of the bilateral development finance are channeled through these banks, such as KFW for Germany or AFD for France.

  Several IDFC members focus on the private sector or have established dedicated private sector branches. In addition to grants, concessional loans and credits, development banks can often leverage additional public and private funds through debt, equity shares, or de-risking investments. De-risking investments, for example, use public guarantees or insurances to overcome risks.

- **Private impact investors:** Over the past decade 31 private funds and project promoters – also called private impact investors – invested around USD 7 billion in projects contributing to LDN. They expect to double their financing by 2021.

  Many private sector initiatives are already supporting the ambitious LDN target, including those, which have subscribed to the Bonn Challenge to restore 150 million hectares of degraded and deforested lands by 2020. While the private sector role in LDN is increasing, many of its engagements still require public support to be accelerated.

Knowledge Systems

The MENA region must be equipped with tailored knowledge systems that will be able to provide solutions for its unique challenges. The two principal strategies that will determine soil quality must revolve around: (i) enhancing soil resilience, and (ii) improving farming systems.[60] Agricultural research organizations, civil society organizations, and government establishments should ensure any SSM practices that are promoted in agricultural lands address either or both of these principal strategies. Important properties pertinent to soil resilience are CEC (cation exchange capacity), aggregation and stability, AWC, etc. The key soil parameter that moderates all of these properties is the SOM concentration and its quality.[61]

Knowledge systems can be developed around various types of farming:

- **Tillage / Residue management**: Reduced- or no-till efforts in the region have proven to improve the quality of soil consistently. Ensuring residue is left over in the form of mulch has also reduced the loss of soil from wind erosion.
- **Farmer-managed, natural regeneration:**[62] A tree-based agricultural system that incorporates native and indigenous trees along with farmers' annual crops. This

60. Lal, R. (2013). Climate change and soil quality in the wana region. *Climate Change and Food Security in West Asia and North Africa*, 55–74. https://doi.org/10.1007/978-94-007-6751-5_3

61. Lal, R. (2013). Climate change and soil quality in the wana region. *Climate Change and Food Security in West Asia and North Africa*, 55–74. https://doi.org/10.1007/978-94-007-6751-5_3

62. *Farmer managed natural regeneration (FMNR): A technique to effectively combat poverty and hunger through land and vegetation restoration.* United Nations Partnerships for SDGs Platform. United Nations. https://sustainabledevelopment.un.org/partnership/?p=30735

system has transformed over 5 million ha of land in Niger, and also increased the farmer household incomes by 18–24%.

- **Grazing, forages and fodder trees:** A majority of land use in MENA is allocated for grazing and foraging for animals. Overgrazing of lands has led to loss of SOM and available water holding capacity (AWC). To balance fodder needs with SSM, practices such as controlled grazing, low stocking rates and sourcing some animal fodder from trees should be introduced. Animal dung can be integrated into grazing lands to build back soil strength. Native and indigenous fodder trees have the ability to build drought resistance, improve the microclimate, rainfall use efficiency (of the land), and AWC.
- **Salinity management**: There are local practices of growing specific fruit, oil seed, fuel wood and forage crops, which can reverse salinization of soils in Africa.[63] These should be promoted where applicable.
- **Conservation Agriculture (CA) practice**: It is estimated that around 25–40% of the 53 million ha of arable lands in MENA are suitable for CA. There are CA practices that have been developed specifically for MENA soil types.
- **Integrated crop, livestock, and forest**:[64] An agricultural production strategy that integrates different production systems, namely agricultural, animal farming and forestry systems, within the same area.

The interventions for SSM strategies should be in line with the MENA regions' specific and unique conditions, and this will be possible only when there is an ecosystem with researchers, extension workers and training to support farmers.

Local Research Ecosystem: ICARDA, IFPRI, and the Arab Center for the Study of Arid Zones and Dry Lands (ASCAD) are engaged in building SSM practices for the region. They should engage local researchers from within the country, or at the very least from within the region to build and disseminate knowledge systems for the MENA region. This will ensure that expertise is built within the region. Also, being native to the region, researchers would be well-versed with the socio-political context.

Currently, agricultural research in MENA is predominantly donor-funded and substantially donor-guided. These donor-driven activities should also deploy experts

63. Lal, R. (2013). Climate change and soil quality in the WANA region. *Climate Change and Food Security in West Asia and North Africa*, 55–74. https://doi.org/10.1007/978-94-007-6751-5_3

64. *Sustainable Land Management and restoration in the Middle East and North Africa Region: Issues, Challenges, and Recommendations*. World Bank. (2019). https://doi.org/10.1596/33037

from within the country or the region to build internal expertise locally. Donor nations should ensure that they follow SSM practices when intervening in any aspect of agriculture.

The research ecosystem should be looking at helping farmers adopt SSM practices without much loss during the transition period. Advice and research should also facilitate climate resilience for farmers.

Farmer Support Ecosystem

A strong farmer support ecosystem[65] will help transition farmers from prevailing unsustainable soil management practices by:

- Helping them change their mindset and behavior towards SSM practices
- Setting up a robust last mile farmer extension system with high extension-officer to farmer ratio
- Creating engaging and educational training material and curricula for farmers
- Setting up field demonstration plots
- Running frequent trainings for farmers
- Setting up 24x7 (or readily accessible) farmer helplines

Seed to Market Support: All current SSM practices specific to the MENA region ask farmers to go back to native and indigenous crops. However, these crops do not have readymade markets or government subsidies in place at present. The governments should therefore support farmers not only with assistance in production but also with access to markets.

Access to Training: For farmers to transition to SSM practices, they need hands-on training on their land. There has to be access to training material and experts round the clock, as on-farm emergencies like a pest attack cannot afford a delay in response.

Soil Doctors: The concept of soil doctors has been developed and adopted in certain African countries. They are grassroots farmers who are trained to address specific

65. Devkota, M., Singh, Y., Yigezu, Y. A., Bashour, I., Mussadek, R., & Mrabet, R. (2022). Conservation agriculture in the drylands of the Middle East and North Africa (MENA) region: Past trend, current opportunities, challenges and future outlook. *Advances in Agronomy*, 253–305. https://doi.org/10.1016/bs.agron.2021.11.001

local issues of farmers. Soil doctors must be developed and nurtured to support farmers in their region. The soil doctors to farmers ratio should be such that it ensures effective extension work to farmers.

Reward Farmers: Farmers must be incentivized and rewarded for putting SOM back into soil by measuring SOC. Carbon credit markets can pay farmers for sequestration in their lands. However, pricing must be fair, transparent and just. Middle men and evaluators should not earn more than 10% as a commission or administrative fee.[66]

Reward Monitoring of SOM: Farmers must be rewarded for ecosystem services provided by their SSM practices. This can be achieved by monitoring SOM, other soil biology parameters, and terrestrial biodiversity on their land.[67]

Incentives and Resource Support During Transition: Farmers should be supported in the transition to SSM practices with access to free seeds, and with incentives to follow specific practices such as cover cropping and similar interventions. The transition to SSM will need a change in equipment to be used on the land. The government can set up equipment lending for groups of farmers.

Legal Provisions

Soil to Be Enshrined in Legal Systems

Soil should be treated like any other natural resource that is enshrined by the law of the land. Healthy soils and their characteristics must be clearly defined. The "healthy soil" definition should include a clear quantified range for physical, chemical and biological parameters. The biological parameters should ensure the SOM of a healthy soil is a minimum of 3–6%. SSM practices should also be detailed in laws specific to the country's context. These practices can be drawn from FAO's Voluntary Guidelines for Sustainable Soil Management.[68]

66. *A Food Systems Approach to Transforming Africa's Soil Health: Policy, science, implementation and impact*. IFDC. (2021). https://ifdc.org/2021/10/25/a-food-systems-approach-to-transforming-africas-soil-health-policy-science-implementation-and-impact/

67. Lal, R. (2022). *Soil Organic Carbon and Feeding the Future: Basic Soil Processes*. CRC Press.

68. Baritz, R., Wiese, L., Verbeke, I., & Vargas, R. (2017). Voluntary guidelines for sustainable soil management: Global action for healthy soils. *International Yearbook of Soil Law and Policy 2017*, 17–36. https://doi.org/10.1007/978-3-319-68885-5_3

Land Tenure

The issue of land tenure in the region should be resolved by the governments at the earliest, as this is a significant bottleneck that deters farmers from adopting SSM practices. The Voluntary Guidelines on Tenure developed by FAO can assist in this process.[69]

Monitoring and Learning Systems

National Soil Information Systems: Set up national soil information systems that will capture soil health information using both primary data collection (as much as possible) and secondary data from satellite imagery. The information systems can monitor the threats to soil – salinization, erosion, water scarcity, dust storms, SOM and other crucial parameters.

Digital Systems for Data Collection and Monitoring: Provisions to measure indicators of progress on various aspects of the soil, especially the change in SOM and soil biology, should be in place. This can facilitate remote monitoring, knowledge exchange among farmers and also between farmers, experts and other stakeholders.[70]

Soil Testing Ecosystem: Soil biology should be made a part of soil testing reports, and the testing ecosystem – non-existent at present – should be established and strengthened. Instead of setting up elaborate infrastructure for laboratories like the rest of the world, MENA can try to use field testing kits that are being developed across the world. The soil testing kits can be used extensively to help farmers make scientific decisions on crop inputs. There can be some physical infrastructure laboratories run by research organizations for a more detailed understanding of what is happening to the soil.

69. Seufert, P. (2013). The FAO voluntary guidelines on the responsible governance of tenure of land, fisheries and Forests. *Globalizations*, *10*(1), 181–186. https://doi.org/10.1080/14747731.2013.764157

70. Bahn, R. A., Yehya, A. A., & Zurayk, R. (2021). Digitalization for Sustainable Agri-Food Systems: Potential, status, and risks for the MENA region. *Sustainability*, *13*(6), 3223. https://doi.org/10.3390/su13063223

3.7 Policies for North America

North American Countries: Canada and the United States of America

North America Statistics[1]

Total Population: 367.5 million

GDP: USD 22.6 trillion

GDP per Capita: USD 61,502

Total Landmass Area: 18.11 million km²

Landmass under Agriculture: 4.64 million km²

Population Dependent on Agriculture as a Percentage of Total Employment: 1.37%

Average Farm Size in Acres: 445 (USA),[2] 880 (Canada),[3] 483 (USA and Canada)

1. *World Bank Open Data*. https://data.worldbank.org/

2. USDA, National Agricultural Statistics Service. (2020). Farms and Land in Farms: 2019 Summary. *USDA*. https://www.nass.usda.gov/Publications/Todays_Reports/reports/fnlo0220.pdf

3. *Overview of Canada's agriculture and agri-food sector*. Government of Canada. (2021). https://agriculture.canada.ca/en/canadas-agriculture-sectors/overview-canadas-agriculture-and-agri-food-sector

Executive Summary

This policy recommendation covers the North American region of Canada and the USA. This region has been home to indigenous agricultural practices well before the arrival of Europeans. Canada has 581,990 sq. km of land under agriculture.[4] The USA has 4.058 million sq. km, the second largest next to China.[5]

In the USA, rural lands are predominantly rangeland, forest land and cropland with small areas of rural settlements, pasturelands and water bodies. Rangelands are mostly found in the western half of the USA (deserts, Great Plains, semi-arid prairies and western Cordillera regions). Croplands are dominant in central US plains, the Mississippi Alluvial and Southeast Coastal Plains, Temperate Prairies, West Central Semi-Arid Prairies, South Central Semi-Arid Prairies and Mediterranean California ecoregions.[6]

In Canada, the largest agricultural region is in Temperate Prairies and West Central Semi-Arid Prairies in southern Alberta, Manitoba and Saskatchewan. The farmlands in Ontario and Quebec are predominantly Mixed Wood Plains Ecozone. British Columbia is dominated by forage production and pasture in the ecoregions of Cold Desert and the Cordillera. The Atlantic Canada region has highlands and mixed wood plains where farmlands, forage production and potato production are prevalent.[7]

In this section, we will highlight the state of soils due to land use practices, the ramifications of the same for the people of the region, an analysis of present soil-specific policies, and finally, recommendations to reverse current trends of soil management, and the ramifications of this.

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4. *Agricultural land (sq. km)*. The World Bank Open Data. https://data.worldbank.org/indicator/AG.LND.AGRI.K2?end=2018&locations=1W&most_recent_year_desc=false&start=1961&view=map

5. *ibid.*

6. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. Chapter 14: Regional Assessment of Soil Changes in North America. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.* https://www.fao.org/3/bc603e/bc603e.pdf

7. *ibid.*

The State of Agricultural Soil in North America

Indigenous tribes of the USA and Canada have long practiced agriculture on these lands. When the European settlers moved into the region, agriculture spread into prairie and forest lands.

Common threats to soil health in the North American region include soil acidification, soil contamination, soil salinization, soil sealing and capping, compaction, and waterlogging. The region also faces challenges of soil erosion, changes in SOC, nutrient imbalance, and loss of soil biodiversity – all of which will be discussed in further detail here.

Erosion

Erosion in the USA and Canada accelerated after the settlement of Europeans whose farming practices were not in line with the agroecological conditions of the region.[8] Over the last two centuries, mechanization, use of inorganic nitrogen, and intensified cash crop production supported by agricultural policies, were the new farming practices adopted. Forage-based rotations were shortened or eliminated, field sizes were increased by the removal of hedgerows and fences, and tillage intensity remained high. These practices led to large-scale erosion in both the USA and Canada.

According to the National Resource Inventory (NRI) of the USA, the rate of soil loss by water and wind erosion between 1982 and 2010, reduced by 41% and 46%, respectively. The average rate of loss of soil due to erosion in 2010 was 10 Mg/ha, of which 57% was due to sheet erosion.[9] This is 10 times higher than the annual soil renewal rate of 1 Mg/ha.[10,11]

Soil erosion in Canada includes wind, water and tillage-based erosion, and is monitored by the Agri-Environmental Indicators Programme. Thanks to interventions between 1991 and 2006, there has been a sustained reduction in lands susceptible

8. Montgomery, D. R. (2008). *Dirt: The Erosion of Civilizations.* Univ. of Calif. Press.

9. USDA. (2013). Natural Resources Conservation Service. Rapid Carbon Assessment (RaCA). *NRCS Soils.* https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054164

10. Alexander, E. B. (1988). Rates of soil formation: Implications for soil-loss tolerance. *Soil Science, 145*(1), 37–45. https://journals.lww.com/soilsci/Abstract/1988/01000/RATES_OF_SOIL_FORMATION__IMPLICATIONS_FOR.5.aspx

11. Montgomery, D. (2007). Soil erosion and agricultural sustainability. *Proceedings of the National Academy of Science, 104*(33), 13268–13272. https://doi.org/10.1073/pnas.0611508104

to erosion. In 2011, 61% of croplands were at very low risk of erosion as a result of a reduction of tillage in the summer fallow season. Lands under potato production are at high risk of water erosion as intensive conservation tillage is still followed in these areas. Lands with slopes of 10% or more are most prone to water erosion, especially in central and eastern Canada, where it is facilitated by climatic conditions.

Reduction in SOC/SOM

Both USA and Canada utilize national-scale modeling of SOC changes for GHG emissions inventories and reporting.[12] Models predict that converting areas of native vegetation (e.g., prairies and native forest) to cropland and forest plantations result in decreased SOM. Field studies in Canada have shown that land use change from native lands to cropland led to 24 ± 6 percent of SOC being lost.[13] In general, there has been a net loss of SOC since the beginnings of intensive agriculture, which threatens soil health in the USA and Canada.

However, in the last few years, less intensive agriculture[14] and reduced tillage intensity[15] have increased SOC levels compared to a decade ago. For instance, SOC in US croplands increased by 14.6 Tg/year and 17.5 Tg/year during 1990–1995 and 1995–2000, respectively, primarily due to reductions in tillage intensity.[16]

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12. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. Chapter 14: Regional Assessment of Soil Changes in North America. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.* https://www.fao.org/3/bc603e/bc603e.pdf

13. VandenBygaart, A. J., Gregorich, E. G., & Angers, D. A. (2003). Influence of agricultural management on Soil Organic Carbon: A Compendium and assessment of Canadian studies. *Canadian Journal of Soil Science*, *83*(4), 363–380. https://doi.org/10.4141/s03-009

14. McLauchlan, K. K., Hobbie, S. E., & Post, W. M. (2006). Conversion from Agriculture to Grassland Builds Soil Organic Matter on Decadal Timescales. *Ecological Applications, 16*(1), 143–153. http://www.jstor.org/stable/40061787

15. West, T. O., Brandt, C. C., Wilson, B. S., Hellwinckel, C. M., Tyler, D. D., Marland, G., De La Torre Ugarte, D. G., Larson, J. A., & Nelson, R. G. (2008). Estimating Regional Changes in Soil Carbon with High Spatial Resolution. *Soil Science Society of America Journal, 72*(2), 285–294. https://doi.org/10.2136/sssaj2007.0113

16. Ogle, S. M., Breidt, F. J., Easter, M. A., Williams, S., Killian, K., & Paustian, K. (2010). Scale and uncertainty in modeled soil organic carbon stock changes for US croplands using a process-based model. *Global Change Biology*, *16*(2), 810–822. https://doi.org/10.1111/j.1365-2486.2009.01951.x

Similarly, Canadian national-level modeling indicates that improvements in farm management have resulted in increasing SOC levels in the majority of croplands from the mid-1990s to 2011.[17]

Nutrient Imbalance

Soil nutrient imbalance happens due to excess application of fertilizers and chemicals. In North America, soils are polluted by elevated levels of N and P. The nitrogen application is 60–100 kg/ha more than what is needed across the Canadian Temperate Prairie and Mixed Wood Plains and Southeast United States Coastal Plains.[18] The excess N and P in the soil leads to serious water quality issues when irrigation or rainwater leach these excess soil nutrients into freshwater bodies. For example, in Lake Winnipeg, USA, the ramifications of soil nutrient imbalance ranges from eutrophication to hypoxia across both ends of the lake, where agriculture is practiced.[19]

Excess nitrogen can also leach as nitrate and pollute shallow aquifers, especially in humid and sub humid climates with coarse soil textures. According to the Canadian Environmental Indicators, the concentration of N in groundwater increased from 5 mg/L to 10 mg/L from 1981 to 2006.[20]

Soil N levels exceeding plant requirements are also linked to other environmental issues, especially the enhanced release of the potent greenhouse gas, N_2O. In both Canada and the United States, agriculture accounts for 6–7% of the total GHG

17. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. Chapter 14: Regional Assessment of Soil Changes in North America. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.* https://www.fao.org/3/bc603e/bc603e.pdf

18. *ibid.*

19. Schindler, D., Hecky, R., & McCullough, G. (2012). The rapid eutrophication of Lake Winnipeg: Greening under global change. *Journal of Great Lakes Research, 38*, 6–13. https://doi.org/10.1016/J.JGLR.2012.04.003

20. *Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Report Series – Report #4*. Government of Canada. (2021). https://agriculture.canada.ca/en/agriculture-and-environment/agri-environmental-indicators/environmental-sustainability-canadian-agriculture-agri-environmental-indicator-report-series-report

emissions.[21, 22] Emissions of N_2O from soils account for 75% of the total agricultural GHG emissions in the United States and 65% in Canada.[23]

Soil Biodiversity Loss

According to the SWSR report, North America lacks regional or national-level programs that monitor soil biodiversity. However, all factors that are known to endanger soil biodiversity are present in North American agriculture.

