Sustainable Soil Management and Soil Carbon Sequestration

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Abstract Globally, food systems are associated with many unsustainable land use practices that lead to environmental damage such as greenhouse gas emissions, land degradation and biodiversity loss. Social issues, such as poor labour conditions, receive ever greater attention as farming has often been associated with practices that harm humans and society. From an economic standpoint, food systems need to be viable and resilient in order to allow operators in the food chain to make a living from their work. The importance of a global shift towards sustainable land use and food production has been commonly accepted for some time and there is an increasing interest by enterprises in the food and agriculture sector in assessing their sustainability performance. As the world has become increasingly vulnerable to the impacts of changing climate so too has the urgency to establish national and international guidelines and rules to acknowledge carbon management in agricultural supply chains and to improve the policy, strategic and legislative systems to manage soil carbon sequestration. An essential aspect of improved carbon management is legislation which has the ability to enable the development and implementation of soil organic carbon land management practices as sustainable soil standards.

1 Introduction

The importance of a global shift towards sustainable food production is commonly accepted and there is an increasing interest in the food and agriculture sector in assessing their sustainability performance, which may include social, ecological and economic aspects.[1] As sustainability within food systems increases in importance

[1] UNCTAD (2019) see pp. 51–52; https://unctad.org/system/files/official-document/tdr2019_en.pdf (Last access: 22 June 2022).

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the different approaches that are used to assess sustainability should adopt a common definition of the notion of "sustainability," along with a description of the methodological approach, indicators and assumptions.[2] Sustainability has become a guiding principle for the assessment of food systems.[3] Most recently, the COVID-19 pandemic has added new pressure to global land use. The global nature of this crisis sheds new light on how our ability to ensure food security and provide key ecosystem services inherent to soils, such as climate regulation and increased carbon sequestration, will increasingly depend on sustainable use of soil.

The term "carbon sequestration" is used to describe both natural and deliberate processes by which carbon dioxide (CO_2) is either removed from the atmosphere or diverted from emission sources and stored in the terrestrial environment (vegetation, soils, and sediments).[4] Before human-caused CO_2 emissions began, the natural processes that make up the global "carbon cycle" maintained a near balance between the uptake of CO_2 and its release back to the atmosphere. However, existing CO_2 uptake mechanisms, sometimes called CO_2 or carbon "sinks", are insufficient to offset the accelerating pace of emissions related to human activities. It is argued that successful adaptation to climate change impacts will include advances in international and national environmental law, particularly in the areas of institutional, technological, education, research, and regulatory practices that encourage soil carbon sequestration (SCS).[5]

1.1 Sustainability Tools and Indicators

Sustainability assessment is an evaluation exercise that directs decision-making to ensure ongoing feasibility of the production system. Indicator-based sustainability assessment tools and frameworks can either guide or conduct sustainability

[2] Schader et al. (2014), p. 1, https://www.ecologyandsociety.org/vol19/iss3/art42/ (Last access: 22 June 2022).

[3] Ibid. Schader et al. (2014), p. 2, state that the primary purposes of a sustainability assessment approach can vary considerably and include the following: purely science-oriented approaches for research; monitoring and certification schemes intended to provide proof, such as to consumers, of the sustainability performance of companies; landscape planning tools that focus on the regional level and consider, for example, the environmental and socioeconomic surroundings of a number of farms and assess the impacts on sustainability; farm advisory tools to didactically assess the strengths and weaknesses of a farm and serve as a basis for management improvement or strategy development; and self-assessment tools that serve a similar purpose, but without the support of an adviser.

[4] United States Geological Survey (2008), p. 2, "Terrestrial sequestration (sometimes termed 'biological sequestration') is typically accomplished through forest and soil conservation practices that enhance the storage of carbon (such as restoring and establishing new forests, wetlands, and grasslands) or reduce CO2 emissions (such as reducing agricultural tillage and suppressing wildfires)"; https://pubs.usgs.gov/fs/2008/3097/pdf/CarbonFS.pdf (Last access: 22 June 2022).

[5] Hannam (2019), p. 399.

assessments[6] and they vary widely in whom they target (e.g. farmers or policy makers), selection of indicators, aggregation and weighting method and time required.[7] Scientific evidence on farm sustainability assessments, as well as the sustainability assessment tools available to support decision-making, are ever-expanding. However, these assessment tools can vary enormously in their scope and approach.[8] It is argued that the most pressing need is for the development of an agenda that includes, for example: (i) information on region-specific soil distribution and degradation status, (ii) matching of sustainable management practices to respective soil groups and their degradation status, and (iii) stopping the carbon loss from specific soils that have the potential to significantly affect the global C balance, e.g., peatlands under drainage.[9]

Different terms are used in the literature to describe sustainability assessments, such as methods, methodological approaches, frameworks, and tools. Sustainability assessments that assess the sustainability performance of farms using indicators are called indicator-based sustainability assessment tools.[10] Zaralis et al. provide a list of 103 sustainability tools,[11] many of which were selected and prioritised based on their coverage of the 2014 FAO Sustainability Assessment of Food and Agriculture systems (SAFA) framework guidelines. The SAFA Guidelines provide a hierarchal structure of dimensions, themes and subthemes. An objective for each sub-theme describes the target state of sustainability. In addition to the economic, social and environmental dimensions, the SAFA Guidelines include governance as a fourth dimension that relates to the other three. Governance assesses the ability of an operator, a farm, a processor or a retailer, to deliver adequate sustainability performance.[12]

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[6] Gasparatos and Scolobig (2012), p. 1; www.gasparatos-lab.org/uploads/7/6/6/1/76614589/gasparatos_and_scolobig_2012_ecological_economic.pdf (Last access: 22 June 2022).

[7] Ibid. Schader et al. (2014), p. 1.

[8] Ibid. Gasparatos and Scolobig (2012), p. 3, Table 1.

[9] Amelung et al. (2020), p. 3.

[10] Zaralis et al. (2017), p. 635, identify scientific papers on sustainability assessments relevant to agricultural systems.