Over the years, US agriculture has moved towards an intensely regulated and specialized monocropping system, unbridled use of nutrients, and reduction in SOM, all of which have had a negative impact on soil biodiversity. Crop production is heavily concentrated in certain areas, crop diversity is declining, large farms are growing larger still while the number of smaller operations is decreasing.[24] The excess use of fertilizers and other chemicals, as mentioned in the previous section, change the environment (soil pH, moisture, temperature, availability of organic matter) in which the soil organisms live. The intricate relationship between soil organisms below ground and plant species above ground means the loss of soil biodiversity will have dire consequences.

Ramifications of the State of Soil in North America

The ramifications of poor soil quality span across food security, climate change, water scarcity, and poor health. Annually, the United States alone incurs a loss of around $85.1 billion through loss of biodiversity, eutrophication, loss in agriculture productivity, contamination of soil and water resources, crop loss due to climate shock, etc.[25]

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21. Environmental Protection Agency. (2014). Overview of Greenhouse Gas Emissions. *EPA*.

22. Environment Canada. (2014). National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-2012. *Submission to the United Nations Framework Convention on Climate Change*. http://unfccc.int/ national_reports/annex_i_ghg_inventories/national_inventories_submissions/ items/8108.php

23. Manassaram, D. M., Backer, L. C., & Moll, D. M. (2006). A review of nitrates in drinking water: maternal exposure and adverse reproductive and developmental outcomes. *Environmental Health Perspectives, 114*(3), 320–327. https://doi.org/10.1289/ehp.8407

24. Spangler, K., Burchfield, E. K., & Schumacher, B. (2020). Past and current dynamics of US agricultural land use and policy. *Frontiers in Sustainable Food Systems, 4*, 98. https://doi.org/10.3389/fsufs.2020.00098

25. *reThink Soil: A Roadmap to U.S. Soil Health*. The Nature Conservancy. (2021) https://www.nature.org/content/dam/tnc/nature/en/documents/rethink-soil-executive-summary.pdf

Threat to Food Production: Food Insecurity

The United States is losing 10.8 tons of fertile soil per hectare per year, a rate that is at least ten times greater than the rate of soil renewal.[26] Some parts of the United States have already run out of soil, and many more will run out in the next 50 years if nothing is done. In the Piedmont region of the eastern United States, farming practices ill-suited for the topography caused topsoil erosion and abandonment of agriculture.[27, 28] Similarly, the northwestern Palouse region has lost over 40% of topsoil,[29] and one third of the Midwest corn belt has lost its topsoil.[30] When this is compounded with extreme weather events like intense flooding in northeastern USA and drought in the Southwest, farmlands lose productivity. Climate change further worsens the effect on yields. According to the USDA model in 2015, average yields of corn, soybeans, rice, sorghum, cotton, oats, and silage under both irrigated and dryland production are projected to decline as a result of climate change as early as 2020.[31]

In Canada, however, the food production problem has more to do with the types of crops largely produced in the country. Although Canada is the fifth largest food exporter after the EU, USA, Brazil, and China,[32] one in seven Canadians faced food insecurity during the COVID-19 pandemic.[33] Canada exports half of its beef, 70% of its soybeans, 70% of its pork, 75% of its wheat, 90% of its canola and 95% of the pulses it

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26. Pimentel, D., & Burgess, M. (2013). Soil Erosion Threatens Food Production. *Agriculture, 3*(3), 443–463. https://doi.org/10.3390/agriculture3030443

27. Andersen, C. B., Donovan, R. K., & Quinn, J. E. (2015). Human Appropriation of Net Primary Production (HANPP) in an Agriculturally-Dominated Watershed, Southeastern USA. *Land, 4*(2), 513–540. https://doi.org/10.3390/land4020513

28. Daniels, R. B. Soil Erosion and Degradation in the Southern Piedmont of the USA. In: Wolman, M. G., Fournier, F. G. A. (Eds.). (1987) Land Transformation in Agriculture. New York. John Wiley and Sons. pp. 407–428. https://scope.dge.carnegiescience.edu/SCOPE_32/SCOPE_32_2.5_Chapter12_407-428.pdf

29. Ebbert, J. C., & Roe, R. D. (1998). Soil erosion in the Palouse River Basin: Indications of Improvement. *USGS Fact Sheet FS-069-98.* https://wa.water.usgs.gov/pubs/fs/fs069-98/

30. Thaler, E. A., Larsen, I. J., & Yu, Q. (2021). The extent of soil loss across the US Corn Belt. *Proceedings of the National Academy of Sciences of the United States of America, 118*(8), e1922375118. https://doi.org/10.1073/pnas.1922375118

31. Marshall, E., Aillery, M., Malcolm, S., & Williams, R. (2015). Climate change, water scarcity, and adaptation in the U.S. Fieldcrop Sector. *Economic Research Report No. (ERR-201) 119 pp. USDA ERS*. https://www.ers.usda.gov/publications/pub-details/?pubid=45496

32. *Agri-Food Exports*. Canadian Agri-Food Trade Alliance. (2018). https://cafta.org/agri-food-exports/#:~:text=We%20export%20half%20of%20our,of%20our%20food%20processing%20sector.

33. Dinesen, D. (2021). Opinion: Why Canada must fix its food security issues before the next crisis. *The Globe and Mail.* https://www.theglobeandmail.com/business/commentary/article-why-canada-must-fix-its-food-security-issues-before-the-next-crisis/

produces. However, it also imports fresh vegetables and fruits from the USA, Mexico, China, Peru, Spain, etc.[34]

Over 90% of Canada's farmers are dependent on exports, as well as about 40% of its food processing sector. One in two jobs in crop production and one in four jobs in food manufacturing depend on exports. Canada's largely export-oriented agriculture has made farmers in the region susceptible to international market volatility.[35] If Canada's agri-commodities basket were to diversify, it could de-risk farmers from such volatility and also work towards food sovereignty. Food sovereignty is one of the most discussed topics in Canada, where farmers and communities want local production as much as possible.[36] Ironically, large-scale industrial farming, where a few crops predominate, has threatened the food security of the nation, especially in times of emergency.

Food insecurity can also result from declining crop yields. The decline in crop yield is not a major concern for western Canada, but in the eastern provinces, higher rainfall and conventional tillage may lead to poor soils, thus affecting crop yield.[37]

Agrarian Distress

Agrarian distress among farmers, in the form of bankruptcy, reduced income, and suicides is caused by non-diversified crop production, reduced yields due to climate shock, and poor quality of soil.

Bankruptcy due to non-diversified crop production: In the USA, the median total household income among all farm households ($80,060) exceeded the median

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34. Dinesen, D. (2021). Opinion: Why Canada must fix its food security issues before the next crisis. *TheGlobe and Mail.* https://www.theglobeandmail.com/business/commentary/article-why-canadamust-fix-its-food-security-issues-before-the-next-crisis/

35. Deaton, B. J., & Deaton, B. J. (2020). Food security and Canada's agricultural system challenged by COVID-19. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie, 68*(2), 143–149. https://doi.org/10.1111/cjag.12227

36. Desmarais, A. A., & Wittman, H. (2014). Farmers, foodies and First Nations: Getting to food sovereignty in Canada. *The Journal of Peasant Studies*, *41*(6), 1153–1173. https://doi.org/10.1080/03066150.2013.876623

37. *Risk to soil and water quality from agriculture.* Government of Canada. https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/risk-soil-water-quality-agriculture.html

total household income for all households ($67,521).[38] In spite of this fact, a study found that bankruptcy rates in 2019 in most of the main agricultural states were the highest in at least 15 years.[39] Among the larger agricultural states like Nebraska, Iowa, Illinois, Kansas, and Minnesota, the bankruptcy rate in 2019 was higher than in 2005. However, in states where agriculture is characterized by mixed commodities (e.g., California and Florida), 2019 bankruptcy rates were below the 10-year average.

Bankruptcy is one of the last steps farmers take before selling their farm business. In summary, there are a few specific drivers of bankruptcy among farmers:

- A few commodities grown in large quantities by a large group of farmers
- Stagnation or fall of prices of commodities grown widely by farmers

Reduced income due to climate shocks: Due to the various soil threats discussed earlier, there is also a significant possibility of dip in crop yields. Farms are thus not resilient to climate risks. For example, an analysis of the stream gauge time series and crop loss records show that during the past 70 years, around 43% of large spring floods (discharges) were associated with widespread crop loss, which indicates that cropping systems prevalent today are not resilient to floods.[40]

Suicide among farmers: In short, due to current intensive monoculture practices, the poor state of soil health and climate change events, the uncertainty that weighs on a farmer is multiplied compared to what it would have been in the early 20th century. This agrarian distress can unfortunately lead to suicide among farmers. This is also reflected in a recent study on suicide risk factors among farmers in midwestern United States.[41]

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38. *Farming and Farm Income*. USDA ERS. https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/farming-and-farm-income/

39. Key, N., Law, J., & Whitt, C. (2021). Chapter 12 Bankruptcy rates have increased in most agricultural states. *USDA ERS*. https://www.ers.usda.gov/amber-waves/2021/november/chapter-12-bankruptcy-rates-have-increased-in-most-agricultural-states/

40. Shirzaei, M., Khoshmanesh, M., Ojha, C., Werth, S., Kerner, H., Carlson, G., Sherpa, S. F., Zhai, G., & Lee, J.-C. (2021). Persistent impact of spring floods on crop loss in U.S. Midwest. *Weather and Climate Extremes*, *34*, 100392. https://doi.org/10.1016/j.wace.2021.100392

41. Bjornestad, A., Cuthbertson, C., & Hendricks, J. (2021). An Analysis of Suicide Risk Factors among Farmers in the Midwestern United States. *International Journal of Environmental Research and Public Health, 18*(7), 3563. https://doi.org/10.3390/ijerph18073563

Water Scarcity and Reduced Quality of Freshwater

Agriculture both affects and is affected by water scarcity. Around 70% of the planet's freshwater is used for agriculture. In the USA, irrigation amounts to 80% of water consumption on average, and in regions prone to water scarcity, 94%.[42]

The present agricultural practices for the four major crops grown in the USA – cotton, soybean, maize and wheat – are riddled with water use inefficiencies.[43] Water intensive crops are grown in water-stressed regions, and are pushing the economic and environmental limits of the freshwater systems of the region. It requires twice as much water to produce grain in a water-scarce region as in a water-rich region.[44] The difference is due to high temperature, high evapotranspiration, soil conditions and other climate factors. These dynamics will become more consequential as water scarcity and water prices increase.

When water-intensive crops are grown by intensive inorganic farming in water-stressed regions, nutrients will drain with the irrigation water and affect the quality of aquifers. Shallow aquifers will also receive a high dosage of leached nutrients due to lack of any buffer in the form of SOM.

Extreme droughts are also more frequent and more severe, such as the recent "500-year scale" droughts in California and Texas, two of the USA's largest food producers. Water use efficiency for food production in these regions is already low and is worsening in most regions as water stress expands.

SOM as a Single-Point Focus to Resolve Issues of Soil Degradation in North America

Restoring food and water security, and ensuring a prosperous agrarian community will need multi-pronged interventions. However, increasing SOM to 3–6% is an important – possibly the most important – intervention that governments and people can invest in.

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42. *Solutions to address water scarcity in the U.S.* The Nature Conservancy. (2020). https://www.nature.org/en-us/what-we-do/our-priorities/provide-food-and-water-sustainably/food-and-water-stories/solutions-address-water-scarcity-us/

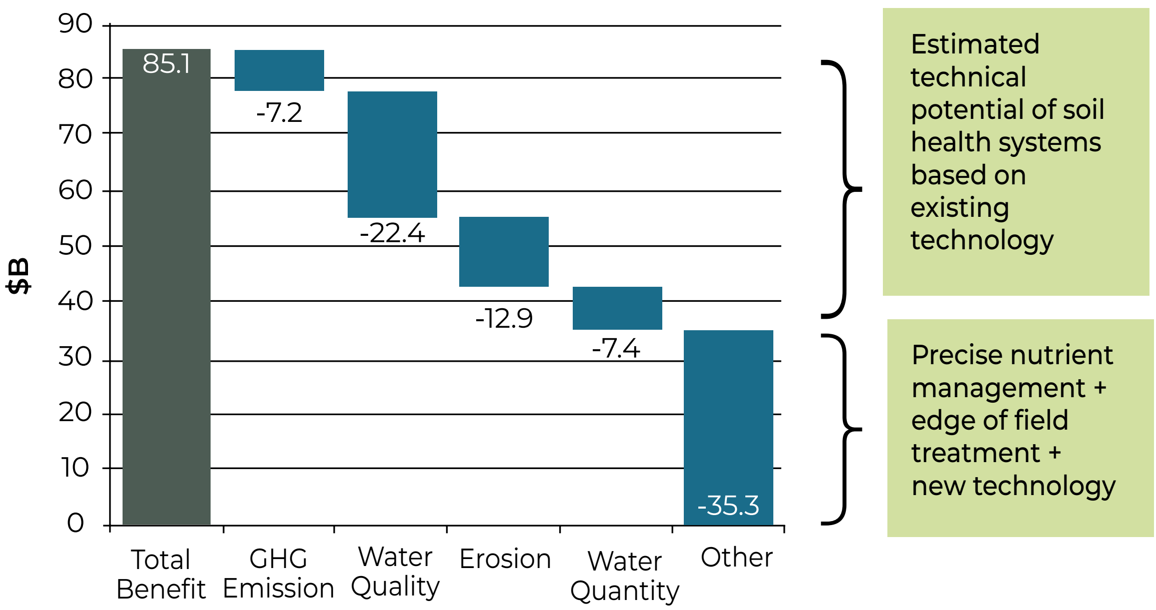
43. Kehl, J. (2020). Moving beyond the Mirage: Water scarcity and agricultural use inefficiency in USA. *Water, 12*(8), 2290. https://doi.org/10.3390/w12082290

44. Hoekstra, A. Y., & Hung, P. Q. (2005). Globalisation of Water Resources: International virtual water flows in relation to crop trade. *Global Environmental Change*, *15*(1), 45–56. https://doi.org/10.1016/j.gloenvcha.2004.06.004

Increasing SOM by adapting sustainable soil management (SSM) practices will significantly alleviate the threats of soil erosion by 20–30%,[45] increase available water capacity (AWC) in soil and thus reduce irrigation needs,[46] and increase filtering of excess nutrients to create a conducive environment for life in soil to proliferate.

Crop yields will also rise, thus improving nutrition levels and reducing food insecurity.

Figure 1: Potential Mitigation of Environmental Impact by Soil Health Practices[47]



Present Policy Ecosystem in North America

Federal farm programs in the late 20th and early 21st centuries had both favorable and unfavorable impacts on soil health in Canada and the USA. In this section we go over evolution of policies related to soil health and look at the most recent provisions to safeguard soil health.

45. Funderburg, E. (2001). What does organic matter do in soil? *Noble News and Views. Noble Research Institute.* https://www.noble.org/news/publications/ag-news-and-views/2001/august/what-does-organic-matter-do-in-soil/

46. Hudson, B. D. (1994). Soil organic matter and available water capacity. *Journal of Soil and Water Conservation, 49*(2), 189–194. https://www.jswconline.org/content/49/2/189

47. *reThink Soil: A Roadmap to U.S. Soil Health*. The Nature Conservancy. (2021) https://www.nature.org/content/dam/tnc/nature/en/documents/rethink-soil-executive-summary.pdf

Policy Ecosystem in the United States

Farm policy over the years has directed agriculture towards intense, regulated monocrop systems.[48] This has also led to consolidation of farms and homogenization of production. Past and current agricultural land use largely reflect two objectives: satisfying food, feed, fiber, and biofuel needs; and sustaining the economic viability of agriculture. But these objectives have been met at the cost of depletion of environmental quality and the resource base, and reduced quality of life for farmers, farm workers, and society as a whole.[49]

These trends are now beginning to change. This is reflective in the journey the nation has taken over the decades since its first soil-related policy in the 1930s. Here, we look at the major milestones in soil policy in USA.

The Soil Erosion Act (1935): The Soil Erosion Act was authorized to research and demonstrate efforts to control erosion by farmers in their lands.

The Soil Conservation and Domestic Allotment Act (1936): This act authorized direct payment to farmers who cut back on growing soil-depletion crops.

Agriculture Act (1956): The next step to stop soil erosion was taken up under this act. Soil banks were formed under the Acreage Reserve Program (ARP) through which farmers were paid rent for *not* growing water-intensive crops and plowing degraded soils.[50] The soil bank also encouraged less productive lands to be retired for a decade, a forerunner of the USDA's Conservation Reserve Program (CRP).[51, 52]

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48. Spangler, K., Burchfield, E. K., & Schumacher, B. (2020). Past and current dynamics of US agricultural land use and policy. *Frontiers in Sustainable Food Systems, 4*, 98. https://doi.org/10.3389/fsufs.2020.00098

49. *ibid.*

50. Helms, J. D. (1985). Brief history of the USDA Soil Bank program. *Historical Insights 1*, 1–3. *USDA NRCS.* https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1045666.pdf

51. Cain, Z., & Lovejoy, S. (2004). History and outlook for farm bill conservation programs. *Choices: The magazine of food, farm and resource issues. American Agricultural Economics Association.* https://www.choicesmagazine.org/2004-4/policy/2004-4-09.pdf

52. Coppess, J. (2018). *The Fault Lines of Farm Policy: A Legislative and Political History of the Farm Bill.* Lincoln: University of Nebraska Press.

The Soil and Water Resources Conservation Act (RCA) (1977): This act provides the USDA a broad strategic assessment and planning authority for the conservation, protection, and enhancement of soil, water, and related natural resources. Through RCA, USDA:

- appraises the status and trends of soil, water, and related resources on non-federal land and assesses their capability to meet present and future demands
- evaluates current and needed programs, policies, and authorities
- develops a national soil and water conservation program to give direction to USDA soil and water conservation activities

RCA collects data at a 5-year interval. The most recent appraisal was in 2011, which provides an overview of land use and the USA agricultural sector; of the status, condition, and trends of natural resources on non-Federal lands; and of the USDA's program for soil and water resource conservation.[53]

Conservation Reserve Program (CRP) (1985): CRP was introduced as part of the 1985 Farm Bill where payments for retiring erodible lands and conservation compliance (compliance with restrictions on harmful practices required to receive farm payments) was introduced.[54] The 1990 reauthorized Farm Bill expanded the CRP to include environmental goals beyond soil erosion. The land parcels thus defined were ranked under the Environmental Benefits Index (EBI) by the potential environmental benefits they generate. EBI was used as one of the categories through which the CRP program was rolled out going forward.[55]

The Conservation Reserve Program led to a reduction of the rate of erosion and further degradation of already eroded soils. The estimated decrease in sheet and rill erosion between 1982 and 2002 was 39%, and 41% between 1982 and 2010. In the case of wind erosion, between 1982–2002 and 1982–2010, erosion decreased by 41% and 46%, respectively.[56]

53. *Soil and Water Resources Conservation Act (RCA)*. USDA NRCS. https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/rca/

54. Hellerstein, D. M. (2017). The US Conservation Reserve Program: The evolution of an enrollment mechanism. *Land Use Policy*, *63*, 601–610. https://doi.org/10.1016/j.landusepol.2015.07.017

55. *ibid.*

56. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. Chapter 14: Regional Assessment of Soil Changes in North America. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.* https://www.fao.org/3/bc603e/bc603e.pdf

In the USA today, there are two large legislatures that have the budget to incorporate SSM goals into agricultural land use practices. They are the 2018 Farm Bill and the Build Back Better Act. The following sections will look at them in closer detail.