[11] Ibid p. 635; these tools were in turn categorized based on the following criteria: i. the quantification of sustainability used (functional units; e.g. currency, carbon footprint, standardised units etc.), ii. farm, product or sector level (spatial scale), iii. whether the tool was designed for a specific country or region or is more widely applicable (transferability), iv. Whether it is sector specific (i.e. specific to dairy/crops/etc. or covers a range of farm types), v. time taken to complete the assessment and vi. software or platform used.

[12] FAO (2014), p. 80.

1.2 Carbon Sequestration

One of the essential aspects of sustainability of agricultural systems is the maintenance or improvement of soil organic carbon (SOC). Currently, 33% of the global soils have been degraded and have lost much of their SOC through the historical expansion of agriculture and pastoralism and subsequent land-use conversion from native ecosystems (e.g., peatlands, forests, grasslands) to arable land.[13] This has resulted in a decline in soil structural stability, increased erosion risks, and reduced water storage and nutrient supplies. Soil degradation has thus become a major threat to food security, especially in developing countries. Soil degradation can be stopped with the maintenance of SOC stocks with good agricultural practice. The related soil health benefits from sequestering carbon may then help to close yield gaps in arable soils due to associated improvements in nutrient supplies, water-holding capacity, and soil structural stability. Priority for the transformation of agricultural systems to increase SOC sequestration should also be considered for regions with low SOC contents caused by large historic SOC losses. Unfortunately, the total area of degraded soil, ranging from 1000 to 6000 M ha^{-1}, is not well-defined globally, thus impairing a global agenda that can target land restoration and thereby support climate mitigation.[14]

1.3 Climate Change

Of significance to the sustainability of soil resources, and of food production in agricultural systems, is the impact of agricultural land use on climate change. Present-day global concentrations of atmospheric CO_2 are higher and rising faster than at any time in at least the past two million years. The speed at which atmospheric CO_2 has increased since the industrial revolution (1750) is at least ten times faster than at any other time during the last 800,000 years, and between four and five times faster than during the last 56 million years. About 15% of CO_2 is generated from land use change, in particular agriculture, and usually results in land degradation.[15] The Intergovernmental Panel on Climate Change (IPCC) warn that the Earth's surface temperature will increase until at least 2050 under all emission scenarios presented in the 6th Assessment Report of 2021 (AR6). The AR6 shows Earth could well exceed 1.5 °C warming limit by the early 2030s. If emissions are reduced sufficiently, there is only a 50% chance global temperature rise will stay around 1.5 °C. To get Earth back to below 1.5 °C warming, CO_2 would need to be removed from the atmosphere using negative emissions technologies or

[13] Ibid Amelung et al. (2020), p. 2.

[14] Ibid Amelung et al. (2020), pp. 2–3.

[15] 85% is from burning fossil fuels.

nature-based solutions including increasing SCS in agricultural systems.[16] Therefore, achieving sustainable soil management (SSM) has never been more important as it relies on practices that improve soil functions. Moreover, SOC-centred SSM practices improve soil health, enhance food security and farm incomes and also help mitigate climate change.[17] Agriculture can provide solid data on the emissions output per unit of production as a way to meet consumer demand for sustainable products and investor requirements for substantiated evidence of on-farm sustainability. In addition, to lower emissions and enhanced production, sustainable farming offers a range of economic benefits, which can deliver important long-term financial gains to agricultural producers.[18]

In this regard, an investigation into countries' commitments to SOC under the Nationally Determined Contributions (NDCs) prepared in response to the 2015 Paris Agreement,[19] found that twenty-eight countries referred to SOC in their NDCs, citing quantified or unquantified mitigation targets, national policies or programs, and actions and measures to be implemented in agricultural lands (14 countries), peatlands (6 countries) or wetlands (14 countries).[20] It also found that countries' reasons for not including SOC in NDCs included the need to prioritize goals of sustainable development and food security above climate mitigation, a lack of incentives for farmers to improve management practices, and the difficulty of accurately monitoring changes in SOC. Other highlights of the investigation included: many NDCs specify practices known to have the potential to achieve SOC sequestration or protection without explicitly mentioning SOC; NDCs are not presently a good indicator of countries' interest or commitment to SOC action at the national level; and increased collaboration between countries with experience managing SOC and countries needing support to develop SOC-related targets, policies, measures and incentives for land users and farmers would facilitate the provision of such needed support.[21]

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[16] IPCC (2019), pp. 17–18.

[17] FAO (2019) www.fao.org/global-soil-partnership/areas-of-work/recarbonization-of-global-soils/en/ (Last access: 22 June 2022).

[18] CEFC (2008), p. 1; https://www.cefc.com.au/media/v5klidlc/cefc_investmentinsight_farmprint_aug2021_web.pdf (Last access: 4 September 2021).

[19] Paris Agreement, available at: http://unfccc.int/paris_agreement/items/9485.php; adopted by consensus on 12 December 2015; Nationally Determined Contributions (NDCs) are at the heart of the Paris Agreement and the achievement of these long-term goals. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement (Art 4, para 2) requires each Party to prepare, communicate and maintain successive nationally determined contributions (NDCs) that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions—https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/national (Last access: 4 September 2021).

[20] Wiese et al. (2021), p. 1 and Table 3 p. 7; https://www.tandfonline.com/doi/full/10.1080/14693062.2021.1969883?scroll=top&needAccess=true (Last access: 22 June 2022).

[21] Ibid p. 1.

2 Sustainability

Sustainable development has become one of the most frequently used frameworks for analyzing the agricultural and food sector in a comprehensive way.[22] The objective of sustainable development is to improve people's quality of life without exploiting natural resources beyond the capacities provided by the natural environment. Sustainable development was defined by the FAO in 1989 as "the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable".[23] The farm level is one of the main levers for designing sustainable food systems, as many decisions related to farming practices with the most severe social and environmental impacts are made at this level.[24] To enable farmers to make sound decisions, all dimensions of sustainability need to be considered in particular increasing the sequestration of carbon in the soil.