2018 Farm Bill (P.L. 115-334)

The Farm Bill is one legislature that affects agriculture and its soils profoundly. This bill sets the agenda for the farm sector and allocates large budgets for the focus area agreed under this bill. The bill was first mooted in 1965. The latest version of this bill that is relevant for soils and farmers is the 2018 Farm Bill, or the Agriculture Improvement Act of 2018. The bill is tabled every five years and covers all agriculture- and food-related aspects.

Over the years, the bill has grown more complicated and politically sensitive. Reauthorization of the farm bills has become uncertain. There have been 12 Farm Bills spanning 54 years.[57] The USDA is responsible for planning, budgeting and administering all activities under the Farm Bill.

The Dust-Bowl era Agricultural Conservation Program was revived as the Environmental Quality Incentive (EQIP) in the 1996 Farm Bill.[58] The EQIP has become the largest working lands program in the USA. The 2002 Farm Bill authorized the Conservation Security Program, later converted to the Conservation Stewardship Program (CSP) in 2008,[59] which rewarded farmers already practicing conservation agriculture with funding and technical assistance.[60]

Farm bills traditionally have focused on farm commodity program support for a handful of staple commodities—corn, soybeans, wheat, cotton, rice, peanuts, dairy, and sugar. They have become increasingly expansive in nature since 1973, when a nutrition title was first included. Other prominent additions since then include horticulture and bioenergy titles and expansion of conservation, research, and rural

57. *Farm Bills: Major Legislative Actions, 1965–2018.* CRS Report, Congressional Research Service. (2018). https://sgp.fas.org/crs/misc/R45210.pdf

58. Helms, J. D. (1985). Brief history of the USDA Soil Bank program. *Historical Insights 1, 1–3. USDA NRCS.* https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1045666.pdf

59. Stubbs, M. (2019). Agricultural Conservation in the 2018 Farm Bill. *CRS Report, Congressional Research Service.* https://crsreports.congress.gov/product/pdf/R/R45698

60. Baylis, K., Coppess, J., Gramig, B. M., & Sachdeva, P. (2022). Agri-environmental programs in the United States and Canada. *Review of Environmental Economics and Policy, 16*(1), 83–104. https://doi.org/10.1086/718052

development titles. The Farm Bill includes many programs. Every time a farm bill is revised, these programs need to be reauthorized to prevent expiry. The expansive nature of the bill allows for a coalition of support among stakeholders from varied groups.[61]

The Congressional Budget Office (CBO) estimated that the total cost of the mandatory programs in the farm bill was $428 billion over its five-year duration, FY2019–FY2023.[62]

The 2018 Farm Bill covers 12 Titles (thematic areas) under which programs and budgetary allocations are made. The titles are: Commodities, Conservation, Trade, Nutrition, Credit, Rural Development, Research Extension and related matters, Forestry, Energy, Horticulture, Crop Insurance, and Miscellaneous. The budget allocation for the period 2018-23 under all these thematic areas totals $428 billion.

Table 1: Budget for the 2018 Farm Bill and 2021 Baseline for Farm Bill Programs[63]

	2018 Farm Bill at Enactment	Baseline as of July 2021
Titles	FY^{2}019–FY^{2}028 ($ millions)	FY^{2}022–FY^{2}031 ($ millions)
Commodities	61,414	55,003
Conservation	59,748	59,402
Trade	4,094	4,220
Nutrition	663,828	814,503
Credit	-4,558	a/
Rural Development	-2,362	a/
Research Extension	1,219	1,280
Forestry	10	a/
Energy	737	500
Horticulture	2,047	2,100
Crop Insurance	77,933	94,819
Miscellaneous	3,091	760
Total	867,200	1,032,587

Under the Farm Bill, the budget allocated under conservation has steadily risen over

61. *Farm Bill Primer: What Is the Farm Bill?* Congressional Research Services. (2022). https://crsreports.congress.gov/product/pdf/IF/IF12047#:~:text=The%20farm%20bill%20is%20an,address%20agricultural%20and%20food%20issues.

62. *ibid.*

63. *ibid.*

the years. Crop insurance, although variable, has also steadily risen over a period of time. Nutritional assistance has gone up while commodity spending has gone down.

The titles of the 2018 Farm Bill that are relevant to soil health in agricultural lands are:

- **Conservation:** *Encourages environmental stewardship of farmlands and improved management through land retirement programs, working lands programs, or both.*
- **Research extension and related matters:** *Supports agricultural research and extension programs to expand academic knowledge and help producers be more productive.*

The titles that will be affected positively by ensuring soil health are:

- **Crop insurance:** *Enhances risk management through the permanently authorized Federal Crop Insurance Program.* Insurance expenditure by the government crops will reduce if farmers take up SSM to ensure soil health. SSM will require diversification of crops and other practices that reduce crop failure risks. Healthy soils can withstand climate shocks and over a period of time also improve yields of crops.
- **Credit**: *Offers direct government loans and guarantees to producers to buy land and operate farms and ranches.* The expenditure on credit waivers over the years costs the US billions of dollars. With healthy soils and associated SSM practices, the risk associated with the profession will reduce. It will also increase profitability of the profession. This will lead to farmers paying back the credit and eventually reducing government expenditure on bad debts.

In the following sections, we will analyze the two titles that will yield the above two favorable outcomes: Conservation, and Research Extension and Related Matters.

Conservation Title[64]

The expenditure for conservation activities has a budget that may cross $6 billion annually from 2023. The funding is allocated under the following activities which will lead to improvement in quality of land and soil.

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64. *Farm Bill Primer: Conservation Title.* CRS Report, Congressional Research Services. (2022). https://crsreports.congress.gov/product/pdf/IF/IF12024

- **Working lands programs:** Allow private land to remain in production while implementing various conservation practices to address natural resource concerns specific to the area.
- **Land retirement programs**: Provide payments to private agricultural landowners for temporary changes in land use and management to achieve environmental benefits.
- **Easement programs:** Voluntarily impose a permanent or long-term restriction on land use in exchange for a payment.
- **Partnership and grant programs**: Use partnership agreements and grants to leverage program funding with non-federal funding.
- **Conservation compliance:** Prohibits a producer from receiving selected federal farm program benefits (including crop insurance premium subsidies) when conservation program requirements for highly erodible lands and wetlands are not met.
    - Under the Food Security Act of 1985, there are programs for highly erodible land conservation that tie various programs to conservation standards. But farmers overall have felt burdened by compliance and therefore debates on the compliance program under the Conservation title continue.

Research Extension and Related Matters Title

The budgetary allocation of R&E is $649 million for 2018–2023, which is 0.15% of the total Farm Bill budget.

There are four USDA agencies that carry out research and extension, namely:

- National Institute of Food and Agriculture (NIFA) administers extramural programs.
- Agricultural Research Service (ARS) conducts intramural scientific research.
- Economic Research Service (ERS) conducts economic and social science research.
- National Agricultural Statistics Service (NASS) conducts the Census of Agriculture and provides official statistics on agricultural production and other farm sector indicators.

Along with these research agencies funded by the farm bill, the USDA has other research agencies that receive $1.5 billion dollars annually. The research and extension activities of the above-mentioned listed entities along with other USDA entities are to help farmers become competitive, build their capacities to face climate risk and to help farmers from marginalized communities like BIPOC (Black, Indigenous and People of Color).

The R&E funding under the Farm Bill does not have provisions for upgrading the aging research infrastructure. It is suggested that when the time comes to reauthorize the Farm Bill and the Build Back Better Act, Congress can consider providing $1 billion dollars through the Build Back Better Act to upgrade the infrastructure across the country.[65]

Build Back Better Act's (BBBA) Funding Specific to Agriculture and Forestry

Under the BBBA framework under Forestry (Subtitle B), Conservation (Subtitle F), Rural Development (Subtitle C – Part 1), Agriculture Credit (Subtitle C – Part 2), and Miscellaneous (Subtitle E), there has been $81 billion of funding allocated specifically for agriculture and forestry activities for 2022–31.[66]

Climate Smart Agriculture:[67] Of the $81 billion of funding, around $27 billion is earmarked to equip farmers and ranchers to adopt climate smart agriculture by helping them:

- implement and expand conservation practices to safeguard resources and sequester carbon in soil
- expand practices like cover crop, nutrient management, buffers, and leverage private and outside investment to support locally-led conservation
- create strategies to address root causes of the climate crisis (preventive measures) on par with crop insurance (reactive measures) that are implemented to reduce damages from climate-driven extremities

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65. *Farm Bill Primer: Agricultural Research and Extension*. CRS Report, Congressional Research Service. (2022). https://crsreports.congress.gov/product/pdf/IF/IF12023

66. *Funding for Agriculture and Forestry in the Build Back Better Act*. CRS Report, Congressional Research Service. (2021). https://crsreports.congress.gov/product/pdf/IN/IN11805

67. *Agriculture, Nutrition, and Forestry Provisions in the Build Back Better Act*. United States Senate Committee on Agriculture, Nutrition and Forestry. (2021). https://www.agriculture.senate.gov/imo/media/doc/10-28-21%20Agriculture%20Provisions%20in%20the%20Build%20Back%20Better%20Act.pdf

Research: A dedicated budget of $2 billion is allocated under BBBA's agriculture specific funding for research, and for renovating and upgrading agriculture facilities. This entails:

- Investment in agricultural climate research extension to help farmers adapt to climate crisis.
- $1 billion research facilities at Minority Serving Institutions
- Funding scholarships for BIPOC students and Black land-grant universities.

Table 2: Agriculture in the Build Back Better Act (FY2022–FY2031)[68]

Subtitle of Title I (Agriculture)	**Amount (in millions of dollars)**
Subtitle B - Forestry	
National Forest System Restoration	17,100
Non-Federal Land Forest Restoration	6,000
State and Private Forestry Conservation	3,850
Administrative Costs	200
Subtotal	**27,150**
Subtitle F – Conservation	
Additions to Farm Bill Programs	21,077
Soil Conservation Assistance	5,048
Conservation Technical Assistance	950
Subtotal	**27,075**
Subtitle C Part 1 – Rural Development	
Rural Electric Clean Energy Transition	9,700
Rural Energy for America; Biofuels	-
Infrastructure and Rural Energy Savings	3,125
Electric Loans for Renewable Energy	2,880

68. *Build Back Better Act: Agriculture and Forestry Provisions*. CRS Report, Congressional Research Service. (2021). https://crsreports.congress.gov/product/pdf/IF/IF11988

Subtitle C Part 1 – Rural Development *(contd.)*	
Rural Water Assistance	1,067
Rural Partnership Program; Admin. Costs	1,523
Subtotal	**18,295**
Subtitle C Part 2 – Agricultural Credit	
Farm Debt Relief and Loan Modifications	11,676
Offset: Rescinding Debt Relief in P.L. 117-2	-5,029
Assistance for Underserved Farmers	1,384
Offset: Rescinding Outreach in P.L. 117-2	-1,010
Subtotal	**7,021**
Subtitle E – Miscellaneous	
Farm and Food Worker Relief Grants OIG	205
Total	**79,746**

In the summary of Subtitles, we have removed the budgetary allocation under Subtitle D (Research Urban Agriculture) in BBBA's allocation under Agriculture and Forestry Title, as it is not relevant to large scale rural agriculture.

Soil Carbon Monitoring Effort for CRP lands (2020): The USDA launched the first phase of Soil Carbon Monitoring Efforts to assess the carbon sequestered through the Conservation Reserve Program Initiative. The USDA will spend $10 million in this endeavor where they will sample, measure and monitor the climate benefits from these lands.[69]

Policy Ecosystem in Canada

In Canada, the most significant cropping change was the major reduction in summer fallow[70] in the country's two prairie ecoregions, and wide adoption of zero-till or conservative tillage. These changes substantially reduced the risk of wind erosion.

69. *USDA Launches First Phase of Soil Carbon Monitoring Efforts through Conservation Reserve Program Initiative*. USDA, Farm Service Agency. (2021). https://www.fsa.usda.gov/news-room/news-releases/2021/usda-launches-first-phase-of-soil-carbon-monitoring-efforts-through-conservation-reserve-program-initiative

70. The practice of leaving land fallow for one growing season and suppressing weed growth by one or more tillage events.

Federal Prairies Farm Rehabilitation Act (1935): Canada's agri-environment program began in 1935 with the enactment of the Federal Prairie Farm Rehabilitation Act, which mandated reduction in soil erosion and increase of water access in the western provinces.[71]

National Soil Conservation Program (1987): After the major dust storms in the 1980s, Canada established its National Soil Conservation Program in 1987. This program conducted technology development, education, land conversion (from lands with degraded soil to conserved land) and research and monitoring. Forty percent of the budget of this program was allocated to support farm-soil conservation activity.[72]

Zero-till Seeding (1990s): In the 1990s, zero-till and conservation tillage gained popularity in Canada, especially for cereal crops in the west and for soybean and wheat in the east. This was supported by Canadian companies that led the equipment design and manufacture for reduced tillage farming.

Green Cover Canada (2003): In spite of the above initiatives, there was continued soil erosion in the prairies. Therefore, the Permanent Cover Program (PCP) was introduced, where all highly erodible croplands were removed from crop production except for land used for pasture or hay production.[73] The most recent efforts under PCP is Green Cover Canada (2003–2007) and the Cover Crop Protection Program built on PCP.

Agricultural Policy Framework (APF) (2003): In 2003, Canadian federal and provincial agriculture ministers designed and administered the Agriculture Policy Framework. The framework covered agricultural income support and conservation programs just as the CRP initiative of the USA did. The framework had several environmental goals including soil and air quality and promotion of environmentally beneficial practices.[74] The APF specifically included the Environmental Farm Planning (EFP) and the Farm

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71. Baylis, K., Coppess, J., Gramig, B. M., & Sachdeva, P. (2022). Agri-environmental programs in the United States and Canada. *Review of Environmental Economics and Policy*, *16*(1), 83–104. https://doi.org/10.1086/718052

72. Cressman, D., Duff, S., Brubacher, P. & Arnold, J. (2000). Soil conservation policy in Canada: Adrift or in a state of evolution? In: Napier, T. L., Napier, S. M. & Tvrdon, J. (Eds.). (1999). *Soil and water conservation policies and programs: successes and failures.* pp. 169–90. CRC Press.

73. *ibid.*

74. Draper, D., & Reed, M. (2009). *Our Environment: A Canadian Perspective.* 4th Ed. Toronto: Nelson Education.

Stewardship Program. Under EFP, farmers developed a stewardship plan (best management practices) for their farms all over Canada and rolled it out by 2005. By 2011, 35% of farmers and ranchers across the country had completed their EFP plan, making it the largest widespread environment program in Canada.[75] By 2011, 45% of these farmers and ranchers with an EFP plan completed its implementation.[76, 77] Recently, the federal government along with a few provincial governments launched a program to compensate farmers financially for adopting carbon sequestering practices on their land.[78]

Food Policy (2017): The first ever food policy for Canada was intended to build healthier and more sustainable food systems – based on a robust agenda to support growth for farmers, producers, and food businesses in Canada. The actions involved were based on policies to:

- improve food systems[79]
- reduce greenhouse gas emissions from agriculture[80]

Agriculture-Agrifood Canada (AAFC) Department's Initiatives: The department of agriculture in Canada was formed in 1985. Over the years, it has transformed itself to remain relevant to the challenges and opportunities of the times. The department has a dedicated team: AAFC – Agriculture and Environment, that has been monitoring soil health since the early 2000s. In the 2021 budget for this department, there is an allocation of $200 million for the Agricultural Climate Solution to help reduce GHGs from agricultural lands.[81]

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75. *Human activity and the environment*. Statistics Canada. (2014). https://www150.statcan.gc.ca/n1/en/catalogue/16-201-X

76. Gagnon, G., Lecavalier, C., Soulard, F., St. Lawrence, J., Tait, M., & Wang, J. (2014). Human activity and the environment: Agriculture in Canada. *Catalogue No. 16-201-X, Statistics Canada, Ottawa.*

77. Clearwater, R., Martin, T., & Hoppe, T. (2016). Environmental sustainability of Canadian agriculture. *Agrienvironmental Indicators Report Series, Report # 4. Agriculture and Agri-food Canada, Ottawa.*

78. *Agricultural Carbon Offsets*. Alberta, Government of Alberta. (2020).

79. Food systems are the sum of actors and interactions along the food value chain—from input supply and production of crops, livestock, fish, and other agricultural commodities to transportation, processing, retailing, wholesaling, and preparation of foods to consumption and disposal. (International Food Policy Research Institute. *Food Systems)* https://www.ifpri.org/topic/food-systems#:~:text=Food%20systems%20are%20the%20sum,foods%20to%20consumption%20and%20disposal

80. *The Food Policy for Canada*. Government of Canada. (2020). https://agriculture.canada.ca/en/about-our-department/key-departmental-initiatives/food-policy/food-policy-canada

81. *Budget 2021 and Canada's Agriculture and Agri-Food Sector*. Government of Canada. https://agriculture.canada.ca/en/agri-info/budget-2021-and-canadas-agriculture-and-agri-food-sector

Agriculture and Environment Initiative of AAFC (Soil and Land):[82] This department hosts all information relevant and useful to farmers. The Canadian Soil Information Service (the source of data on soil and land resources of Canada) includes soil management techniques to address the problems faced by farmers, soil nutrient management, drought and flood management techniques, on-farm biodiversity and soil health indicators, among other areas of focus. Three parameters of soil health have been measured since 1991 – soil erosion indicator, SOM indicator, and soil salinization indicator.[83]

Two other key department initiatives that will bear results on improving soil health are the *Federal Sustainable Development Strategy*[84] and *Working with Indigenous Peoples in Canadian Agriculture*.

There are many on-farm funding opportunities available to reduce GHGs in agriculture for producers to leverage. In 2021 under the budget a dedicated $200 million is allocated to the Agricultural Climate Solutions program from a total investment of $385 million, to accelerate emission reductions in the sector. And AAFC can also leverage part of the $7.2 billion over seven years for the Strategic Innovation Fund.[85]

AAFC will also have to come up with the quantified climate change mitigation (net zero) targets that it will achieve through agricultural soils and all other food production activities from there.[86]

'Soil Conservation Act'-Bill C 290 was tabled in the Canadian Parliament in April 2021, directing both federal and provincial governments to develop a soil strategy for the future. This bill did not pass and was dismissed in August 2021.[87]

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82. *Soil and land*. Government of Canada. https://agriculture.canada.ca/en/agriculture-and-environment/soil-and-land

83. *Agri-environmental indicators*. Government of Canada. https://agriculture.canada.ca/en/agriculture-and-environment/agri-environmental-indicators#b2

84. *2020-2023 Departmental Sustainable Development Strategy*. Government of Canada. https://agriculture.canada.ca/en/about-our-department/key-departmental-initiatives/federal-sustainable-development-strategy/2020-2023-departmental-sustainable-development-strategy

85. *Budget 2021 and Canada's Agriculture and Agri-Food Sector*. Government of Canada. https://agriculture.canada.ca/en/agri-info/budget-2021-and-canadas-agriculture-and-agri-food-sector

86. *Net-Zero Emissions by 2050*. Government of Canada. https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/net-zero-emissions-2050.html

87. *Bill C-290*. House of Commons. Parliament of Canada. https://parl.ca/DocumentViewer/en/43-2/bill/C-290/first-reading#ID0EKAA

Canadian Net-Zero Emissions Accountability Act (2021): This enshrines in legislation, Canada's commitment to achieve net-zero emissions by 2050. The Act ensures transparency and accountability as the government works to deliver on its targets. The Act requires public participation and independent advice to guide the government's efforts. The Environment and Natural Resources ministry should, in consultation with relevant departments, come up with targets for GHG reduction that are possible through their stakeholders.

Policy Recommendations for North America

Since the 1930s, both Canada and the USA have acknowledged the threats that soil in the region can face. While in the early part of the 20th century, the focus of both nations was to become food secure, over a period of time, it is evident that the Farm Bill in the USA and the AAFC in Canada have made substantial amounts of strategic and budgetary provisions to make agriculture environmentally sustainable.

In spite of these efforts, the USA still loses 10 Mg/ha of topsoil, which is unsustainable compared to the soil renewal rate of 1 Mg/ha.[88] The present policy ecosystem is complex, especially in the USA where policies cater to opposite values existing at the same time. For example, while conservation of working lands is well covered in the Conservation title, which seeks diversification of crops, the financial support for produce under the Commodities title is limited to a small list.

The policy recommendations detailed in this publication are to help farmers transition to SSM practices that will increase SOM in farmlands to a minimum range of 3–6%. This is a **supply-side** policy intervention. To ensure the interventions happen at an accelerated pace, we need the ***pull*** factors at play as well. For farmers, the pull factor will come from both backward and forward linkages and the end consumer – the citizens of a nation. These are the **demand-side** interventions that will vary from country to country.

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88. USDA. (2013). Natural Resources Conservation Service. Rapid Carbon Assessment (RaCA). *NRCS Soils.* https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054164

In the following recommendations, we will see how to enable farmers and empower them to take up SSM practices in their land through interventions under the following four pillars:

- Knowledge Systems
- Farmer Support Ecosystem
- Legal Provisions
- Monitoring and Learning Systems

Knowledge Systems

Cataloging and Creation of SSM Package of Practices:

USDA's NRCS, Regenerate America, Kiss the Ground and many other organizations have developed specific interventions to improve soil health for various types of soil, the climatic condition of land and the crops grown in it. These need to be cataloged and curated specific to agroecological zones of lands. Specific packages of practices and options of SSM practices for the crop types – such as agroforestry, combination of intercrops, species of cover crop for specific staple, etc. – have to be researched and developed. The nutritional requirements and means of production for these crops should be precise to avoid problems that arise due to excess usage of inputs or application of the wrong inputs – both organic and inorganic.

Farmer Support Ecosystem

A study involving farmers from the midwestern USA found that the major reasons for farmer suicides were complex regulations, climate shocks and lack of technological awareness.[89] The farmer support ecosystem should address these knowledge/ awareness gaps by implementing the following recommendations.

Make conservation / healthy soil promotion programmatic information simple and accessible to farmers: The present policy ecosystem for agriculture is complex and not all farmers are able to leverage the farmer benefits offered by the government. In the USA, there are four programs under which farmers can access assistance for the conservation activity they do in their working land or retired lands – Conservation

89. Bjornestad, A., Cuthbertson, C., & Hendricks, J. (2021). An Analysis of Suicide Risk Factors among Farmers in the Midwestern United States. *International Journal of Environmental Research and Public Health, 18*(7), 3563. https://doi.org/10.3390/ijerph18073563

Stewardship Program, Environmental Quality Incentives Programs, Agriculture Conservation Easement Program and Regional Conservation Partnership Program under the Farm Bill. There are a few SSM programs under the BBBA as well.[90]

Similarly, in Canada, SSM schemes are spread across the Ministry of AAFC and the Climate Action departments. Information regarding such programs (application process, benefits, procedures involved) must be made simple and communicated widely to farmers.

Generate farmer-friendly information: Knowledge cataloged and produced in the knowledge systems pillar should be translated into "farmer-friendly information" and made available to farmers.

Training: Training sessions on SSM, regenerative agricultural practices, and PoPs for specific crops must be conducted for farmers. Agricultural research institutions should also facilitate the creation of model farm plots that demonstrate the benefits of such practices. It should be noted that such training sessions have maximum impact when conducted by fellow progressive farmers whose livelihoods depend on agriculture.

Last mile extension support / soil doctors: Investment in training and nurturing grassroots farmers (soil doctors) who can address specific issues of other local farmers is a must. The ratio of soil doctors to farmers should be sufficient to ensure effective outreach to farmers.

Payment for conservation activities: In the USA, under the BBBA, there is a provision for payment towards climate mitigating conservation activities. This translates to $25/acre of cover crop.[91, 92] In Canada, the incentives provided for conservation

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90. Good, K. (2022). Conservation Title Kicks Off 2023 Farm Bill Debate in House Ag Subcommittee Hearing. *Farm Policy News. Univ. of Illinois Urbana Champaign.* https://farmpolicynews.illinois.edu/2022/02/conservation-title-kicks-off-2023-farm-bill-debate-in-house-ag-subcommittee-hearing/

91. *Funding for Agriculture and Forestry in the Build Back Better Act*. CRS Report, Congressional Research Service. (2021). https://crsreports.congress.gov/product/pdf/IN/IN11805

92. Good, K. (2022). Conservation Title Kicks Off 2023 Farm Bill Debate in House Ag Subcommittee Hearing. *Farm Policy News. Univ. of Illinois Urbana Champaign.* https://farmpolicynews.illinois.edu/2022/02/conservation-title-kicks-off-2023-farm-bill-debate-in-house-ag-subcommittee-hearing/

activities are far less than the USA or EU.[93] A Senate Agriculture Committee hearing discussed how carbon markets can offer agricultural producers the opportunity to create additional streams of revenue from voluntary carbon markets.[94] Another way to nudge farmers to move towards regenerative and SSM practices is to reduce premiums for insurance for farmers following these practices.

Legal Provisions

Soil to Be Enshrined in Legal Systems

Most countries in the world have legislation to govern and manage natural resources such as water and air. USA and Canada both have the Clean Water Act and Clean Air Act that define what parameters make water or air safe and healthy. However, healthy soil and its characteristics are not similarly enshrined. It will be best to ensure that healthy soil is defined along with its physical, chemical and biological characteristics. This definition should include the need to maintain a minimum SOM of between 3–6%.

Land Owner (Leaser/Renter)

The issue of land tenure that acts as a bottleneck in most parts of the world is not an issue for any agriculture / soil policy in this region. But the proportion of farmers who lease and rent land is substantial. In the USA, 35–40% of farms are operated by farmers who either rent or lease the land.[95] Renting in croplands is higher (54%) than that of pasture lands (24%). The trend in rentals is going up in Canada too.[96] Given the trend, SSM activities will get implemented at large scales only when both farm operators and land owners can share the benefit from these activities. That is, incentives provided for any conservation activities should be fairly divided between the operators and owners.

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93. McDonnell, E., & Thorpe, C. (2021). Canada needs a bold new soil-health strategy. *Policy Options.* https://policyoptions.irpp.org/magazines/november-2021/canada-needs-a-bold-new-soil-health-strategy/

94. Good, K. (2020). Senate Ag Committee Hearing: Monetizing Voluntary Conservation Practices. *Farm Policy News. Univ. of Illinois Urbana Champaign.* https://farmpolicynews.illinois.edu/2020/06/senate-ag-committee-hearing-monetizing-voluntary-conservation-practices/

95. *Farmland Ownership and Tenure.* USDA ERS. https://www.ers.usda.gov/topics/farm-economy/land-use-land-value-tenure/farmland-ownership-and-tenure/

96. Kamchen, R. (2021). Farmland rentals in Western Canada continue to rise. *Country Guide.* https://www.country-guide.ca/guide-business/farmland-rentals-in-western-canada-continue-to-rise/

Monitoring and Learning Systems

National soil information systems: Set up national soil information systems that will capture soil health information using both primary data collection (as much as possible) and secondary data from satellite imagery. The information systems can monitor the threats to soil – salinization, erosion, water scarcity, dust storms, SOM and other crucial parameters. In Canada, the Canadian Soil Information System has been monitoring soil erosion, SOM and salinization since 1991. Similarly, there is the National Soil Information System (NASIS) database in the USA. However, this information can be made more accessible to farmers and other users.

Create cost-effective soil health measurement standards and tools: Create accurate, accessible, and standardized methods for rapid measurement of key soil health indicators at a scale that impacts management choices by farmers and landowners.[97] Soil health indicators should ensure that the biological health of soil is also monitored along with physical and chemical parameters.

The parameters to be measured can be based on the SSM guide put together by the FAO, which is presented in the worldwide policy recommendation of this publication. This level of soil monitoring by the farmers helps them understand and seek technical assistance based on their assessment of soils in their farm. On-farm monitoring systems and standards can help farmers access rewards from government-run conservation programs or the carbon markets.

Soil biodiversity monitoring: Regional or national-level programs that monitor soil biodiversity are currently lacking in North America, and should be initiated.[98]

97. *reThink Soil: A Roadmap to U.S. Soil Health*. The Nature Conservancy. (2021) https://www.nature.org/content/dam/tnc/nature/en/documents/rethink-soil-executive-summary.pdf

98. FAO and ITPS. (2015). Status of the World's Soil Resources (SWSR) – Main Report. Chapter 14: Regional Assessment of Soil Changes in North America. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.* https://www.fao.org/3/bc603e/bc603e.pdf

3.8 Policies for Oceania

Oceania Countries: Australia, Cook Islands, Fiji, Kiribati, Marshall Islands, Federated States of Micronesia, Nauru, New Zealand, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu and Vanuatu.[1]

1. *Pacific Soil Partnership*. Global Soil Partnership. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/global-soil-partnership/regional-partnerships/pacific/en/

Oceania Statistics

Total Population: 41.61 million[2]

GDP: USD 1.64 trillion[3]

GDP per Capita: USD 39,416 (varies significantly across the region – Australia: USD 54,875, Kiribati: USD 1,602)[4]

Total Landmass Area:[5] 8.47 million sq. km

Landmass under Agriculture:[6] 3.71 million sq. km

Population Dependent on Agriculture as a Percentage of Total Employment: 13.44% (varies significantly across the region – Australia: 2.56%, Vanuatu: 56.78%)[7]

Average Farm Size: 2,844 hectares (Australia[8] and NZ[9]) (varies significantly across the region – (Australia: 4,294 hectares,[10] Cook Islands: 0.6 hectares[11])

Executive Summary

Oceania is a region made up of thousands of islands in the south and central Pacific Ocean. Australia, Papua New Guinea and New Zealand are the countries with the largest landmass in the region. These three islands make for the continental islands, which have natural resource-driven economies while the other islands in the region depend on natural resources for subsistence.[12]

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2. Mahler, D. G., Aguilar, R. A. C., Baffes, J., & Slabykh, I. (2022). World Bank Open Data. https://data.worldbank.org/ (Data presented for year 2019)

3. *ibid.*

4. *ibid.*

5. *ibid.*

6. *ibid.* (Data presented for year 2017)

7. *ibid.* (Data presented for year 2019)

8. *Agricultural Commodities, Australia, 2019–20 Financial Year*. Australian Bureau of Statistics. (2020). https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/latest-release#data-download

9. *Farm numbers and size*. Stats NZ. (2021). https://www.stats.govt.nz/indicators/farm-numbers-and-size

10. *Agricultural Commodities, Australia, 2019–20 Financial Year*. Australian Bureau of Statistics. (2020). https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/latest-release#data-download

11. Ritchie, H., & Roser, M. (2021). Farm size. *Our World in Data*. https://ourworldindata.org/farm-size

12. *Australia and Oceania: Resources*. National Geographic Society. (2012). https://www.nationalgeographic.org/encyclopedia/oceania-resources/

Australia has the most diverse climate on the continent because of its size and position. The northern coasts of the continent are tropical while the southern coasts have a Mediterranean climate. Tropical regions produce dairy and beef, and Mediterranean regions grow wheat, cereals, oilseeds, legumes and wines. Most of Australia's mainland is desert, surrounded by temperate grasslands. On the other hand, New Zealand is exposed to cold western winds and is mostly suitable for livestock rearing. Papua New Guinea has a tropical warm climate, and 85% of its population is engaged in subsistence agriculture producing sweet potatoes, coffee, cocoa and rubber. The rest of the tropical islands are spread between the Tropic of Cancer and the Tropic of Capricorn, and produce banana, coconut, kava, etc.[13]

The islands have gone through a lot of changes since the first navigators and settlers arrived. Because of massive deforestation, only 1.6% of forest in Oceania is primary forest.[14] *From 1975–1990, the state of soils in the region was drastically altered because of land use,*[15] *and is a cause of great worry. In the first part of this section, we elaborate on the various threats to soils of the region, especially soil erosion, soil contamination and nutrient imbalances which will have an adverse effect on both the land-based food product systems as well as the fisheries of these islands.*

The ramifications of the present state of soil are increased food insecurity, increased vulnerability to climate change and agrarian poverty. Food security is not only impacted by soil degradation on subsistence farming, but also by subsistence fisheries, which together affect the livelihood of 70% of the population in the small islands of the region.[16] *The solution is to bring back SOM in the lands and move towards tree-based farming, especially in tropical islands. The forest ecosystems in the region are known to be rich and diverse. The land use can mimic the forest ecosystems that produce high-value forest produce in the global market, and it can help build climate-resilient systems in the face of climate change.*

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13. *Australia and Oceania: Resources*. National Geographic Society. (2012). https://www.nationalgeographic.org/encyclopedia/oceania-resources/

14. Spriggs, M. (2010). Geomorphic and archaeological consequences of human arrival and agricultural expansion on Pacific Islands: A reconsideration after 30 years of debate. *Altered Ecologies (Terra Australis 32): Fire, Climate and Human Influence on Terrestrial Landscapes*. https://doi.org/10.22459/ta32.11.2010.13

15. *State of Environment and Conservation in the Pacific Islands: 2020 Regional Report*. SPREP PROE. https://soec.sprep.org/

16. WFP and Pacific Community. (2018). Food Security in Vulnerable Islands: A Regional Food Security Atlas of the Pacific. *The UN World Food Programme and the Pacific Community.* https://docs.wfp.org/api/documents/WFP-0000071751/download/

This section goes on to analyze existing soil-specific policies in the region. For example, Australia and New Zealand have realized the importance of healthy soil and have taken various actions towards this goal since the 1990s. We also review the policies of the Pacific Islands by studying the policy repositories in FAO's SOILEX database. The last part recommends specific policy interventions and support systems needed in the region to help farmers manage their soils sustainably.

The State of Agricultural Soil in Oceania

Historically, the region has seen many distinct waves of human settlements, of which European settlers wrought drastic changes to the land in a short period of time. They introduced land use changes in Australia and New Zealand in the 1850s which bore catastrophic results over the next century, culminating in the dust bowl of the 1930–1940s.[17] Meanwhile, other islands' land use changes involved switching from subsistence farming to commercial cropping, at the expense of native forests which saw large-scale deforestation. Some irreversible changes made during this period include the clearing of native vegetation, and mining operations such as the gold rush, as well as coal, natural gas, and phosphorus mining. Though irreversible, the effects of these land use changes can be mitigated by compensatory mechanisms to manage the soils sustainably. On the other hand, the effects of intensive farming and grazing can be reversed through the introduction of soil and climate-specific SSM practices, which are discussed in detail in this section.

Erosion

Rates of erosion in Australia and New Zealand today are lesser than in the past when land clearing was at its peak. However, soil loss by wind erosion and water erosion are still major problems progressing at unsustainable rates. Current rates of water erosion exceed soil formation rates by a factor of at least several hundred, and in some areas, several thousand.[18] Gully and river bank erosion carry sediment to streams and disrupt river systems. Similarly, land runoff has led to a decline in marine water quality and ecosystems in the Great Barrier Reef, a World Heritage site.

17. FAO and ITPS. (2015). Status of the World's Soil Resources – Main Report. Chapter 15: Regional Assessment of Soil Changes in Southwest Pacific. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.* https://www.fao.org/3/bc604e/bc604e.pdf

18. *ibid.*

In its first inventory of soil erosion in 1983,[19] New Zealand found that an estimated 9 million ha of farmland was at significant risk of sheet erosion, wind erosion, slip erosion, or gully erosion. Since then, while large-scale afforestation of hill country and steep-land pastures significantly reduced rates of soil erosion (especially sheet and slip erosion), forest harvesting continues to cause soil disturbance and poses soil erosion risks.

Larger countries among the Pacific Islands have steep slopes and receive high rainfall, making them vulnerable to soil loss by water erosion. For example, Fiji and Samoa lose 50 tonnes of soil per hectare per year.[20, 21] Additionally, although a majority of the atoll island nations are away from the cyclone belt in the Southwest Pacific, a few have been hit by tropical cyclones which have washed away the limited soil resources or left them highly salinized with decreased productivity.

Reduction in SOC/SOM

For most of the Oceania region, large SOC and soil nutrient losses took place when land was first cleared for agriculture during the settlement of different peoples, and still continues in certain islands such as Papua New Guinea and the Solomon Islands. Across the region, soil carbon typically reduces to 20–70% of the pre-clearing amount.[22] Today, the prevalent agriculture practices in the region continue to deplete the existing SOC.

For instance in New Zealand, irrigation and erosion impact carbon stocks in soil. Some irrigated soils which have been used for grazing over many decades have seen a decrease in carbon stocks, as compared to non-irrigated soils that receive only

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19. Eyles, G. O. (1983). The distribution and severity of present soil erosion in New Zealand. *New Zealand Geographer*, *39*(1), 12–28. https://doi.org/10.1111/j.1745-7939.1983.tb01012.x

20. Glatthaar, D. (1988). The sediment load of the Waimanu River, Southeastern Viti Levu, Fiji. In: Liedtke, H., & Glatthaar, D. (Eds.). Report about two research projects in the Republic of Fiji, pp. 52–75. *Sponsored by the German Research Foundation (Deutsche Forschungsgemeinschaft, Bonn, Federal Republic of Germany). Bochum, Ruhr-University Bochum, Geographical Institute.*

21. Terry, J.P., Kostaschuk, R.A. & Garimella, S. (2006). Sediment deposition rate in the Falefa River basin, Upolu Island, Samoa. *Journal of Environmental Radioactivity, 86*(1), 45–63. https://doi.org/10.1016/j.jenvrad.2005.07.004

22. Sanderman, J. & Baldock, J. A. (2010). Accounting for soil carbon sequestration in national inventories: A soil scientist's perspective. *Environmental Research Letters, 5*, 034003. http://dx.doi.org/10.1088/1748-9326/5/3/034003

rainfall.[23] This may be because of greater soil respiration rates in the irrigated system.[24] Also, eroded soils makes the process of SOC sequestration (the process of bringing SOC back into the soil) an uphill task. Even the best efforts to restore SOC in eroded soils will only bring it back to 80% of the original SOC amount before erosion.[25]

SOC in Australian fields is still in decline despite conservation land management practices like no-till farming. This suggests that how a soil management practice is implemented is important: poor application of a potentially very effective practice can result in SOC loss, while good application of a moderately effective practice may increase SOC stocks.[26]

Expansion of agriculture and uncontrolled logging in Papua New Guinea, and the conversion of native vegetation into coconut plantations in atolls, led to great declines in soil carbon. SOC is also lost in the small size of Fiji farm holdings (60% are less than 3 ha) as farmers practice intensive monocropping for higher output in short-term production, with no or minimal fallow periods.[27] With cash cropping and grazing claiming the flatter lands, higher competition is forcing subsistence gardeners onto steeper slopes ill-suited for cultivation practices, further contributing to loss of soil carbon through erosion.