2.1 Sustainable Soil Management

The FAO Global Soil Partnership (GSP), which commenced in 2012, is a key organization in achieving the goal of SSM. The GSP was created to fill a global gap in soil governance where its purpose was to reverse the growing trend of soil degradation through the promotion of SSM. The GSP adopted three different but interrelated approaches to address global soil issues: policy advocacy; development of technical tools; and programmatic actions focused on the implementation of SSM practices at field level.[25] Under its SSM guidelines, the GSP furthers it role in addressing global challenges, and meeting international commitments, in particular, "the commitment to combat desertification and mitigate effects of drought, especially the strive to achieve a land degradation neutral world, taking note of the

[22] Ibid. Schader et al. (2014), p. 1.

[23] FAO (1989), p. 5, para 6; www.fao.org/3/z4920en/z4920en.pdf (Last access: 22 June 2022).

[24] E.g., see Future Food Systems at https://www.futurefoodsystems.com.au/about/ (Last access: 22 June 2022) The Future Food Systems Cooperative Research Centre (CRC) was created to support innovation and growth across the value chain. The CRC works to advance the development of sustainable food systems across three overlapping areas, including renewable energy, new equipment, tools, technology and systems for high-tech protected cropping, solutions for adding value to produce.

[25] http://www.fao.org/global-soil-partnership/areas-of-work/soil-governance/en/# (Last access: 22 June 2022).

potential benefits for all as per the last UNCCD COP12."[26] Achieving SSM is now highly dependent upon the world reaching the goal of land degradation neutrality (LDN).[27] In this regard, Keesstra et al. point out that "There is an increasing pressure on land, and due to improper use, land resources are quickly degrading, which will create even greater pressure on the remaining land. This calls for a new sustainable approach to land use and land management. There is a sense of urgency; the deadline for LDN (2030) is pressing, especially when it comes to environmental issues. Healthy soils and healthy land are essential to achieving many of the societal goals in the framework of the SDGs [Sustainable Development Goals]".[28]

Developing and implementing an integrated approach to the analysis of different sustainability dimensions, for SSM in particular, and integrating them in agricultural land use strategies, remains a major challenge. To this extent, SSM requires balancing the needs for human purposes with those for environmental conservation and soil quality and soil health is reduced through human-induced degradation processes such as soil erosion, nutrient mining, compaction, acidification, and pollution. FAO specifies that "Soil management is sustainable if the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced without significantly impairing either the soil functions that enable those services or biodiversity. The balance between the supporting and provisioning services for plant production and the regulating services the soil provides for water quality and availability and for atmospheric greenhouse gas composition is a particular concern".[29]

In addition to soil degradation and climate change, globally, agriculture faces many challenges including ability for free trade, and the continuing development of new technologies.[30] Moreover, new strategies are emerging that pursue sustainable

[26] FAO (2017), p. 5.

[27] The concept of LDN was officially recognised by UNCCD in October 2015 by a decision of the twelfth session of the UNCCD Conference of the Parties (COP12). Under Decision 3/COP.12, LDN is defined as "A state whereby the amount and quality of land resources, necessary to support ecosystem functions and services and enhance food security, remains stable or increases within specified temporal and spatial scales and ecosystems"; to date, many countries have identified various land management programs that include SSM practices to manage soil carbon sequestration under the Target Setting Program—https://knowledge.unccd.int/ldn/ldn-target-setting/ldn-country-information (Last access: 22 June 2022).

[28] Keesstra et al. (2018), p. 15.

[29] Ibid. FAO (2017), p. 3.

[30] European Commission (2021) Study on the possibility to set up a carbon border adjustment mechanism on selected sectors, Final Report, p. 223; on 14 July 2021 the European Commission adopted a proposal for a new Carbon Border Adjustment Mechanism which will put a carbon price on imports of a targeted selection of products so that ambitious climate action in Europe does not lead to 'carbon leakage'. This will ensure that European emission reductions contribute to a global emissions decline, instead of pushing carbon-intensive production outside Europe. It also aims to encourage industry outside the EU and our international partners to take steps in the same direction; See Carbon Border Adjustment Mechanism—https:ec.europa.eu/taxation_customs/green-taxation-0/carbon-border-adjustment-mechanism_en.

development of agricultural production with improved environmental practices. In order for agriculture to be sustainable, it must be sufficiently productive, economically viable, culturally and socially acceptable and ecologically adequate; that is, it needs to conserve natural resources and preserve ecological diversity and the capacity of agroecosystems to self-maintain. To this end, increasing the sequestration of carbon as a feature of sustainable agriculture preserves diversity, improves soil biology, provides healthy food, reduces the producer's dependence on external sources, and grants a reliable source of income for farmers.[31] Indicators are useful for assessing the degree of achievement of the sustainability of an agroecosystem. The sustainability indicators make perceivable a phenomenon that is not immediately and easily detectable, and allow us to understand the sustainability status of an agroecosystem or the critical aspects that endanger it. In this regard, various aspects of the FAO SAFA guidelines can be applied to develop and implement an integrated approach to analyzing different sustainability dimensions for SSM. Applying them in agricultural management does however pose some challenges. Sustainable soil management requires balancing the needs for human purposes with those for environmental conservation and functioning.

2.2 Sustainable Development Goal 15

In 2015 sustainability became the fundamental theme of society in constituting the cornerstone of the United Nations Sustainable Development Goals 2030 (SDGs). The 17 SDGs are an urgent call for action by all countries in a global partnership that applies strategies to improve health and education, reduce inequalities, and stimulate economic growth, while tackling climate change and working to preserve land, oceans and forests.[32] Moreover, what is of significance to this chapter derives from paragraph 206 of the Rio+20 Outcome Document which states "We recognize the need for urgent action to reverse land degradation. In view of this, we will strive to achieve a land-degradation neutral world in the context of sustainable development". The SDGs were adopted by the UN General Assembly in September 2015 and include SDG 15.3 as a target on land degradation neutrality (LDN) where "by 2030, combat desertification, and restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation neutral world".[33] Managing soil carbon is a key component to achieving

[31] Technological advances in agriculture have allowed farmers to cultivate more land with less labour, and one of the main consequences of the increase in the mechanization of the agricultural system is that there are fewer job opportunities on farms, pushing many families to move to urban centres, leaving rural communities to decline, which are the custodians of agricultural traditions and natural resources.

[32] Sustainable Development Goals available online at: https://sustainabledevelopment.un.org/content/documents/4538pressowg13.pdf (Last access: 22 June 2022).