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23. Kelliher, F. M., Condron, L. M., Cook, F. J. & Black, A. (2012). Sixty years of seasonal irrigation affects carbon storage in soils beneath pasture grazed by sheep. *Agriculture Ecosystems and Environment, 148*, 29–36. https://doi.org/10.1016/j.agee.2011.10.022

24. Kelliher, F. M., Curtin, D., & Condron, L. M. (2013). Soil carbon stocks in particle-size fractions under seasonally irrigated, grazed pasture. *New Zealand Journal of Agricultural Research, 56*(3), 239–244. https://doi.org/10.1080/00288233.2013.808673

25. Rosser, B. J. & Ross, C. W. (2011). Recovery of pasture production and soil properties on soil slips scars in erodible hill siltstone country, Wairarapa, New Zealand. *New Zealand Journal of Agricultural Research, 54*(1), 23–44. https://doi.org/10.1080/00288233.2010.535489

26. Page, K. L., Dalal, R. C., Pringle, M. J., Bell, M., Dang, Y. P., Radford, B., & Bailey, K. (2013). Organic carbon stocks in cropping soils of Queensland, Australia, as affected by tillage management, climate, and soil characteristics. *Soil Research, 51*(8): 596–607. http://dx.doi.org/10.1071/SR12225

27. Leslie, D. M. & Ratukalou, I. (2002). Review of rural land use in Fiji: Opportunities for the new millennium. *MASLR and SPC/GTZ - PGRFP.* https://spccfpstore1.blob.core.windows.net/digitallibrary-docs/files/c0/c03b6d54f54f5665ed8a52d8a15242e6.pdf?sv=2015-12-11&sr=b&sig=rJh1Mv09iUkfDbdnYTf%2Ba2VWHcjLTnJv7PjdYyUXEMg%3D&se=2022-10-15T01%3A58%3A14Z&sp=r&rscc=public%2C%20max-age%3D864000%2C%20max-stale%3D86400&rsct=application%2Fpdf&rscd=inline%3B%20filename%3D%2228968_2002_Review_of_rural_landuse_in_Fiji.pdf%22

Salinization and Sodification

Dryland salinity is common in many parts of southern and eastern Australia, and is the costliest form of land degradation in this region.[28] Removal of native vegetation causes more water either to infiltrate or run off the surface. When native vegetation is replaced with shallow-rooted species that require less water, water tends to pass through the soil, increasing groundwater levels and dryland salinity. This type of degradation has slowed, but is still expected to spread. The same can be said of soil salinity in many irrigation districts of Australia.

Meanwhile, for the 1,000 or more inhabited atoll islands in the Oceania region, saltwater intrusion and freshwater systems management is a major issue.

In terms of sodification, while Australia has a wide presence of sodic soils, they are rare in other parts of the region. Sodic soils are difficult to manage due to poor soil-water and soil-air relations. It was estimated that more than 60% of the 20 million ha of cropping soils in Australia are sodic and that the resulting yield of grains on these soils is often less than half of the potential yield.[29]

Soil Contamination

Phosphorus fertilizers, agricultural chemicals, mining, waste disposal, former industrial sites, and nuclear testing are all causes of soil contamination.[30] Throughout the Oceania region, there are tens of thousands of contaminated sites.

In recent years, Australia and New Zealand have been able to manage this problem and mitigate future risk. Although they have banned or regulated agricultural chemicals such as fertilizers and herbicides, the past residues can linger in the land and continue to affect crop production. Cadmium and fluorine are of utmost concern in the region as cadmium can move from soil to edible parts of plants and further up

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28. George, R. J., Kingwell, R., Hill-Tonkin, J., & Nulsen, R. (2005). Salinity investment framework: Agricultural land and infrastructure. *Resource Management Technical Reports, 270. Department of Agriculture, Western Australia.* https://researchlibrary.agric.wa.gov.au/rmtr/253/

29. Rengasamy, P. (2002). Transient salinity and subsoil constraints to dryland farming in Australian sodic soils: an overview. *Australian Journal of Experimental Agriculture, 42*(3), 351–361. https://www.publish.csiro.au/an/ea01111

30. FAO and ITPS. (2015). Status of the World's Soil Resources – Main Report. Chapter 15: Regional Assessment of Soil Changes in Southwest Pacific. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.* https://www.fao.org/3/bc604e/bc604e.pdf

the food chain to humans and animals.[31] Copper, arsenic and lead are contaminants associated with orchards and market gardens. In both countries, thousands of former cattle and sheep-dip sites are contaminated with DDT and other pesticides, including arsenic-based compounds.[32] Construction of dwellings near these sites is a threat to human health as well.

In Papua New Guinea, mining residue disposed of into rivers is having a long-term impact on soils. Nuclear testing in the Marshall Islands in the 1940–50s and in French Polynesia from 1960–90s led to severe contamination and was detrimental to the citizens. Detailed investigation found that some areas will be contaminated essentially forever, while in undisturbed areas, the radioactivity is mostly in the upper 0.15 m of soil profile, posing a risk of exposure for the terrestrial food chain.[33]

Soil Acidification

Soil acidification can be a slow but irreparable process of soil damage if it is not properly managed. This is a major issue in places with inadequate farming practices, light-textured and infertile soil that cannot adequately buffer a decrease in pH, and soil that already has a low pH. Soil acidification can cause loss or changes in soil biota, acceleration of nutrient leaching, and nutrient deficiencies or toxicities, which play a role in reduced soil productivity and carbon sequestration. This can also increase eutrophication, siltation, and acidification of waterways.

Half of Australia's agricultural soils are affected by acidification, which lays heavy costs on the economy. In 2001, the estimated annual cost of lost agricultural production due to acidity was AUD 1,585 billion, about 8 times the estimated cost of salinity at

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31. Loganathan, P., Hedley, M. J., Grace, N. D., Lee, J., Cronin, S. J., Bolan, N. S., & Zanders, J. M. (2003). Fertiliser contaminants in New Zealand grazed pasture with special reference to cadmium and fluorine — a review. *Australian Journal of Soil Research, 41*(3), 501–532. https://www.publish.csiro.au/SR/SR02126

32. FAO and ITPS. (2015). Status of the World's Soil Resources – Main Report. Chapter 15: Regional Assessment of Soil Changes in Southwest Pacific. *Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils, Rome, Italy.* https://www.fao.org/3/bc604e/bc604e.pdf

33. Morrison, R. J., Gangaiya, P., & Koshy, K. (1996). Contaminated soils in the South Pacific islands. In: Contaminants and the Soil Environment in the Australasia-Pacific Region, pp. 659–675. Netherlands, Springer. https://link.springer.com/content/pdf/10.1007/978-94-009-1626-5_23.pdf

that time.[34] Soil acidity in Western Australia is estimated to cost broad-acre agriculture AUD 498 million per year, which is equivalent to about 9 percent of the average annual crop.

In New Zealand, acidification of legume-based pastures resulting from nitrate leaching and nutrient transfer or removal is of particular concern. While regular liming can ameliorate soil acidity, its application in the hill country is too costly. Soil acidification also is prevalent in the sugarcane lands of Papua New Guinea and agricultural lands in Fiji.

Nutrient Imbalance

Intensive systems of land use lead to the prevalence of nutrient imbalance in the soils. Nutrient mining, in which large amounts of nutrients are removed from soil with minimal additions, leads to decline in soil fertility. For example, in Queensland, Australia, extensive low-input systems once relied heavily on the natural fertility of the rich vertisols, but now crop production requires fertilizers.

The few studies conducted in Melanesia show that increased population is causing shortening of rotations in agricultural systems, which leads to reduced fallow periods for the land. That is, the soil does not get the time required to replenish its own nutrient balance through the natural process.

Soil Compaction

In Australia, compaction is widespread due to the use of heavy machinery, causing the most damage when soil is wet. Soil constraints of compaction mostly exist in surface and subsurface soil horizons, restricting root growth in these regions. Fortunately, the uptake of controlled-traffic farming in Australia and New Zealand has minimized compaction and mitigated further damage. In Western Australia, farm profit increased by 50% through the adoption of this practice. In New Zealand, where compaction is common in grazed pastures due to animal treading, managed grazing

34. Lockwood, P., Wilson, B., Daniel, H., & Jones, M. (2003). Soil acidification and natural resource management: directions for the future. *NSW, Armidale, University of New England.* https://www.researchgate.net/publication/236736946_Soil_acidification_and_natural_resource_management_Directions_for_the_future

systems in which animals are partially or completely excluded from parts of the land at a time have been shown to help soil recover from compaction.[35]

Ramifications of the State of Soil in Oceania

Food Insecurity

Oceania has a low population density compared to the rest of the world. In spite of this, 12% of the population in the region was affected by moderate to severe food insecurity in 2020.[36] Of this 12%, 2.6% faced severe hunger. This amounts to 1 million people suffering severe hunger and 5.1 million facing moderate to severe food insecurity. This is connected with soil health.

The small island nations in the Pacific traditionally ate fish, forest produce and root vegetables like cassava, yams, and sweet potatoes,[37] but the adoption of intensive monoculture that threaten soil health have reduced yields of crops and also reduced catch in subsistence fisheries. Furthermore, the region's vulnerability to climate change, with increasing temperatures and changes in rainfall patterns, can significantly impact crop yields.

In addition to crop yield, crop quality is also impacted by declining soil quality. An example is the reduction in the size of the corm of Colocasia, from 4–5 kg per corm in the past to around 1 kg per corm in recent times.[38]

Apart from farming, subsistence/commercial fisheries, both inland and marine, are a significant source of food for the region, and they are directly impacted by soil erosion, soil contamination and nutrient imbalance. Soils eroded by wind or water in large countries are carried and deposited in other lands or water bodies in or around the region, or even travel much longer distances with the gust of a storm (e.g., dust bowls). Particularly, the wetland ecosystem of the region is composed of coral reefs

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35. Sparling, G. P., & Schipper, L. (2004). Soil quality monitoring in New Zealand: trends and issues arising from a broad-scale survey. *Agriculture, Ecosystems & Environment, 104*(3), 545–552. http://dx.doi.org/10.1016/j.agee.2003.11.014

36. UNICEF. (2021). The State of Food Security and Nutrition in the World 2021. https://data.unicef.org/resources/sofi-2021/

37. Salem, S. (2020). Climate change and food security in the Pacific. *E-International Relations*. https://www.e-ir.info/2020/02/18/climate-change-and-food-security-in-the-pacific/

38. Koreis, D. (2019). Pacific faces crop yield declines, turns to past for modern solution. *ECOS, 258*. https://ecos.csiro.au/pacific-faces-crop-yield-declines-turns-to-past-for-modern-solution/

(31%), mangroves (12%) and seagrass (17%), and is important for the local fisheries. This ecosystem is extremely sensitive to sediment concentration, contaminants, and excess nutrients in water that in turn affect the operation of fisheries, which account for a significant source of income in the region.[39, 40]

Increasing SOM to 3–6% is an important – possibly the most important intervention – that governments and people can invest in to safeguard and strengthen the food security of the region. This can be achieved by adopting sustainable soil management agricultural practices, such as tree-based farming. This will significantly increase crop yields, which will improve nutrition levels and reduce poverty. Tree-based farming will also protect fisheries, as it helps reduce the leaching of soil contaminants and nutritions into the sea and other water bodies, thus ensuring that fish populations thrive better.

The two tree-based SSM practices that can be adopted in the region are: (1) intercropping models with trees as part of the land use and (2) building livelihood by harvesting non-timber produce from existing forests.

Intercropping: Intercropping models of annual crops with perennial tree crops can be developed to ensure the coastal regions of the islands are shielded by wind-breaking trees. This can arrest water and wind erosion and compaction of soil. Also intercropping with species that nurture each other and the soil for long-term productivity, can result in high-value agricultural products. Some intercropping models found in the region involve shade-grown coffee, vanilla, cacao, and medicinal plants (non-timber forest produce).[41]

Collection of Non-timber Forest Produce: Indigenous communities are adept at harvesting tree-based commodities like medicinal plants and leaves that make up for a portion of export from the Pacific islands. These islands are known to be rich in biodiversity and can offer many products with potential benefits which are still being studied and marketed.[42]

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39. FAO. (2020). The State of World Fisheries and Aquaculture 2020. *Food and Agriculture Organization of the United Nations, Rome, Italy.* https://doi.org/10.4060/ca9229en

40. *Ocean pollution and marine debris*. National Oceanic and Atmospheric Administration. (2020). https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-pollution

41. *State of Environment and Conservation in the Pacific Islands: 2020 Regional Report*. SPREP PROE. https://soec.sprep.org/

42. Lesa, S. (2022). Pacific Partnerships At Work In Global Biodiversity Negotiations. *SPREP*. https://www.sprep.org/news/pacific-partnerships-at-work-in-global-biodiversity-negotiations

Increased Vulnerability to Climate Change

Climate change is already having a drastic impact on coastal and forest ecosystems, freshwater supplies, biodiversity, and indeed all aspects of life. Today, soils degraded by intensive agriculture and large-scale clearing of native forests have further increased the susceptibility of the region to the effects of climate change.

The carbon lost from soils in the islands due to the practice of intensive agriculture is released into the atmosphere as CO_2 or as particulate organic carbon (POC) into the oceans. While the first increases the temperature of the atmosphere, the second increases the acidity of the ocean and makes the water warmer. Both of these contribute to the visible rise in sea levels that has led to social and economic disruptions in low-lying small island countries in the Pacific.[43] Rising sea levels also lead to salinity intrusion into freshwater aquifers, thus putting stress on the already fragile freshwater ecosystems of the region.

For example, in New Zealand, present agricultural practices lead to soil erosion that carry large sediments and particulate organic carbon (POC) directly to the sea. The North Island was estimated to export 1.9 (-0.5/+1.0) million tonnes of POC per year to the sea. The South Island was estimated to export 2.9 (−0.7/+1.5) million tonnes of POC per year, and to sequester approximately the same amount.[44] This influx of POC adds to the rise in sea level.

A 30–50 cm rise in sea level due to climate change costs coastal communities of the Pacific Islands around USD 1.419 billion per year.[45] Sustainable soil management can play a vital role in offsetting this cost, by increasing SOM in the land and, in turn, mitigating erosion and climate vulnerability. Water retention in soil will also increase with SOM, which will improve water availability. The water held in soil can then infiltrate aquifers and counter salinity intrusion from rising sea levels.

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43. Pacific: Secretariat of the Pacific Environment Programme - The SPREP Convention. *UNEP*. https://www.unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/regional-seas-programmes/pacific

44. Dymond, J. R. (2010). Soil erosion in New Zealand is a net sink of CO2. *Earth Surface Processes and Landforms, 35*(15), 1763–1772. http://dx.doi.org/10.1002/esp.2014

45. *Climate Change Impacts: Pacific Islands*. The Global Mechanism, UNCCD and IFAD. https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/pacific-islands/micronesia/IFAD.--CC-Impacts.pdf

Agrarian Poverty

Agriculture remains the backbone of the Pacific Island economies: it is the main source of livelihood for the population as well as a major export earner.[46] Around 50–70% of the population in the region depend on agriculture as their primary source of livelihood.[47] However, in Australia, native forests are also an important part of local economies, accounting for roughly 70% of its exports. Yet, intensive logging practices are unsustainable. For example, the Solomon Islands have lost 21.5% of forest cover between 1990 and 2005.

Besides agriculture, the commercial fishing industry is an important contributor to economies throughout Oceania. About 600 marine and freshwater seafood species are sold in Australia for local and foreign consumption. "Wild-caught" seafood makes up about two-thirds of total seafood production. Rock lobster, pearls, abalone, and prawns make up $1.3 billion (86%) of total seafood exports.[48] Yet, this economically important production system is at risk from marine pollution, roughly 80% of which originates on land.[49] The majority of pollution that originates from land comes from nonpoint source pollution from agricultural runoffs.

Scientific studies state that in the absence of adaptation of sustainable agriculture practices that can alleviate climate change effects, high islands such as Fiji could experience damage costs of USD 23–52 million per year by 2050. If the present agriculture practices were to continue and extreme climate change were to manifest (temperatures have increased in the range of 2–4°C), it can cost the region upto USD 8 billion per year.[50]

As covered in the "Food Insecurity" section, increasing SOM by adapting tree-based SSM practices can protect the farmers' livelihoods.

46. Malua, M. B. Case Study: The Pacific Islands. *UNCTAD*. https://unctad.org/system/files/official-document/ditctncd20031p5_en.pdf

47. World Food Programme, Pacific Community. (2018). Food Security in Vulnerable Islands: A Regional Food Security Atlas of the Pacific https://docs.wfp.org/api/documents/WFP-0000071751/download/

48. *Australia and Oceania: Resources*. National Geographic Society. (2012). https://www.nationalgeographic.org/encyclopedia/oceania-resources/

49. *Addressing Land-Based Pollution*. UNEP. https://www.unep.org/explore-topics/oceans-seas/what-we-do/addressing-land-based-pollution

50. *Climate Change Impacts: Pacific Islands*. The Global Mechanism, UNCCD and IFAD. https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/pacific-islands/micronesia/IFAD.--CC-Impacts.pdf

Present Policy Ecosystem in Oceania

Australia and New Zealand have soil strategies in place and also clear budgetary commitments to sustainably manage soil. Both countries have acknowledged the importance of soil as a key natural resource since the early 1990s. This is reflected in some of the national policies that have been rolled out to collect soil specific data and to incorporate sustainable soil management practices. In this section we will look at the soil-specific policy interventions taken by Australia, New Zealand and the Secretariat of the Pacific Regional Environment Programme (SPREP), and review the SOILEX repository to understand the efforts towards soil policy in the rest of the Pacific Islands.

Present Soil/Land Policies in Australia

Australia set up the Australian Soil Resource Information System (ASRIS) under the leadership of the Australian Collaborative Land Evaluation Program (ACLEP) in the early 2000s, to capture various soil-specific data that may be needed by a broad group of stakeholders, including education institutions, natural resource managers, communities, etc.[51] The data captured in this system included scientific soil types, a database of soil profiles, and the quality of land in terms of degradation.

Development of a Strategic Approach to Manage Australian Soils (2006): In 2008, the National Committee on Soil and Terrain (NCST) produced a report *Managing Australia's Soils: A Policy Discussion Paper*[52] which acknowledged the significant role of soil with respect to food security and climate change mitigation, and sought an action plan to ensure soils are managed sustainably in Australia. The existing data and information collection systems are only a means to achieve the sustainable management paradigm.

Soil-specific Areas of Action (2009): The discussion paper presented to the public by the national/state and territorial governments sparked public discussion around soil in 2009. These debates and public discussions gave rise to a finite set of areas pertaining to soil that needed government intervention.[53]

51. *Australian Soil Resource Information System*. https://www.asris.csiro.au/about.html

52. Campbell, A. (2008). Managing Australia's Soils: A policy discussion paper. https://www.clw.csiro.au/aclep/documents/Managing%20Australias%20Soils%20summary%20of%20submissions.pdf

53. Schoknecht, N. (2010). Soil Policy Development in Australia. *19th World Congress of Soil Science, Soil Solutions for a Changing World. 1 – 6 August 2010, Brisbane, Australia.* https://www.iuss.org/19th%20WCSS/Symposium/pdf/2172.pdf

The activities listed included:[54]

- a national strategic approach to manage future threats to the soil resource
- increasing research and development on soil health
- improving national soil-related skills and knowledge
- improving soil information and data management
- improving education and extension capacities to support practice change
- improving public awareness of critical soil management issues

Revamp and Upgradation of Soil Information Systems (2010–2016)

The soil information system in Australia has been set up with a limited perspective, but over a period of time it has developed to be a very useful and powerful source of information to understand the state of Australian soils and also a guide to managing soils sustainably. The journey to streamline soil information began in 2010. Discussed below are some of the major milestones in the journey.