[33] Resolution adopted by the General Assembly on 27 July 2012, 66/288, The Future We Want.

LDN. Boer and Hannam (2021)[34] outline the problems of land degradation worldwide and ways in which LDN can be promoted through international legal mechanisms, as well as at the national level.

3 Soil Organic Carbon

3.1 Linking Soil Carbon Sequestration to Food Security

An adequate supply of SOC and nutrients is essential to maintain crop yields and the nutritional values of the agri-food system. The global agri-food system needs to be reshaped to meet population needs, and become more productive, more inclusive of poor and marginalized populations while remaining environmentally sustainable and resilient.[35] Healthy, productive soils are the key to delivering wholesome and nutritious diets to all humans, and to avoid compromising food security and nutrition for future generations. In this regard, an integrated understanding of carbon cycling in the soil-plant-atmosphere continuum is crucial to adapt to current and future changes and challenges including sustainable production of food, feed, fuel, and fiber in a climate change scenario.[36] Achieving SSM has never been more important as it relies on the establishment of practices that foster improved soil functions that enable ecosystem services and biodiversity.[37] Soil Organic Carbon-centred SSM practices are essential not only to improve soil health and enhance food security, but also to mitigate climate change,[38] but efforts to increase SOC content through SSM practices may be subject to the antagonistic effects of nitrous oxide (N_2O) emissions from unsustainable nitrogen (N) fertilizer management. To ensure that croplands become a sink of atmospheric CO_2 with the implementation of re-carbonization programmes, SSM should be an important part of the solution to N_2O emissions, soil degradation, and water contamination, through practices and tools to improve N use

[34] Boer and Hannam (2021), pp. 392–404.

[35] FAO (2018), p. 4, see Fig. 2; www.fao.org/3/ca2079en/CA2079EN.pdf (Last access: 22 June 2022).

[36] FAO (2020), p. 2; www.fao.org/3/cb0509en/cb0509en.pdf (Last access: 22 June 2022).

[37] FAO (2017), p. 5; www.fao.org/3/bl813e/bl813e.pdf (Last access: 22 June 2022).

[38] Ibid. FAO (2020), p. 1, outlines that the adoption of site-specific Sustainable Soil Management (SSM) practices in agricultural lands can harness a large C sink capacity at a global scale, and it has been highlighted as a significant greenhouse gas (GHG) removal strategy. It has been estimated that the global technical potential of terrestrial C sequestration is between 1.7 and 4.6 Pg C/ year. Sequestration rates due to management practices in agricultural lands are usually in the range of 0.2 to 0.8 t C/ha/ yea. The magnitude and rate of carbon sequestration in soils can vary greatly, depending on the different land uses and practices, soil characteristics, vegetation, topography and climate, among other soil forming factors and processes, which add to the many challenges for quantifying SOC stocks and changes.

efficiency.[39] To this extent, an integrated and joint N management framework, in conjunction with re-carbonization programmes would contribute to unlocking the potential of cropped soils to mitigate and adapt to climate change. The role of SOC in the climate system, and especially in climate change adaptation and mitigation, has been widely recognized and scientifically validated.[40]

The Paris Agreement,[41] the Koronivia Joint Work in Agriculture[42] and the recent Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate and Land,[43] have also led to the development of an enabling political-institutional environment that will allow the support and adoption of sustainable management practices based on SOC maintenance and/or sequestration. In addition, in the context of the SDGs, a sustainable global food system must foster a sustainable environment in which agriculture, biodiversity conservation and climate change adaptation and mitigation can thrive, but also co-exist and complement each other. The Monitoring, Reporting and Verification (MRV) voluntary protocol established by FAO could support the adoption of SSM practices for healthy soils and help protocol users to reliably measure their success in sequestering carbon in the fight against climate change and in the provision of other key ecosystem services. This would also make a great contribution to achieving the SDGs.[44]

Any CO_2 that is sequestered in soil has been removed directly from the atmosphere and will thus help to mitigate climate change.[45] The science of CO_2 sequestration in soils is currently advanced enough to support policy and incentive programs despite some uncertainty in the absolute sequestration rates of particular practices in specific parts of the world.[46] To be successfully implemented at a global scale, appropriate SOC sequestration management strategies are likely to be adopted faster if SOC is considered not only as a means for mitigating climate change but also as a contributor to soil health, food security, and sustainable development goals. The potential to sequester C in soil varies substantially from one region to another, even under similar types of management, due to variations and gaps in current and potential SOC levels.[47] Variations in C sequestration potentials increase with differences in climate, soil groups, cropping systems, and available technologies as

[39] Ibid. Amelung et al. (2020), pp. 2–3.

[40] Ibid. FAO (2020), p. XVI.

[41] Ibid.

[42] The Koronivia Joint Work on Agriculture (KJWA), a landmark decision under the United Nations Framework Convention on Climate Change, recognizes the potential of agriculture in tackling climate change; www.fao.org/koronivia (Last access: 22 June 2022).

[43] Ibid.

[44] Ibid. FAO (2020), p. XX comments that the GSOC-MRV Protocol "A protocol for measurement, monitoring, reporting and verification of soil organic carbon in agricultural landscapes" is the result of a very inclusive and collaborative work of scientists from many countries around the world, international organizations, panels, initiatives and institutions.

[45] Ibid. FAO (2020), p. 4.

[46] Ibid. Amelung et al. (2020) Box 1, p. 4.

[47] Ibid. Amelung et al. (2020), p. 3.

well as with different yield gaps [48] and soil-specific, historical C losses. This situation can be a barrier to the global implementation of a soil carbon climate-mitigation initiative, which will thus need a coordinated effort at regional scales adapted to these variations. Amelung et al. specify that "the most pressing need is the development of an agenda that includes: (i) information on region-specific soil distribution and degradation status; (ii) matching of sustainable management practices to soil group and its degradation status; and (iii) stopping the C loss from specific soils that have the potential to significantly affect the global C balance, e.g., peatlands under drainage. Currently, only a few countries have robust monitoring, reporting, and verification systems, but there are ongoing research efforts to expand these capabilities."[49]

4 Legislation

An outline of the global legislative framework to manage SCS was presented in 2019.[50] It was argued that an understanding of the physical and human related land use issues associated with SCS provide a guide as to the most appropriate legislative system needed to manage the soil environment. These issues involve how to adapt to climate change impacts, the problems associated with agricultural land use and food security, maintaining and restoring biological and ecosystem diversity and the control and prevention of land degradation. A comprehensive understanding of these issues points towards the actual legislative and institutional elements essential within a national legal and institutional system to effectively manage soil carbon, as well as the appropriate land management practices to improve soil carbon levels. A legal framework provides law and policy-makers with a practical method and guideline for identifying, developing, or strengthening a legal and institutional system that is concerned with aspects of the environment.

At the national level, there are many ways to frame legislation to control the impacts of land use on soil carbon levels. However, the ability of legislation to achieve effective soil carbon management will depend on the legal and institutional elements that protect physical processes associated with SCS and the establishment, maintenance and protection of carbon sinks and reservoirs. Such elements should be incorporated within procedures that regulate and manage the land use activities that

[48] See Global Yield Gap Atlas at https://www.yieldgap.org (Last access: 2 October 2021)—the world's leading database on high-quality agronomic data with local to global relevance that covers 70 countries across six continents and 13 major food crops with the following data: actual and potential yield and yield gap; actual and potential water productivity; actual and potential nutrient requirement; underlying data on weather, soil and cropping systems; climate zones and technology extrapolation domains (TEDs).The data serves research, strategic decision making and local-global actions that aim to improve yield and resource use efficiency by public and private sectors.

[49] Ibid. Amelung et al. (2020), p. 3.

[50] Hannam (2019), pp. 399–433.

cause the loss of soil carbon, lead to land degradation and contribute to the atmospheric CO_2 and global warming. Legislation and policy reform should be approached from a sound conceptual basis, preferably with an overall societal goal of sink management and enhancement. Importantly, a change in attitude to create legislation for SCS management depends on the willingness of society to accept new values in a legal system for land management. Some of the important conceptual and ethical elements for land management include the concept of natural rights for soil, to provide for the public interest, to apply the precautionary principle, and to conserve biological diversity.[51]

There is a variety of ways to design a legal and institutional system to manage soil carbon. Two principal approaches have been suggested, depending on the respective national physical, sociological and economic conditions.[52] However, individual laws could practically use a mix of each of these two broad approaches.

Non-Regulatory Strategy—characterised by elements that focus on:

- Extension, education, and awareness programs for soil carbon management
- Financial support to research soil carbon processes and sink protection.
- Extensive use of community participatory facilities in sink education.
- Development of land use practices that minimise the loss of soil carbon.
- Development of soil carbon management, protection, and incentive-based programs.

Regulatory Strategy—characterised by elements that focus on:

- Development of statutory land use plans that prescribe legal limits and targets of soil and land use to reduce the loss of soil carbon (e.g., cultivation practices, vegetation retention levels and water quality levels).
- Issue of licenses or permits to control soil use. These would prescribe use entitlements relating to soil restoration, management of sinks, habitat protection, organic matter level etc.
- Land use agreements between the State and individuals that set binding land use standards.
- The use of restraining notices where sustainable use limits are exceeded.
- Prosecution for failure to follow prescribed standards for managing soil carbon sinks and reservoirs

4.1 Global Picture of National Soil Carbon Legislation

The FAO GSP soil legislation database, "SoiLEX", has gathered and classified national legislation on soil protection, conservation, and restoration. It provides

[51] Ibid. Hannam (2019), p. 403.
[52] Ibid. Hannam (2019), p. 430.

access to information on the existing legal instruments in force.[53] All instruments in the portal have been validated by national experts and each instrument can be searched by country profile or by soil-related keywords. It includes a ranking system based on the relevance of the document to the selected keyword, the scope of the legislation, its nature and year.[54] The fourteen keywords in SoiLEX comprise recognized soil problems and characteristics associated with soil and land degradation processes. One of the fourteen keywords is legislation for "soil organic carbon loss." Boer and Hannam (2021) note that "as states implement LDN through legislation, SoiLEX could likely become a source for measuring the rate of legally backed uptake of LDN."[55] The same understanding could also apply for "soil organic carbon loss" legislation. At this point SoiLEX identifies 92 laws, regulations, decrees, ordinances and strategies under the soil organic carbon loss keyword, spread between 48 countries.[56] However, none of these instruments have been developed specifically to manage SCS, certainly not along the lines as advanced by Hannam (2019 at 401), for example.

Given the picture from the SoiLEX data, one of the opportunities available is for individual countries to use a combination of laws and instruments to manage SCS. In this situation, however, it would be appropriate to have a principal coordinating instrument which establishes the basic principles, objectives and legal elements for managing SOC.

4.2 Coordinating Legislative Approach: People's Republic of China

In 2012, a study carried out in the People's Republic of China (PRC) presents the results of the analysis of three PRC laws to determine their capacity to manage carbon associated with agricultural land use.[57] The study analysed the capability of the Agriculture Law 2003,[58] the Grassland Law 2002 and the Desertification Law 2001, from an integrated perspective, to manage soil organic carbon (SOC) in PRC's

[53] www.fao.org/soils-portal/soilex/en/ (Last access: 22 June 2022).

[54] www.fao.org/soils-portal/soilex/country-profiles/ (Last access: 22 June 2022).

[55] Boer and Hannam (2021), p. 401.

[56] www.fao.org/soils-portal/soilex/soil-keywords/soil-organic-carbon-loss/en/ (Last access: 22 June 2022).

[57] Ibid. Hannam (2012).