- **Soil User Need Analysis (2011):** The Australian Collaborative Land Evaluation Program (ACLEP) was given the responsibility to assess the type of soil data needed by the users of ASRIS. The report listed the issues users shared. Some of the findings of the report were: present information is not easy to access; users wanted access to comprehensive meta data; and single soil databases should be available to users (ACLEP, NCST and ASRIS should work together and provide soil data through ASRIS alone)[55]
- **Physiographic Regions of Australia (2010):** In parallel, the Physiographic Map of Australia was also updated and published in the ASRIS platform.[56]
- **Digital Soil Mapping (2010):** National, state and territorial governments of Australia attended the Global Digital Soil Mapping workshop and came up with ways to implement mapping across the nation at various levels of granularity

54. Campbell, A. (2008). Managing Australia's soils: A policy discussion paper. https://www.clw.csiro.au/aclep/documents/Managing%20Australias%20Soils%20summary%20of%20submissions.pdf

55. Wood, B.G., & Auricht, C. M. (2011). ASRIS/ACLEP User Needs Analysis. *CSIRO, ACLEP, Auricht Projects.* https://www.clw.csiro.au/aclep/documents/ASRIS_User_Analysis.pdf

56. Pain, C., Gregory, L., Wilson, P., & McKenzie, N. (2011). The physiographic regions of Australia: Explanatory notes. *ACLEP.* https://www.clw.csiro.au/aclep/documents/PhysiographicRegions_2011.pdf

under the leadership of NCST.[57] The learning from the global workshop was used by ACLEP to develop digital mapping of soils of Australia to provide near real-time data to the users of ASRIS. This was done with support from CSIRO (Commonwealth Scientific and Industrial Research Organization, Australian government) satellite imagery and other scientific methodologies relevant to soil sciences.[58]

- **National Soil Condition Monitoring Systems for pH and Soil Carbon (2011):** This system was set up to understand how agricultural practices are affecting soils of Australia – thus helping to understand the magnitude of change and, therefore, to plan for actions commensurate to the status reported by the monitoring.[59]
- **Soil Information Governance (2012):** A proper data governance system with appropriate processes, people and technology was set up to efficiently and effectively manage the soil information. This will ensure quick and easy access to users and facilitate informed decisions on sustainably managing soils.[60]
- **Legacy Data Capture of Australian Soils (2016):**[61] ACLEP, along with state and territorial agencies, worked for many years to capture, collate and disseminate soil data in a consistent manner. The data captured under this project were locally and regionally significant soil data sets that can underpin land development and management decisions related to agriculture, rangeland, mining, and other land uses.

National Soil Strategy (2021): This is the first comprehensive soil strategy put together for the country for a period of 20 years. This strategy prioritizes soil health, empowers soil

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57.Robinson, N., Thomas, M., Hopley, J., Kidd, D., Owen, G., Schoknecht, N., Searle, R., & Hall, J. (2010). Recommendations for the advancement of Digital Soil Assessment in Australia. *4th Global Digital Soil Mapping Workshop – Rome.* https://www.clw.csiro.au/aclep/documents/Global%20Digital%20Soil%20Map%20Workshop%202010.pdf

58. Wilson, P., & Thomas, M. (2012). Digital Soil Mapping in ACLEP 2012 and Beyond. *National Research Flagships Sustainable Agriculture, CSIRO, ACLEP.* https://www.clw.csiro.au/aclep/documents/ACLEP%20Digital%20Soil%20Mapping%20Report%20v2_1%20.pdf

59. Grealish, G., Clifford, D., Wilson, P., & Ringrose-Voase, A. (2011). National Soil Condition Monitoring for soil pH and soil carbon: Objectives, Design, Protocols, Governance and Reporting. *CSIRO Land and Water Science Report 05/11 for Caring for our Country.* https://www.clw.csiro.au/aclep/documents/CLW_Science_Report_0511.pdf

60. Wilson, P. (2012). *Improving Australian soil data and information governance*. *National Research Flagships Sustainable Agriculture, CSIRO, ACLEP.* https://www.clw.csiro.au/aclep/documents/Soil%20info%20Governance%20Report.pdf

61. *Final Report on Department of Agriculture and Water Resources funding to support legacy soil data capture through the Australian Collaborative Land Evaluation Program (ACLEP).* Land & Water, CSIRO. (2016). https://www.clw.csiro.au/aclep/documents/LegacyDataCapture2014FinalReport.pdf

innovation and soil stewards and strengthens the knowledge and capabilities required to manage soil sustainably. This strategy's priorities were set by farmers, industry research and other land managers across Australia. The strategy was crafted collaboratively by national, state and territorial governments, the ***National Soil Advocates***[62] and soil community. It will help farmers to build resilience and also contribute to a largely sustainable future. Budgets for activities under the Soil Strategy will come from the National Soil package for 2021–2022. The strategy also supports already existing government programs around sustainable land management: Agriculture Stewardship Program, Bushfire Recovery Program, Future Drought Fund, Australian Collaborative Land Use Mapping Program and Threatened Species Strategy.[63]

National Soil Package (2021–22): The overall budget for the National Soil package is AUD 214.9 million. This will be utilized towards the following areas:

- **Development of National Action Plan – AUD 5.9 Million:** The Action Plan will help identify current programs across Australia that support soil health and may help identify gaps where new funding and resources can be directed.
- **Pilot Soil Monitoring and Incentives Program – AUD 54.4 Million (2 Years)**: This is to allow land managers to access low cost soil sampling and Australasian Soil and Plant Analysis Council (ASPAC)-certified testing in exchange for sharing their data.
- **Historical Soil Data Capture Payments Program – AUD 21 Million:** To pay private and public entities to provide existing soil data to be incorporated into the redeveloped ASRIS.[64]
- **Australian Government Investment in Landcare – AUD 18 Million:** Existing funding from the National Landcare Program's Smart Farms Small Grants initiative will be redirected to soil extension activities that encourage farmers to test their soil and help them interpret and act on results.[65]

62. National Soil Advocate: A world first in terms of elevating soil health to a level of national significance, the position of Advocate was established to raise awareness of the vital role soils play and to provide strong leadership and advocacy on the importance of conserving and improving the health of Australia's soils. The advocates have a role both nationally and internationally. For further details: https://www.pmc.gov.au/domestic-policy/national-soils-advocate

63. *National Soil Package*. DAWE, Australian Government. https://www.awe.gov.au/agriculture-land/farm-food-drought/natural-resources/soils

64. *Historical Soil Data Capture Payments Program*. DAWE, Australian Government. https://www.awe.gov.au/agriculture-land/farm-food-drought/natural-resources/soils/historical-soil-data

65. *Australian government investment in Landcare*. DAWE, Australian Government. https://www.awe.gov.au/agriculture-land/farm-food-drought/natural-resources/landcare/national-landcare-program/australian-government-investment-in-landcare

- **Australian National Soil Information System – AUD 15 Million:** To store soil data, track and report trends and changes in soil health, and be used to monitor the impact of land management practices and environmental shocks over time. The enhancement of a publicly available and federated soil information platform will support decision makers to identify gaps and opportunities to manage and improve Australia's soil assets.
- **Soil Science Challenge Grants Program – AUD 20 Million:** The grants program will support researchers to address fundamental gaps in soil science and improve our understanding of how to better manage soil. This grant will be dispersed over a 4-year period.
- **Review Existing Soil Data – AUD 2 Million:** To establish the quality, quantity and distribution of information across Australia and identify gaps in soil knowledge. The review will inform the scale and value of the incentives so that they can be targeted in a way that will capture the most useful soil information both for government and stakeholder objectives in a cost-efficient manner.
- **Food Waste for Healthy Soils Fund – AUD 67 Million:** A fund to support the diversion of household and commercial food and garden organic waste (FOGO) from landfill to soil via the expansion of existing FOGO processing infrastructure.[66]
- **Soil Education and Expertise – AUD 1 Million:** A new accreditation in soil science will be developed to improve the knowledge base of land management advisors.
- **National Land Management Practices Classification System – AUD 615,000**: A National Land Management Practices Classification System will be developed, tested and implemented over two years in consultation with key land management stakeholders.

Present Soil/Land Policies of New Zealand

Agriculture accounts for two-thirds of merchandise exported by New Zealand, and agricultural land use dates back to the 1890s.[67] New Zealand was one of the first countries in the world to pass soil-related laws, as early as the 1920s. This was prompted by the occurrences of sand drifting, soil erosion and floods that were a

66. *Food waste for healthy soils fund*. DAWE, Australian Government. https://www.awe.gov.au/environment/protection/waste/food-waste/food-waste-for-healthy-soils-fund

67. Ministry for Primary Industries. (2015). Future requirements for soil management in New Zealand - a summary. *New Zealand Government.* https://www.mpi.govt.nz/dmsdocument/10397-Future-requirements-for-soil-management-in-New-Zealand-a-summary

consequence of large-scale deforestation to create agricultural land.[68] The expansion of agriculture into forest land came to a halt in the 1920s, and the dust bowl in the USA and the book *The Rape of the Earth: A World Survey of Soil Erosion (1939)* heightened fears of soil degradation and sand drift. In the 1930s, the newly-formed Department for Scientific and Industrial Research (DSIR) began conducting soil erosion surveys. With lobbying from many scientists and soil conservators, the Soil Conservation and Rivers Control Council was founded in 1941. This marked the recognition by the agriculture department of the problems caused by drastic land use change, such as large-scale deforestation.[69]

The 1991 Resource Management Act (RMA):[70] This law embodies sustainable soil health and soil protection. Various initiatives of New Zealand land management have aspects of regenerative agriculture.[71]

Living Standards Framework (LSF) 2021: The New Zealand Government's recently adopted Living Standards Framework (LSF) and the proposed Genuine Progress Indicator.[72] This LSF framework is to help the Department of Treasury make budgetary decisions based on the wellbeing accrued to the nation from various expenditures. Soil health falls under the broad set of Natural Environment indicators. The state of the indicator can guide the ecosystem service payout for healthy soils.[73] Climate Smart Agriculture is incorporated and encouraged by present policies of the nation. New Zealand has removed agricultural subsidies while partnering on research and development with the private sector as a way to ensure efficiency and resilience in an

68. Beattie, J. (2003). Environmental Anxiety in New Zealand, 1840–1941: Climate Change, Soil Erosion, Sand Drift, Flooding and Forest Conservation. *Environment and History*, *9*(4), 379–392. http://www.jstor.org/stable/20723453

69. *ibid.*

70. *Resource Management Act 1991*. New Zealand Legislation, Parliamentary Counsel Office. https://www.legislation.govt.nz/act/public/1991/0069/latest/DLM230265.html

71. Grelet, G., Lang, S., Merfield, C., Calhoun, N., Robson-Williams, M., Horrocks, A., Dewes, A., Clifford, A., Stevenson, B., Saunders, C. M., Lister, C., Perley, C., Maslen, D., Norton, D., Selbie, D., Chan, D., Burns, E., Le Heron, E., Crampton, E., ...& Kerner, W. (2021). Regenerative Agriculture in Aotearoa New Zealand – Research pathways to build science-based evidence and national narratives. *AERU Publications, Research@Lincoln.* https://researcharchive.lincoln.ac.nz/handle/10182/13899

72. Cameron, C., McQueen-Watton, J., & Shaw, W. (2020). Economic valuation of the ecosystem services provided by Pāmu Landcorp Farms. *New Zealand Journal of Ecology*, *44*(2), 3412. https://doi.org/10.20417/nzjecol.44.19

73. *Living Standards Framework - Dashboard*. The Treasury, New Zealand Government. https://lsfdashboard.treasury.govt.nz/wellbeing/

agricultural sector influenced by climate change and international trade dynamics.[74]

Future Requirements for Soil Management in New Zealand (2015):[75] This study was commissioned to understand the emerging pressures on New Zealand's soil resources, the present actions taken by the country to mitigate it and, finally, what else is needed to ensure the soils of New Zealand serve the needs of the nation over the decades to come. Based on this study it was suggested that the country take up action in the following areas to safeguard the soil resources: increase awareness about soil; ensure quality data and close knowledge gaps; integrate soil management into policy and planning; develop specific legislation for soil management; and manage soil pressures

Like Australia, New Zealand also has enough digital tools and databases to assist various soil stakeholders in sustainable soil management techniques:[76]

- **Smart management of nutrients:** OverseerFM® is a nutrient management tool owned by MPI, the Fertiliser Association of New Zealand and AgResearch Limited. The online software helps farmers and growers improve fertilizer use to optimize plant growth and minimize nutrient losses to the environment.
- **Monitoring soil contaminants**: This responsibility is owned by the Ministry of Environment. The ministry regularly updates the guidelines, standards and reporting procedures on its website.
- **S-Map – digital mapping of soils:** S-map is a digital system for storing and managing soil information in New Zealand from soil types that have been mapped in detail. It currently covers 62% of productive land. Regional councils use S-map for freshwater quality and quantity management. Farm consultants and council land management officials use it to identify soil types to help develop farm plans, dairy effluent management plans, and septic tank location guidance.

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74. Negra, C., Vermeulen, S., Barioni, L. G., Mamo, T., Melville, P., & Tadesse, M. (2014). Brazil, Ethiopia, and New Zealand lead the way on climate-smart agriculture. *Agriculture & Food Security*, *3*(1). https://doi.org/10.1186/s40066-014-0019-8

75. Ministry for Primary Industries. (2015). Future requirements for soil management in New Zealand - a summary. *New Zealand Government.* https://www.mpi.govt.nz/dmsdocument/10397-Future-requirements-for-soil-management-in-New-Zealand-a-summary

76. Ministry for Primary Industries. (2020). Land and soil health. *New Zealand Government.* https://www.mpi.govt.nz/funding-rural-support/environment-and-natural-resources/land-and-soil-health/

There are also enough programs and funding for research in soil management. The fund specifically relevant to agriculture lands is the **Sustainable Farming Fund.**[77] This fund supports problem solving and innovation in New Zealand's agriculture that spreads across food to fiber. Funds are made available from 100,000 to a few million NZD.

Country-Specific Policies from SOILEX

As a region, the majority of countries in Oceania do not have comprehensive legal instruments for soil protection and the prevention of soil degradation. The FAO SOILEX[78] lists parameters of soil conservation, soil erosion, soil restoration, soil monitoring, soil quality, nutrient imbalance, soil pollution, waterlogging, soil biodiversity loss, soil acidification, soil compaction, and SOC loss. According to this portal, most countries have a law under at least one of these parameters, but the majority of countries in Oceania do not have specific policies dedicated towards SSM solutions.

Vanuatu has only one policy in the portal: the National Forest Policy 2013–2023. Unlike most other policies in the region, this policy mentions the maintenance and enhancement of food security through agroforestry systems, specifically. More broadly it aims at promoting farmer and community-based reforestation programs for food security, non-wood products, timber, fuel wood and charcoal production, as well as for conservation, watershed management and climate change adaptation and mitigation. It is notable that a distinct solution to implement has been identified. However, as with most other countries in the region, there is no exhaustive framework for soil conservation.

Australia has over thirty Soil Conservation laws and they are organized by regions to tackle the unique problems of those areas, which is an ideal approach as it is the largest nation in Oceania and spans multiple agroecological zones. Australia and New Zealand have the most advanced frameworks and technology in place to help them plan interventions and achieve their soil health targets in the form of policies, digital tools and national soil databases in the region.

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77. Ministry for Primary Industries. (2022). Sustainable Food and Fibre Futures. *New Zealand Government*. https://www.mpi.govt.nz/funding-rural-support/sustainable-food-fibre-futures/

78. SoiLEX is a global database that aims to facilitate access to information on existing legal instruments on soil protection and prevention of soil degradation.

As a first step in the Rural Land Use Policy 2006, Fiji has set out roles and responsibilities of divisions of the Ministry of Agriculture, Fisheries and Forests and the Nature Lands. It can be noted that the policy has mentioned that public awareness will be raised and capacity building will be ensured through information sharing, education and extension programs on soil improvement, soil conservation, soil fertility, land use planning, forest protection, forest health, biodiversity conservation, water management, natural resources, and rural land use systems.

Kiribati's only policy in the SOILEX portal, Kiribati Integrated Environment Policy 2013, briefly articulates land use planning will be improved for sustainable use of land resources, and agricultural production will be increased in an environmentally sustainable manner through soil conservation practices. Nauru's single policy also acknowledges that protection of scarce land and already infertile soil resources is an important issue for reducing environmental degradation and improving the overall health of Nauru's environmental resources – however, no solution is mentioned.

It is worthy to note that smaller islands, like the Solomon Islands, have recognized that Land Use Planning must now be seriously addressed in light of the increasing exploitation of the environment and land resources. With a rapidly increasing population, the rush to satisfy the need for more food and income come at the cost of the land. Most people are unaware that they are contributing to soil degradation, low soil fertility, low crop productivity, health mishaps such as malnutrition, poverty and lack of economic well-being. As an initial step to counter these trends, the 2008 National Adaptation Programmes of Action and the National Rural Land Use Policy 2015–2020 were created to ensure Natural Resources are used sustainably to empower economic activities and to make sure that environmental assets and ecosystem services are maintained and enhanced. Though Solomon Islands has strong subsistence agriculture and adequate food security, this law mentions that identification and extension of sustainable agricultural systems adapted to new climate regimes is necessary to ensure future food security.

Under the United Nations Convention to Combat Desertification (UNCCD) framework, Tuvalu has developed the National Action Plan to Combat Land Degradation and Drought 2006, in which monitoring of soil erosion and sedimentation will be strengthened. Inventory and mapping of degraded land will be made by using GIS and hazard maps. Standards will be established for soil conservation techniques, and awareness will be raised on soil conservation and its benefits, management of protected areas and the dangers of land degradation. Traditional knowledge will be incorporated into sustainable land management practices and government organizations, non-governmental organizations, private sectors and local communities will be involved in the implementation of this Action Plan.

Marshall Islands has put in place the National Environmental Protection Act 1984, stating that the authority shall recommend soil conservation programs, including encouragement of scientific farming techniques, physical and biological means of soil conservation, and short-term and long-term research and technology for effective soil conservation. The soil conservation programs and the scientific farming techniques mentioned almost 40 years ago need to be elaborated on, based on soil types and agroecological locations in the country to match the conditions of today.

Guam has laws focused on regulations/permits for the control of clearing, grading, filling, excavating, or other earth-moving operations but little elaboration on how to achieve soil conservation. Soil related laws were last passed in the year 2000.

Policy Recommendations for Oceania

The uniqueness of the Oceania region is the positive repercussions of sustainable soil management on the marine environments which are also very important to the food security and livelihood of its communities. This region is home to a large amount of marine and terrestrial biodiversity, which have begun to receive worldwide recognition for the potential economic benefits they can provide. So the knowledge systems and farmer support ecosystem interventions should be established to enhance and protect this biodiversity while improving farmer economics at the same time.