[58] The purpose of this law is to consolidate and strengthen the position of agriculture in the national economy, enable rural reform, develop agricultural productivity, modernize agriculture, protect the lawful interests of farmers and agricultural business organizations, improve farmers' incomes and their knowledge of science and culture, and promote the sustainable, stable and sound development of agriculture and the rural economy, so as to achieve the goal of comfortable social conditions (extracted from Article 1).

grasslands.[59] It also provided an indication of the potential for carbon management in the grasslands to contribute to a national carbon market. These three laws comprise numerous legal elements that are identified with specific individual soil organic carbon land management activities (SOCLMs). Previous PRC studies provide details of the general capabilities of these laws to manage land and ecosystems.[60] Given the duplication of key land management functions between the three laws, it was suggested that PRC could benefit from the introduction of a separate instrument to coordinate key SOCLM functions between these laws in the interest of managing soil carbon more efficiently in the grasslands.[61] The report by Wang et al.[62] provided substantial information on agricultural activities in the grasslands and was used as a major authority on SOCLMs for the study. If not carried out effectively, various agricultural activities can lead to the development of and/or exacerbate problems in the management of carbon. These impacts have potentially severe consequences for people living in PRC in terms of loss of valuable agricultural land and livestock productivity, thus resulting in the more serious issues of human food security, livestock food security and loss of livelihood. Studies in PRC find that overgrazing and conversion of freely grazed grassland (FGG) to cropland lead to an annual average decline of 2.3–2.8% in SOC, and have caused a loss of 30–35% of total grassland SOC in PRC.[63] On the other hand, improved land management activities can reverse the loss of SOC by using practices that retain or increase SOC i.e., "soil organic carbon land management activities". The two key areas examined in the study included:[64]

- Identification of the SOCLMs in each of the three laws;
- Identification of legal procedures in the three laws that enable management of SOC.

[59] In PRC, the term "grasslands" includes rangelands, grazing lands, agro-silvo pastoral systems (a combination of trees or shrubs with crops and animal husbandry), and cultivated pastures.

[60] See Du and Hannam (2011); Chapter 6 (pp. 85–110) of this publication outlines the specific areas where the legislation and policy for prevention and control of LD can be improved, including: integrating key environmental concepts and principles from international environmental conventions into domestic legislation and policy; enacting and improving laws and rules, including new national laws for water and soil conservation, wetland conservation, and soil pollution control; revision of provincial regulations and rules; improving land-use planning administration, ecological compensation and the natural reserve system; closing forests for restoration; improving the EIA procedure and practical water and soil conservation systems; improving policy for LD control, including an increased role of science in policy development; strengthening policy coordination and continuity, policy objectives and market mechanisms.

[61] Ibid. Hannam (2012), pp. 4–5, indicates that various PRC studies document the key climate change impacts on agricultural activity in the grasslands, including land degradation (particularly wind and water erosion), the loss of ecological integrity of grassland, collapsing interconnected ecosystems, and the increasing frequency of dust storms.

[62] Ibid. Wang et al. (2011), pp. 329–340.

[63] Ibid. Wang et al. (2011), pp. 332–335.

[64] Ibid. Hannam (2012), p. 5.

4.2.1 Results

The analysis of the PRC Agricultural Law, Grassland Law and Desertification Law in 2012 indicated that this framework of law has significant potential to manage SOC in the grasslands. In particular, the analysis showed that the existing body of law provides for key SOCLMs that have been identified by various PRC studies. The legislation includes many legal elements that identify with specific SOCLMs. However, there is substantial duplication of key carbon management functions between the three laws. In this regard it was suggested that PRC would benefit from introducing an instrument to coordinate key SOCLM functions between the laws in the interest of managing soil carbon more efficiently in the grasslands.[65]

Significantly, the analysis showed that between the three laws there are many legal procedures to manage SOC, to retain existing levels of SOC or to increase the level of SOC, including procedures:[66]

- That define responsibilities between government, farmers and the community in grassland, livestock, and carbon management;
- That establish mechanisms and obligations for financial management, transfer, allocation, taxation, monitoring and stipulations for on-going funding for grassland and livestock management;
- For making contracts, renewing and revising contracts;
- To transfer carbon benefits and credits between parties;
- Concerning rights and title to revenues from the sale of carbon credits;
- Concerning rights, conditions or restrictions with respect to the grassland on which carbon sequestration activities operate;
- For environmental approvals under particular grassland uses;
- To pay farmers for implementing land management activities according to prescribed standards;
- That enable governments, farmers, and community to share responsibility in carbon management, including provision for the community to participate in grassland decision-making processes;
- For policy development, guidelines and ecological standards to manage carbon, including procedures for implementation, development of special codes of practice, land management indicators and the physical and ecological limits of land use;
- To achieve carbon management in grasslands through a mix of regulatory, part-regulatory, and non-regulatory means, including pastureland management incentives, support programs, and advisory groups;
- To correct unsustainable land use and where sinks are damaged;
- To manage carbon on all classes of grassland (sinks);

[65] Ibid. Hannam (2012), p. 61.

[66] Ibid. Hannam (2012)—for individual articles from the respective laws that provide some support to each of the carbon elements see Table 2, pp. 38–39, and for the legal procedures to manage soil carbon see pp. 40–60.

- To develop grassland management plans based on sustainable land management criteria, sustainable grassland management standards and codes of practice specifically aimed at carbon management in grassland;
- To protect biodiversity and conservation values of grassland and traditional lifestyles;
- To apply a geographic perspective to grassland management, including provisions to develop State and local grassland management plans;

4.2.2 A Coordinating Legal Instrument

The parameters of a legal instrument for the coordinated management of SOC are outlined in the PRC study.[67] It is regarded that a similar approach could be adopted by other countries to frame a coordinating law that would draw on the key elements of existing laws and establish new procedures to improve the coordination of the existing laws in the management of SOC.

- ***Objective***—*The objective of the regulation is to use the procedures of the Agriculture Law, Grassland Law and Desertification Law to manage soil organic carbon, and to assist in the removal of carbon dioxide from the atmosphere and to avoid emissions of greenhouse gases in the grassland region through the implementation of Soil Organic Land Management activities (SOCLMs).*

  The regulation should make reference to the United Nations Framework Convention on Climate Change and the Kyoto Protocol and PRC's obligations under these instruments. The objectives should refer to incentives for PRC farmers to implement SOCLMs and to implement specified offsets projects. There should also be provision to increase carbon abatement in a manner that is consistent with the protection of PRC's natural environment and to improve resilience to the effects of climate change.[68]
- ***Administration***—*The regulation could be administered by an "Administrator for SOCLMs" established under the Agricultural Law with the power to use procedures in the Agricultural Law, Grassland Law and Desertification Law for the purpose of implementing SOCLMs.*
- ***Soil organic carbon land management activities***—*Activities that count towards a PRC national carbon management target include:*[69]

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[67] Ibid. Hannam (2012), pp. 62–64.