Knowledge Systems

According to the Pacific Soil Partnership, the elements of knowledge systems and approach to building sustainable soil management practices in the region are:[79]

- Identify common research needs, current status, gaps and opportunities for collaboration
- Establish frameworks to express the value of research and return on investment

79. *Pacific Soil Partnership*. Global Soil Partnership. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/global-soil-partnership/regional-partnerships/pacific/en/

- Demonstrate how soil research can have wider benefit to the ecosystem, environment, people and economies
- Support improved collaboration between Australian and New Zealand universities and Pacific island nations and universities
- Promote and expand new approaches to research including participatory, transdisciplinary and citizen science

Along with the generic recommendations suggested in Conscious Planet's generic worldwide recommendations, **cataloging and creation of a Sustainable Soil Management (SSM) Package of Practices** for the region should also:

- Leverage the traditional and indigenous knowledge of the communities that have inhabited these islands for over 30,000 years.
- Leverage the unique biodiversity of the region. There have been many patents procured on products developed with raw materials from the forests in the region. The knowledge of harvesting these raw materials and product creation must also be cataloged and widely disseminated.
- Diversification of agriculture in lines with the natural ecosystem will make the islands more resilient to climate shocks. Cropping models in line with local agroecological conditions need to be developed by research organizations in the region.

Farmer Support Ecosystem

Besides the biochemical, physical and economic aspects of soils, soil health, especially in this region should also take into consideration the human, social or cultural dimensions.[80] The aboriginals in Australia have always seen soil as a much bigger entity and not as a resource: "The land was not just soil or rocks or minerals, but a whole environment that sustains, and is sustained, by people and culture."[81]

Similarly, the Maoris of New Zealand have looked at soil with a sense of trusteeship where the intergenerational concepts of guardianship of land/whenua is the guiding

80. Stronge, D. C., Stevenson, B. A., Harmsworth, G. R., & Kannemeyer, R. L. (2020). A Well-Being Approach to Soil Health—Insights from Aotearoa New Zealand. *Sustainability, 12*(18), 7719. https://doi.org/10.3390/su12187719

81. *Indigenous Australians: Australia's First Peoples Exhibition 1996-2015*. The Australian Museum. https://australian.museum/about/history/exhibitions/indigenous-australians/

principle of any land use.[82] When training farmers, it is necessary to respect and also adapt the principles of these communities which are already in line with principles of regenerative agriculture. Including social and cultural dimensions provides a more diverse and inclusive knowledge base and perspective to better inform the development of integrative policy. This would lead to improved management and decision-making of land resources and soils in New Zealand and globally.[83]

Following are some recommended interventions in the farmer support ecosystem:

Generate farmer-friendly information: Knowledge cataloged and produced in the knowledge systems pillar should be translated into "farmer-friendly information" and made available to farmers.

Training: Training sessions on sustainable soil management, regenerative agricultural practices, and PoPs for specific crops must be conducted for farmers. Agricultural research institutions should also arrange for model farm plots that demonstrate the benefits of such practices, such as improvement in crop yield. It should be noted that such training sessions have maximum impact when conducted by fellow progressive farmers whose livelihoods depend on agriculture.

National Soil Advocate and Soil Doctors: Investment in training and nurturing grassroots, regional, national and international soil advisors (like Australia has done) will ensure the soil agenda is not lost in the larger climate change or environment narrative.[84] Soil doctors recruited and trained from the grassroots, who can address specific issues of other local farmers, are very important actors in the farmer support ecosystem. There should also be an optimal ratio of soil doctors to farmers in order to ensure effective outreach to farmers.[85]

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82. Harmsworth, G. (n.d.). The Mana of soil: A Māori Cultural Perspective of Soil Health in Aotearoa-NZ. *Manaaki Whenua Landcare Research*. https://www.landcareresearch.co.nz/uploads/public/Events/Link-series/Mana_Soil.pdf

83. Stronge, D. C., Stevenson, B. A., Harmsworth, G. R., & Kannemeyer, R. L. (2020). A Well-Being Approach to Soil Health—Insights from Aotearoa New Zealand. *Sustainability, 12*(18), 7719. https://doi.org/10.3390/su12187719

84. *National Soil Advocate*. Department of the Prime Minister and Cabinet, Australian Government. (2020). https://www.pmc.gov.au/domestic-policy/national-soils-advocate

85. *Welcome to the Global Soil Doctors Programme*. Global Soil Partnership, Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/global-soil-partnership/pillars-action/2-awareness-raising/soil-doctor/en/

Reward Farmers: Farmers must be incentivized and rewarded for putting SOM back into soil. Carbon credit markets can pay farmers for sequestration in their lands. However, pricing must be fair, transparent and just. Middle men and evaluators should not earn more than 10% as a commission or administrative fee.[86] Also the farmers in Oceania can be supported in sustainable forest (tree-based agriculture) practices through the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization under the Convention on Biological Diversity.[87]

Reward Monitoring of SOM (and other soil parameters): Farmers must be rewarded for ecosystem services provided by their SSM practices. This can be achieved by monitoring SOM, other soil biology parameters, and terrestrial biodiversity on their land.[88] Other nations can emulate Australia's Historical Soil Data Capture Payments Program, which is set up to pay private and public entities to provide existing soil data.[89]

Incentives and Resource Support During Transition: Farmers should be supported in the transition to SSM practices with access to free seeds, and with incentives to follow specific practices such as cover cropping and similar interventions. The transition to SSM will need a change in equipment to be used on the land. The government can set up equipment lending for groups of farmers. The approach taken by New Zealand in nudging farmers towards sustainable soil management practices by removing subsidies for intensive cultivation, and simultaneously supporting farmers in adopting regenerative agriculture through private and research partnerships can be one of the ways to drive large-scale uptake of SSM practices.[90]

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86. *A Food Systems Approach to Transforming Africa's Soil Health: Policy, science, implementation and impact*. IFDC. (2021). https://ifdc.org/2021/10/25/a-food-systems-approach-to-transforming-africas-soil-health-policy-science-implementation-and-impact/

87. Leannam. (2021). Roadmap For Access And Benefit Sharing Legal Framework A Step Closer For PNG. *SPREP.* https://www.sprep.org/news/roadmap-for-access-and-benefit-sharing-legal-framework-a-step-closer-for-png

88. Lal, R. (2022). *Soil Organic Carbon and Feeding the Future: Basic Soil Processes*. CRC Press.

89. *Historical Soil Data Capture Payments Program*. DAWE, Australian Government. https://www.awe.gov.au/agriculture-land/farm-food-drought/natural-resources/soils/historical-soil-data

90. Negra, C., Vermeulen, S., Barioni, L. G., Mamo, T., Melville, P., & Tadesse, M. (2014). Brazil, Ethiopia, and New Zealand lead the way on climate-smart agriculture. *Agriculture & Food Security*, *3*(1). https://doi.org/10.1186/s40066-014-0019-8

Legal Provisions

The efforts to have a law for protection and regulation of soils are only a starting point but more planning is needed for directing the future agricultural expansion towards socially acceptable, economically viable, and environmentally sustainable systems.

Australia and New Zealand are pioneers in the region in monitoring and studying the soils for sustainable management. There is a National Clean Air Agreement[91] and Safe drinking water legislation[92] in Australia. New Zealand has a similar setup for air[93] and water too. However, for soil there is no such legislation. Soil is covered in environmental laws of both these countries and the Pacific islands adequately. But legal and policy frameworks that define what constitutes healthy soil, the responsibility of the custodians of soil, and the incentives and disincentives regarding agricultural practices should be articulated.

For example, the European Union is in the process of formulating its Soil Health Law. The proposal, as it stands, focuses on clearly defining healthy soil and the mechanism to measure the outcome of any interventions on the quality of soil. Even within soil health, while there are a number of parameters, the single most important one is SOM. And the healthy soil's definition should entail SOM to be in the minimum range of 3–6%.

Countries should strategize on making significant headway on this parameter, as it has a far-reaching impact on soil health, covering a wide scope of issues. Once there is sufficient understanding of the significance of SOM, and SSM farm practices become common knowledge, further interventions to improve other indicators of soil health can be introduced.

Monitoring and Learning Systems

Australia and New Zealand have both put a lot of effort into establishing the information systems that can consistently help assess the state of soils of their nations. Their position in the overall data and information setup is advanced

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91. *National Clean Air Agreement*.
https://www.awe.gov.au/sites/default/files/documents/national-clean-air-agreement.pdf

92. *Safe drinking water legislation*. https://www.sahealth.sa.gov.au/wps/wcm/connect/public+

93. *Clean Air Act 1972*. https://www.ecolex.org/details/legislation/clean-air-act-1972-lex-faoc044565/

compared to most Pacific islands in Oceania. Similar rigorous information and data collection and monitoring systems should be established in the rest of the islands.

The Pacific Soil Partnership (PSP), the regional collaboration under Global Soil Partnership, can help these small island nations set up an integrated Pacific Information System for all islands of the region together. PSP, in their Brisbane Communique, suggest and encourage investment in technical cooperation.[94] The monitoring and evaluation systems – Pacific Soil Portal (as suggested by PSP) – should ensure the data monitored also studies biological parameters of soil.

The Inform project that is spearheaded by Secretariat of the Pacific Regional Environment Programme (SPREP) is the unified response to the need for data-driven decision making in the Pacific.[95] The Inform project tried to:

(1) Gather data and increase data availability of environmental resources, trends and drivers of environmental change, for the development and assessment of evidence-based interventions, (2) Improve information management and interpretation as well as standard procedures for environmental data and (3) Provide easy access and timely information for decision making, planning and reporting. The effort of PSP with respect to soil-specific monitoring data can be done in collaboration with the Inform project and the Pacific island country governments.

There are tools and technologies, like remote sensing, that could help Pacific people measure and monitor land-use changes over time. Freely available satellite imagery, such as Copernicus Sentinel data, allows for detection mapping of land-use change. Various companies and organizations in the region can provide or support this service. Although the share of agricultural land is stable, the uses, quality, and habitats on other land areas in the Pacific islands are changing in step with changing Pacific societies.[96]

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94. Pacific Soil Partnership (PSP): A regional collaboration under the FAO Global Soil Partnership (GSP). https://www.fao.org/global-soil-partnership/regional-partnerships/en/

95. *The Inform Project*. SPREP. https://www.sprep.org/inform

96. *State of Environment and Conservation in the Pacific Islands: 2020 Regional Report*. SPREP PROE. https://soec.sprep.org/

CHAPTER 4: Sustainable Soil Management Solutions – From Around the World

There are various Sustainable Soil Management (SSM) practices followed by farmers across the diverse geographies of the world. Although the principles of SSM are common, the specific solutions for each region are guided by two major factors – the agroecological zone and the soil type.

An agroecological zone is defined by the FAO as follows:
Agroecological zoning (AEZ), as applied in FAO studies, defines zones based on combinations of soil, landform, and climatic characteristics. The particular parameters used in the definition focus attention on the climatic and edaphic requirements of crops and on the management systems under which the crops are grown. Each zone has a similar combination of constraints and potentials for land use, and serves as a focus for the targeting of recommendations designed to improve the existing land-use situation, either through increasing production or by limiting land degradation.

The essential components of the core applications that map AEZ comprise:

- Land resource inventory
- Inventory of land utilization types and crop requirements
- Land suitability evaluation, including:
    - Potential maximum yield calculation
    - Matching of constraints and requirements

The solution matrix that we chose to catalog relevant SSM practices across the world is the superimposition of **agroecological zones** of the world over **the soil types present in a particular region.** This is to ensure that recommended regenerative agriculture practices are relevant to both the climatic conditions – temperature and rainfall specifically, and the parent material of the soil.

4.1 Agroecological Zone for SSM – Thermal Climatic Zones

There are 12 thermal climatic zones in the world as per the Global Agro Ecological Zones (GAEZ) modeling of the FAO,[1] described in Table 1. Map 1 shows the zonations across the world.

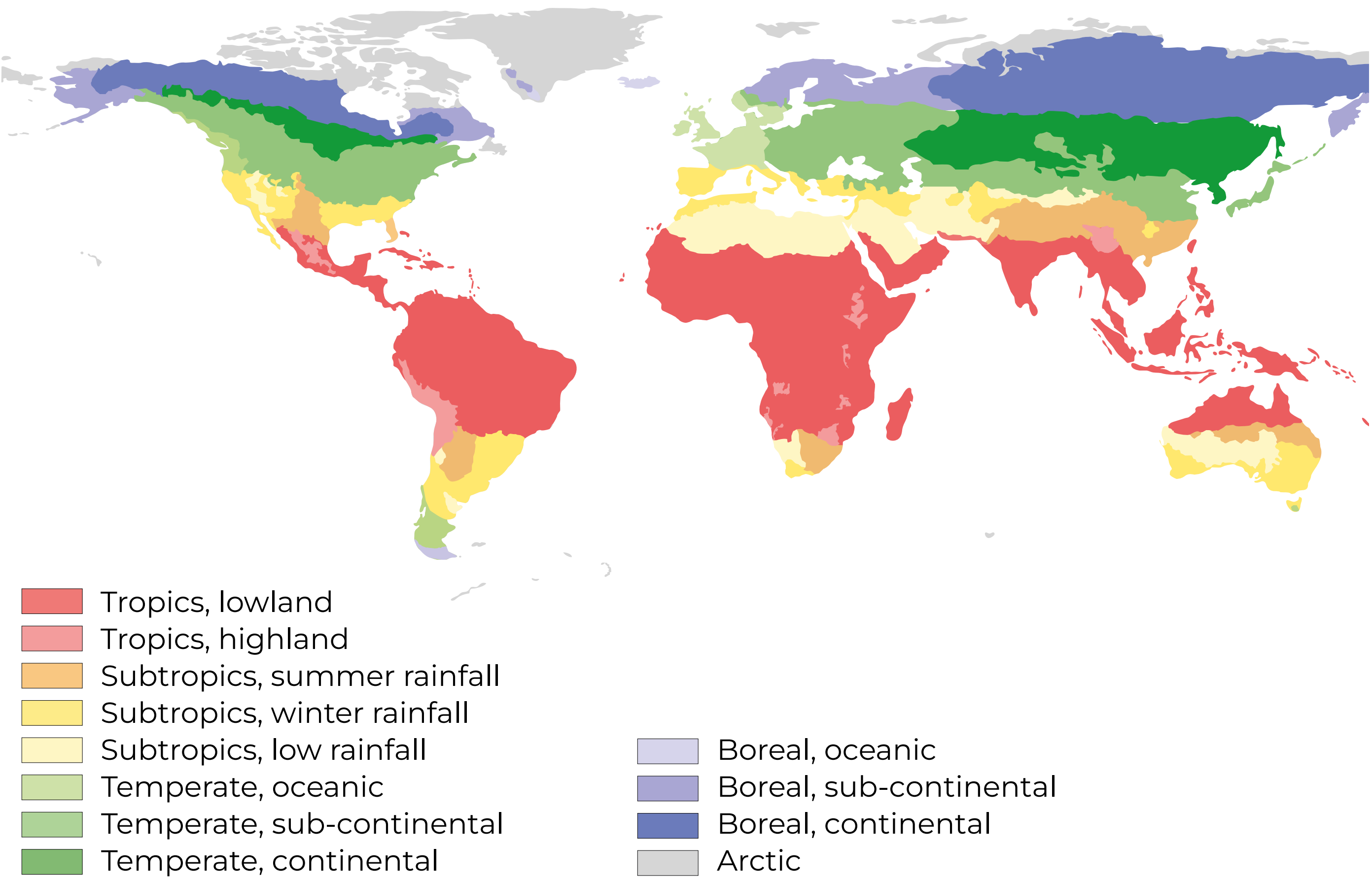
1. *Global Agro-ecological Zones (GAEZ v3.0)*. IIASA, Laxenburg, Austria and Food and Agriculture Organization of the United Nations (FAO). Rome, Italy. (2012). https://pure.iiasa.ac.at/id/eprint/13290/1/GAEZ_Model_Documentation.pdf

Table 1: Basis of Thermal Climatic Zonations of the World.[2]

Climate	Rainfall and Temperature Seasonality
Tropics All months with monthly mean temperatures, corrected to sea level, above 18°C	***Tropical lowland*** ***Tropics with actual mean temperatures above 20°C*** ***Tropical highland*** ***Tropics with actual mean temperature below 20°C***
Subtropics One or more months with monthly mean temperatures, corrected to sea level, below 18°C, but all above 5°C, and 8-12 months above 10°C	***Subtropics Summer Rainfall*** Northern hemisphere: P/Eto in April-September ≥ P/Eto in October-March Southern hemisphere: P/Eto in October-March ≥ P/Eto in April-September ***Subtropics Winter Rainfall*** Northern hemisphere: P/Eto in October-March ≥ P/Eto in April-September Southern hemisphere: P/ETo in April-September ≥ P/ETo in October-March ***Subtropics Low Rainfall*** Annual rainfall less than 250 mm
Temperate At least one month with monthly mean temperatures, corrected to sea level, below 5°C and four or more months above 10°C	***Oceanic Temperate*** Seasonality less than 20°C* ***Subcontinental Temperate*** Seasonality 20-35°C* ***Continental Temperate*** Seasonality more than 35°C*
Boreal At least one month with monthly mean temperatures, corrected to sea level, below 5°C and 1-3 months above 10°C	***Oceanic Boreal*** Seasonality less than 20°C* ***Subcontinental Boreal*** Seasonality 20-35°C* ***Continental Boreal*** Seasonality more than 35°C*
Arctic All months with monthly mean temperatures, corrected to sea level, below 10°C	***Arctic***
*Seasonality refers to the difference in mean temperature of the warmest and coldest month	

2. *Global Agro-ecological Zones (GAEZ v3.0)*. IIASA, Laxenburg, Austria and Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. (2012). https://pure.iiasa.ac.at/id/eprint/13290/1/GAEZ_Model_Documentation.pdf

Map 1: Thermal Climates of the World.[3]



4.2 Soil Classification

Soil classification as a process has evolved over decades. There were many soil classifications followed across the world. Two of the most prevalent ones even now are the USDA classification and the FAO classification (which has been reviewed and updated over years). But in 2014, the FAO, UNEP and the International Union for Social Science decided to adhere to the classification given by the World Reference Base for Soil Resources (WRB).[4] The WRB published its most recent soil map in 2015 (Map 2).

3. *Global Agro-ecological Zones (GAEZ v3.0)*. IIASA, Laxenburg, Austria and Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. (2012). https://pure.iiasa.ac.at/id/eprint/13290/1/GAEZ_Model_Documentation.pdf

4. *World Reference Base*. Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/soils-portal/data-hub/soil-classification/world-reference-base/en/?