[68] The regulation could support the development of a scheme for the issue of PRC carbon credit units in relation to SOCLMs and eligible offsets projects. A point to consider is whether a PRC carbon credit unit is personal property and is generally transferable, including the eligibility requirements for eligible offsets projects (e.g., project must be carried out in PRC; the project must be covered by a methodology determination made under the regulation). It may be appropriate that methodology determination must comply with the offsets standards that could also be established under a regulation.

[69] Ibid. Wang et al. (2011) Table 1, p. 330.

- *Exclusion from grazing*
- *Sustainable grazing*
- *Conversion of FGG to cultivated pasture*
- *Conversion of FGG to cropland*
- *Conversion of FGG to shrubland*
- *Conversion of cropland to abandoned field*
- *Conversion of cropland to cultivated pasture*
- *Conversion of cropland to shrubland*
- *Conversion of bare sand to vegetation*
- *Using fertilizer to improve grassland ecology*
- *Controlling burning*
- *Controlling mowing*

- ***Prevention of natural disturbance****—It is proposed that farmers who apply accredited SOCLMs take steps to prevent the effects of natural disturbance factors on the SOCLM activities, including, poor drainage, bushfire, drought, pest attack, disease, or any other event specified in the regulation.*
- ***Approval****—An approval under the regulation means regulatory approval to undertake a SOCLM activity and this could be provided under a contract or agreement within the three laws. In some circumstances a licence or permit may be required in relation to a specific land management activity or land use or development.*
- ***Relevant carbon pool****—In relation to a SOCLM, a "relevant carbon pool" relates to the extent to which the SOCLM activity would remove carbon dioxide from the atmosphere by sequestering carbon in living biomass; or the extent to which the activity would remove carbon dioxide from the atmosphere by sequestering carbon in dead organic matter, or the extent to which the activity would remove carbon dioxide from the atmosphere by sequestering carbon in the soil.*

  PRC carbon credit units could be issued in relation to an eligible SOCLM activity. The number of carbon credit units issued could be determined by reference to a relevant abatement amount calculated under an applicable methodology; or if the SOCLM activity is a forest protection project—the relevant sequestration amount could be calculated under the applicable methodology.

  The Administrator could declare an offsets project to be an eligible offsets project under the regulation. The Administrator could vary or revoke a declaration of an eligible offsets project.
- ***Certificate of entitlement*** *– This could be applied through a land use contract or agreement system.*
- ***Land use rights****—Occupier rights and responsibilities could be applied through a land use contract or agreement system.*
- ***SOCLM maintenance obligation****—This could be applied through a land use contract or agreement system.*
- ***SOCLM crediting period****—The SOCLM period should be specified and could be up to 20 years, particularly if forestry is involved. The Administrator could*

determine a subsequent crediting period for an eligible SOCLM that is not a forest protection project.

- ***Reporting and notification****—The farmer or occupier should provide a report on the SOCLM activity within a period prescribed under a use right contract.*
- ***Relinquishing****—The benefits from SOCLM activity may be required to be relinquished if the land user fails to comply with the standards set for the prescribed SOCLM activity.*
- ***Soil organic carbon maintenance****—A carbon maintenance obligation could be imposed in relation to an area or areas of land if a prescribed land use activity has not been complied with.*
- ***Methodology****—The State Council or its representative should make or vary a methodology that applies to specified SOCLM activities. Factors to consider include the variation of a methodology and the duration of application of a methodology.*
- ***Multiple SOCLMs****—Provision can apply for more than one SOCLM activity in a land use contract or agreement.*
- ***Issue of carbon credit units****—The State Council or its administrative representative may issue carbon credit units (or a carbon exchange). Entries may be made in a registry of accounts for PRC carbon credit units.*
- ***Transfer of carbon credits****—The State Council or its administrative representative may provide for transfer of carbon credit units (or through a carbon market). Entries may be made in a registry of accounts for PRC carbon credit units.*
- ***Publication of information****—The Administrator must publish information about the operation of SOCLM activities, including the different types of SOCLMs available under the three laws, the prescribed standards for implementation, and the obligations of farmers or occupiers to SOCLM implementation.*
- ***Relinquish carbon credits****—If a person is the registered holder of one or more PRC carbon credit units for applying SOCLMs, provision should be made for the person to relinquish any or all of the units.*
- ***Information gathering power****—The Administrator may obtain any information or documents in relation to the operation of SOCLMs.*
- ***Keeping records and monitoring****—The SOCLM regulation may require a person to make a record of information; and retain the record. It should also provide for the person to record-keeping requirements in relation to the preparation of a SOCLM report. A SOCLM proponent should comply with record-keeping and project monitoring requirements that are established under the regulation.*
- ***Monitoring power*** *– Provision should be made for an inspector to enter a land contract area to determine whether the regulation relating to a SOCLM has been complied with; or to substantiate information provided under the regulation. Entry should be with the consent of the occupier of the land contract area. The occupier of the land has rights and responsibilities.*
- ***Audits****—The Administrator may require audits of one or more aspects of a person's compliance with the regulation.*
- ***Enforceable undertakings*** *– These can be applied through the compliance provisions of the Agricultural Law, Grassland Law or Desertification Law.*

- ***Review of decisions****—These can be applied through the compliance provisions of the Agricultural Law, Grassland Law or Desertification Law.*
- ***Civil penalty orders****—These can be applied through the compliance provisions of the Agricultural Law, Grassland Law or Desertification Law.*

4.3 Carbon Laws and Strategies[70]

The enactment of carbon rights legislation to recognize rights associated with carbon sequestration by vegetation and soil has been around for some time. Carbon rights law enables acquisition and trading in such rights through a covenant that gives access to or the maintenance of land, trees or forest of any sequestered carbon. The main purpose of the legislation is to encourage investment in carbon sinks, a legal concept that must be applied readily to sequester soil carbon. A carbon sequestration right in relation to land may mean a right that is conferred on a person by a legal agreement, to the legal, commercial or other benefit of carbon sequestration by any existing or future use of the land. This area of law opens the way for a market in stored carbon and ultimately the future creation of carbon credit schemes for soil carbon.[71] A number of existing laws and strategies serve as useful examples and approaches to frame different types of instruments to address the management of SCS. The following is a selection.