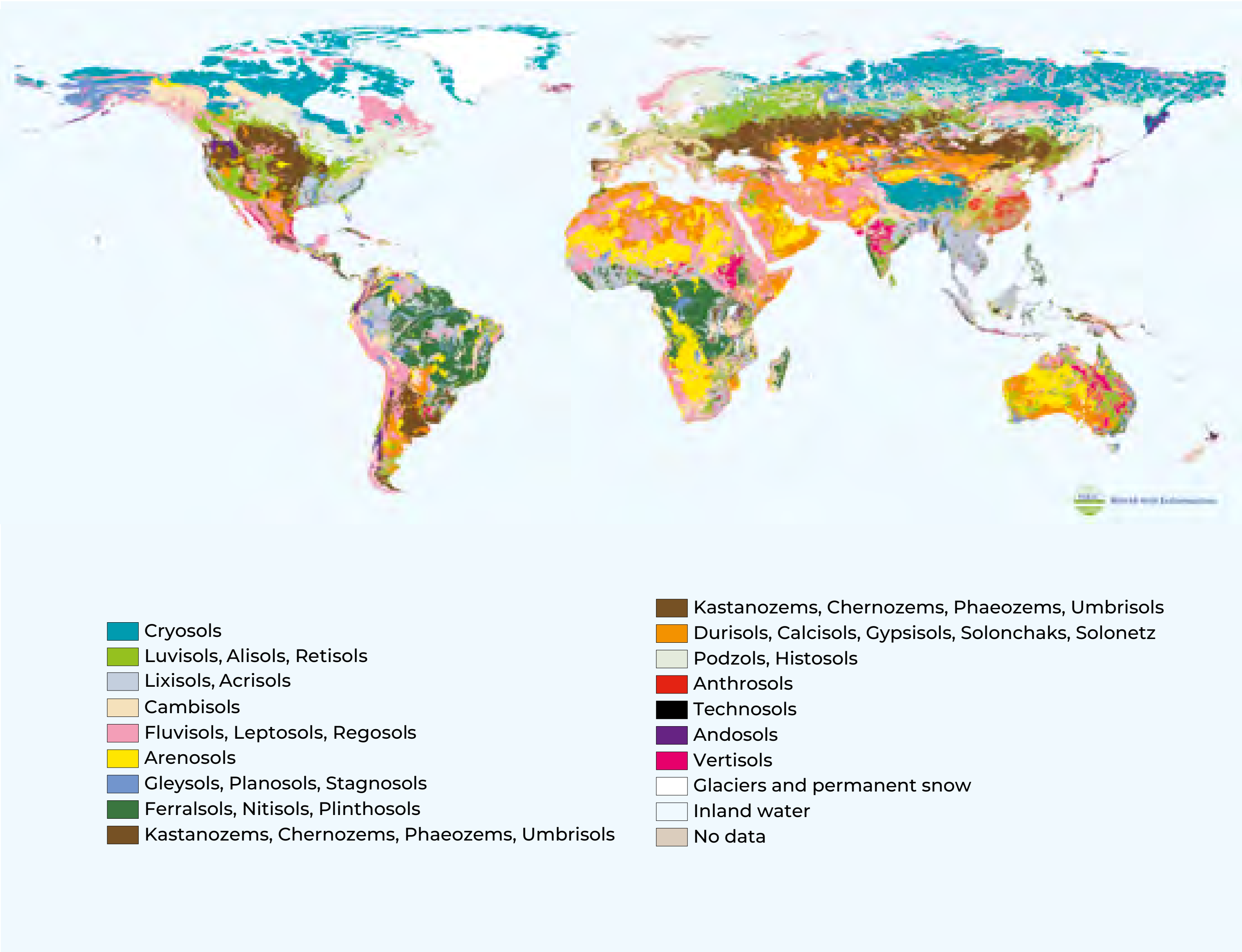
The WRB provides an opportunity to create and refine a common, global language for soil classification. The taxonomic units of the WRB are defined in terms of measurable and observable “diagnostic horizons”, the basic identifiers in soil classification. Diagnostic horizons are defined by (combinations of) characteristic “soil properties” and/or “soil materials”.

4.3 The Solution Matrix

Conscious Planet’s Save Soil Movement has compiled SSM practices for individual countries by classifying each country as a combination of the GAEZ agroecological zones and WRB soil types present in the country.

As an example, the zonation for the SSM solution matrix for the United States of America is presented in Table 2. The USA falls under these thermal climatic zones: Tropical – Lowland, Subtropical – Low Rainfall, Subtropical – Summer Rainfall, Subtropical – Winter Rainfall, Temperate – Subcontinental and Boreal – Subcontinental. And each zone has several soil orders present in it. This is not an exhaustive zonation for the USA; rather it is presented as an example for many states and regions within the country.

Map 2: Soils of the World According to WRB[5]



5. *World Reference Base.* Food and Agriculture Organization of the United Nations (FAO). https://www.fao.org/soils-portal/data-hub/soil-classification/world-reference-base/en/?

Table 2: Zonation for the SSM Solution Matrix Based on Agroecological Zone and Soil Types in the United States.

Agroecological Zone	State(s) / Region	Soil Types
Tropical – Lowland	Florida Keys & Hawaii	Andisols, Entisols, Mollisols, Histosols, Inceptisols, Oxisols, Vertisols
Subtropical – Low Rainfall	New Mexico	Luvisols, Alisols, Retisols, Kastanozems, Chernozems, Phaeozems, Umbrisols
	Colorado, Nevada, Utah, Arizona	Luvisols, Alisols, Retisols
Subtropical – Summer Rainfall	California, Arkansas, Louisiana, Alabama	Kastanozems, Chernozems, Phaeozems, Umbrisols
	Nevada, Arizona, New Mexico, Oklahoma	Luvisols, Alisols, Retisols
	Mississippi	Gleysols, Planosols, Stagnosols, Luvisols, Alisols, Retisols
	Georgia	Kastanozems, Chernozems, Phaeozems, Umbrisols, Luvisols, Alisols, Retisols
	South Carolina	Kastanozems, Chernozems, Phaeozems, Umbrisols, Lluvisols, Alisols, Retisols, Utisols
Subtropical – Winter Rainfall	Florida	Podzols, Histosols, Arenosols, Gleysols, Planosols, Stagnosols, Acrisols, Lixisols, sandy, low nutrient soils
	Texas, Colorado	Durisols, Calcisols, Gypsisols, Solonchaks, Solonetz, Fluvisols, Leptosols, Regosols, Kastanozems, Chernozems, Phaeozems, Umbrisols, Luvisols, Alisols, Retisols
	New Mexico	Kastanozems, Chernozems, Phaeozems, Umbrisols, Luvisols, Alisols, Retisols

Agroecological Zone	State(s) / Region	Soil Types
Temperate – Subcontinental	Southern Region	Kastanozems, Chernozems, Phaeozems, Umbrisols, Licisols, Acrisols
	Prairie Grasslands Region	Leptosol
	Ohio, Indiana, Illinois, Wisconsin, Missouri	Alfisols
	Kansas, Nebraska, Iowa, South Dakota, North Dakota, Minnesota, Texas, Oklahoma	Valent-Tassel, Wann Soils
	Wyoming (Western)	Arisols (sandy, desert), Andisols (volcanic)
	Maine	Cambisols
Boreal – Subcontinental	Alaska	Cryosol, Fluvisol, Leptosol, Regosol, Cambisol, Gleysol, Planosol, Stagnosol
	Clay County: Faceville, Marlboro, and Greenville	Fine, sandy loam

For every such unique zonation of a country, an SSM practice has been found to improve and accelerate the increase of Soil Organic Matter (SOM), for three types of **land use under agriculture**:

1. Land under croplands
2. Land allocated for feed production for animals
3. Land under animal rearing

So in the case of the USA, we would have solutions collated for all three land uses across the 5 zonations, producing 15 unique solutions for the nation to manage their soil sustainably for croplands, feedlands and animal rearing.

These practices are cataloged from studies conducted by FAO programs in the country, credible peer reviewed scientific publications, and Sustainable Land Management Databases like WOCAT.[6] Country-specific SSM practices can be found at our website: savesoil.org.

The solutions suggested are a mere subset of already existing SSM practices on farms of that particular region. They represent successful case studies, best practices (in conservation agriculture, climate smart agriculture and regenerative agriculture), and indigenous farming techniques. Also listed are the sources for detailed perusal by farmers, policy makers, farmer advisory service providers, or farmer networks. If a government or a farm owner chooses to adopt an SSM regime, then a detailed planning exercise along with specific studies of the farmland will need to be conducted.

Some of the SSM practices across various agroecological zones are shared in Table 3 for croplands, Table 4 for feedlands, and Table 5 for animal rearing. The practices involved in SSM related to fodder / feed production and animal rearing, in Tables 4 and 5, usually go hand in hand.

6. World Overview of Conservation Approaches and Technologies (WOCAT). https://qcat.wocat.net/en/wocat/

Table 3: SSM Agriculture Practices Documented Across Various Agroecological Zones for Croplands

Agroecological Zone	Country	Cropland SSM Practices
Tropical – Highland	Bolivia	Hedgerows of native grasses; Chinampas (water jacinth as green manure); Green mulching; Pest repellent plants like garlic; Raised fields (for soil drainage); Terraced hillsides
	Guatemala	Vegetal soil cover
	Peru	Fertilizing with alternative sources: 1) fish; 2) guano; 3) llama dung
	Uganda	Fertigation; Percolation pits; Mulching using banana leaves; Firelines for tree protection; Planting pits for soil fertilization and moisture improvement; Stone lines; Native trees as windbreaks; Underground water abstraction for crop and livestock production; Conservation farming basins in annual crops for water conservation
	USA (Hawaii)	Hillside ditch; Rock and vegetative barrier; Terrace hillsides
Tropical – Lowland	Zambia	Agroforestry of maize with *Faidherbia albida*
	Australia	Green cane trash blanket
	Bangladesh	Floating bed agriculture; Floating dhap cultivation; Embankment cropping; Saline tolerant rice and grass farming; Early crop harvesting
	Belize	Intercropping citrus with coconut, pineapple, soursop, plantain; Crop rotation – maize with beans
	Benin	Intercropping with mucuna; Zaï; System of Rice Intensification (SRI); Transform fallow land with mucuna
	Bolivia	Traditional farming with footplows
	Botswana	Pest management – mixture of tobacco garlic and onion and sunlight for aphid control; Predator repellent – python fat is mixed with seed before planting to protect the arable fields from predators

Agroecological Zone	Country	Cropland SSM Practices
Tropical – Lowland	Brazil	Kayapó Indians strategies; Green manuring; Agroforestry of cocoa and mahogany tree; Agroforestry of cocoa and rubber; Agroforestry of cowpea and maize; Bioengineered rehabilitation; Surface mulching; Agroecological transition systems; Mixed cropping
	Cambodia	Mulching with water hyacinth (*Eichhornia crassipes*) after monsoon floods
	Cameroon	Intercropping maize and sorghum with *Brachiaria ruziziensis* or *Crotalaria retusa*; Wood ash application as a local insecticide
	China	Integrated Nutrient Management (INM)
	Costa Rica	Intermixing legume trees (*Inga edulis* and *Gliricidia sepium*)
	Cuba	Multi-strata vegetation; Windbreaks; Agro-silvo-pastoralism
	Democratic Republic of Congo	Integrated Soil Fertility Management (ISFM)
	Ethiopia	Push-pull intercropping maize with Greenleaf desmodium, napier grass and Brachiaria grass
	Fiji	Fertilization with seaweed
	Ghana	Relay cropping; Crop rotation with legumes
	Honduras	Quesungual system; Milpas
	India	Rice-wheat (RW) system
	Indonesia	Embung; Integrated farming
	Ivory Coast	Combination of crops on mounds
	Jamaica	Live yam stick system; Mini-setts
	Jordan	Smother crop – alfalfa grown as a smother crop on corn and weeds; Raised bed farming
	Malawi	Agroforestry of maize with *Faidherbia albida*
	Mexico	Mixed cropping
	Namibia	Intercropping between pearl millet and cowpea

Agroecological Zone	Country	Cropland SSM Practices
Tropical – Lowland	Nicaragua	Level curves; Live barriers; Integrated Pest Management
	Niger	Multi-strata intercropping
	Nigeria	Alley cropping / farming
	Oman	Multi-strata intercropping
	Paraguay	Organic production
	Peru	Bench terracing; Contour hedgerow intercropping; Fertilization with dung, manure and ashes; Fertilizing with alternative sources: llakoshka; Agroforestry – The Tamshiyacu cyclic agroforestry system in the Amazon; Kayapó Indians strategies; Crop rotation with legumes
	Philippines	Rice-fish system
	Singapore	Vertical farming system
	Sri Lanka	Changing crop establishment techniques (dry sowing)
	Sudan	Bonds – cross slope tied bonding (CSTB), contour ridge with stone bonds (CRSB), cross slope bonding (CSB); Indigenous conservation tillage practices – chisel ploughing (CHP)
	Thailand	Khok-Nong-Na model; Crop-livestock systems
	Timor-Leste	Agroforestry – coffee with Albizia tree; Agroforestry – turmeric and bamboo; Agroforestry – vanilla with Gliricidia and cottonwood tree
	Uganda	Intercropping maize with watermelon; Drainage/ water harvesting – furrows act as drainage channels – into a pond below
	US (Hawaii)	Loʻi – flooded or irrigated agricultural terraces; Māla – dryland (rainfed) agricultural farming; Contour farming for cropland / orchids; Residue management; Tree / shrub management; Row arrangement; Alley cropping / farming
	Vietnam	Integrated farming
	Zimbabwe	Precision application of small doses of nitrogen-based fertilizer

Agroecological Zone	Country	Cropland SSM Practices
Subtropical	Australia	Pasture cropping (Canola–wheat–barley–5-year perennial pasture)
	China	Rice-fish farming
	India	Moringa cultivation
	Nepal	Panchagavya, ancient Vedic fertilizer
	Pakistan	Bioremediation of soils with plants, bacteria
	USA	Runoff agriculture
Temperate	Bulgaria	Minimal-till, no-till; Strip-till methods
	Chile	No-till / direct seeding; Conservative tillage; Continuous crop residue cover, Diverse crop rotations; Cover crops
	France	Permaculture; Biointensive micro-gardening; Calcareous liming; Preserving a permanent soil cover; Minimizing soil disturbance (going as far as NT); Diversifying crop species; No-till
	Ireland	Conservation tillage; eco-tillage; crop rotation
Boreal	Canada	Conservation tilling
	Greenland	Utilization of melted glacial land silt
	Japan	Satoyama landscapes
	Russia	Dacha plots maintenance
	USA	Biochar; Forward Osmosis (FO) technology for the recovery of water from sewage wastewater

Table 4: SSM Agriculture Practices Documented Across Various Agroecological Zones for Fodder Production in Feedlands

Agroecological Zone	Country	Feedland SSM Practices
Tropical – Highland	Bolivia	Monte diferido
	Uganda	Multi-purpose tree species for pasture supplementation
Tropical – Lowland	Brazil	Green manuring
	Cameroon	Grazing on leftover straw and harvest of animal droppings
	Colombia	Grass strips for cut and carry
	Eritrea	Planting fodder shrubs on the contour bunds
	Guinea	Integrated Taungya farming; Apisilviculture; Aquaforestry
	Honduras	Live Hedges Technology
	India	Integrated Farming Systems (IFS)
	Indonesia	Agrosilvopasture “Pagar Tejo” system
	Mali	Bourgou pastures
	Mexico	Silvopastoral
	Uganda	Napier grass intercropping for cut and carry
	Zimbabwe	Crop residue biomass as animal fodder
Subtropical	Afghanistan	Community fodder banks
	Australia	Bunds and rakes with calcrete, for regenerating dry, sandy rangelands; Rotational or cell grazing
	Pakistan	Halophytes (saltbushes) as fodder
	Saudi Arabia	Al-Hima Rangeland Protection and controlled grazing
	South Africa	Insect fodder trees
Temperate	Bulgaria	Intercropping; Restoration and maintenance of High Nature Value (HNV) grasslands; Traditional practices for seasonal grazing of animals (pastoralism); Conservation of endangered local breeds
	France	“Protein mixes”; “Green manure” cover crops; crop rotation feedstock
Boreal	Russia	Deep tillage
	Sweden	Semi-natural pastures
	USA	Multi-Species Pastured Livestock System

Table 5: SSM Agriculture Practices Documented Across Various Agroecological Zones for Animal Rearing

Agroecological Zone	Country	Animal Rearing SSM Practices
Tropical – Highland	Uganda	Bamboo-woven bee hives; Stall feeding of Friesian cow by cut and carry for livestock management; Indigenous Microorganism (IMO) use in natural pig farming; Groundwater fed fish ponds; Rotational grazing; Small-scale irrigation system for pasture production
Tropical – Lowland	Australia	Mini-livestock
	Bangladesh	Quesungual agroforestry system (QSMAS); Transhumant livestock rearing system
	Bolivia	Raising sheep in folds (RSF)
	Burundi	Nomadic herding
	Cambodia	Nomadic pastoralism
	China	Animal trails / walkways
	Congo	Insects as a source of protein and nutrients for the livestock in the form of feed
	Democratic Republic of Congo	Net fish, cage fish, crab farming
	Equatorial Guinea	Silage production technology
	Eritrea	Semi-scavenger housing for livestock
	Ethiopia	Making feed blocks from crop residues
	Ghana	Crop–fodder–tree–livestock systems
	Guinea	Rice-duck system; Ranching
	Honduras	Capture of out-migrating fishes and establishment of fish farming
	Indonesia	Freshwater acquaculture
	Israel	Intensive silvopastoral system

Agroecological Zone	Country	Animal Rearing SSM Practices
Tropical – Lowland	Jordan	Acquaculture
	Nigeria	Holistic planned grazing
	Qatar	Grazing leftover straw after harvest of rice grains
	Senegal	Range planting such as grasses, forbs, legumes, shrubs & trees; Mixed farming; Rearing and conservation of indigenous cattle; Small livestock – native chickens; Restricted grazing on crop residues; Integrated plant-animal production operations such as weeder animals and animal-drawn equipment; Agro-silvo-pastoralism
	Somalia	Seasonal grazing areas management
	South Sudan	Indigenous (ethno-veterinary) practices; Heavy-use area protection by vegetative cover
	UAE	Construction of fodder store houses; Integrated aquaculture and agriculture systems
	Uganda	Intensification and diversification
	USA	Reintroduction of fodder species suitable for improving pastures / grazing land; Introduction of fodder crops into the rotation system for cropland; Straw gathering and processing
	Venezuela	Technique of total or partial stabling
	Vietnam	Supplementary feeding in dry season; Good water management improves water availability and the distribution of cattle in grazing areas
	Zimbabwe	Rehabilitation of communal grazing land
Subtropical	India	Pigeon pea – lac system
	Pakistan	Ethnoveterinary plants for disease treatment and prevention (indigenous knowledge)
	Tunisia	Short duration high stocking rate opportunistic grazing
Temperate	Bulgaria	High Nature Value (HNV) farming / low intensity farming
	France	Integrated Crop–Livestock Systems (ICLS)
	Ireland	Rotational grazing / Management intensive grazing
	Italy	Controlled grazing
Boreal	Kazakhstan	Pastoralism, creating a mosaic of different grazing intensities
	Sweden	Using by products from crops as additives
	USA	Adaptive Multi-paddock (AMP) grazing

Acknowledgements

The task of building policy recommendations for various regions of the world, and curating sustainable soil solutions for all countries requires passion and commitment towards the vision of the Save Soil Movement. We are fortunate to witness that passion and commitment from so many people. We would like to express our gratitude to all those who helped draft this publication.

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We must also make a special mention of the organizations who have dedicated decades to establishing and understanding the importance of soil to life on the planet. These organizations have contributed to documenting and creating many of the SSM practices listed in this publication. The organisations include the United Nation's Food and Agriculture Organization (FAO), the FAO's agricultural science and technology information platform – AGRIS, the World Overview of Conservation Approaches and Technologies (WOCAT), Soil Explorer, FAOSTAT, the World Bank's Open Data platform, databases of various individual nations, think-tanks such as 4p1000, scientific journals on soil and agricultural practices, and many other organizations.

Last but not least, we wish to acknowledge our growing network of volunteers who collated the SSM solutions.


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