4.3.1 Commonwealth of Australia Carbon Credits (Carbon Farming Initiative) Act 2011[72]

The Carbon Farming Initiative (CFI) is a carbon offsets scheme that provides economic opportunities for farmers, forest growers and landholders to help the Australian environment by reducing carbon pollution.[73] Farmers and land managers are able to generate credits that can then be sold to other businesses who want to offset their carbon pollution. In particular, the CFI enables land managers to earn credits for various land management actions including: reforestation and

[70] For a discussion on the history of legislative aspects of carbon in Australia see Guglyuvatyy and Stoianoff (2016) http://www5.austlii.edu.au/au/journals/UTSLRS/2016/25.html (Last access: 22 June 2022), the article in particular observes several interesting and significant aspects of Australian climate law highlighting governmental approaches and processes leading to the introduction of those laws. The historical perspective identifies common features of the climate law implementation procedures and identifies what political factors influence these processes in Australia.

[71] Ibid. Hannam (2019), p. 421.

[72] https://www.legislation.gov.au/Details/C2017C00076 (Last access: 22 June 2022), Ibid. Hannam (2019), pp. 421–422.

[73] Power (2011), p. 59; Macintosh (2012), p. 28.

revegetation; reduced methane emissions from livestock digestion; reduced fertilizer pollution; reduced pollution or increased carbon storage in agricultural soils (soil carbon); savannah fire management; native forest protection; forest management; reduced pollution from rice cultivation; reduced pollution from legacy landfill waste.

Under s 3 of the Act the first object is “to remove greenhouse gases from the atmosphere, and avoid emissions of greenhouse gases, in order to meet Australia’s obligations under the Climate Change Convention, the Kyoto Protocol and an international agreement (if any) that is the successor (whether immediate or otherwise) to the Kyoto Protocol”. The second object of the Act is “to create incentives for people to carry on certain offsets projects”. The third object of the Act is “to increase carbon abatement[74] in a manner that is consistent with the protection of Australia’s natural environment, and improves resilience to the effects of climate change”. The fourth object of the Act is “to authorize the purchase by the Commonwealth of units that represent carbon abatement”.

Under s 5 “eligible carbon abatement” from an offsets project means “carbon abatement that: (a) results from the carrying out of the project; and (b) is able to be used to meet Australia’s climate change targets under: (i) the Kyoto Protocol; or (ii) an international agreement (if any) that is the successor (whether immediate or otherwise) to the Kyoto Protocol”. An “Offsets project” means: “(a) a sequestration offsets project; (b) an emissions avoidance offsets project”. Under s 54 “a project is a sequestration offsets project if it is a project: (a) to remove carbon dioxide from the atmosphere by sequestering carbon in one or more of the following—(i) living biomass; (ii) dead organic matter; (iii) soil; or (b) to remove carbon dioxide from the atmosphere by sequestering carbon in, and to avoid emissions of greenhouses gases from, one or more of the following: (i) living biomass; (ii) dead organic matter; (iii) soil”.

4.3.2 Victoria, Australia: Climate Change Act 2017

The purpose of the Climate Change Act[75] is to establish a long-term greenhouse gas emissions reduction target and set 5-yearly interim greenhouse gas emissions reduction targets in order to reach a long-term greenhouse gas emissions reduction target. It facilitates the development of climate change issues and establishes policy objectives, guiding principles, government policy and provides for a strategic response to climate change through a climate change strategy, adaptation action plans and emissions reduction pledges. Significantly, this Act facilitates the State’s

[74] Carbon Credits (Carbon Farming Initiative) Act 2011, Section 5, “carbon abatement” means: (a) the removal of one or more greenhouse gases from the atmosphere; or (b) the avoidance of emissions of one or more greenhouse gases.

[75] Ibid. Hannam (2019), pp. 422–423; Art. 3 “climate change” means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

contribution to national and international carbon sequestration efforts and provides for the creation of forestry rights, carbon sequestration rights and soil carbon rights, Forestry and Carbon Management Agreements[76] in relation to private land and Carbon Sequestration Agreements in relation to Crown land.

4.3.3 Brazil: Law Establishing the National Policy on Climate Change

The law that establishes the Sectorial Mitigation and Adaptation Plans for Climate Change aims at the Consolidation of a Low Carbon Emission in several land use sectors including agriculture.[77] During the 15th UNFCCC Conference of the Parties the Brazilian government confirmed its voluntary commitment to reduce greenhouse gas emissions for 2020, between 36.1% and 38.9%, estimating a reduction of these emissions around one billion tons of CO_2 equivalent. For this purpose, different actions were proposed under the Law establishing the National Policy on Climate Change,[78] including: reducing the rate of deforestation in the Amazon by 80%, and by 40% in the Cerrado; recover degraded pastures in agriculture; promote land-use integration; increase the use of the Direct Planting System and the Biological Fixation of Nitrogen; and increase energy efficiency, the use of biofuels, the supply of hydroelectric and alternative sources of biomass, wind energy and small hydropower plants, and increase the use of coal from plantation forests in the steel industry.

4.3.4 Brazil: Decree No. 10.431: The National Executive Committee of the Sectorial Plan for the Consolidation of a Low Carbon Emission in Agriculture

This Decree creates the National Executive Committee of the Sectorial Plan for the Consolidation of a Low Carbon Emission in Agriculture.[79] It establishes the composition, duties and responsibilities of the Committee, to perform many activities: monitor the implementation of the Sectorial Plan for Mitigation and Adaptation to Climate Change for the Consolidation of a Low Carbon Emission in Agriculture (ABC Plan); monitor and evaluate the results achieved and promote resilient, productive, and competitive agricultural production systems adapted to climate change; support the Ministry of Agriculture, Livestock and Supply (MALS) and

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[76] Art. 59 (1) The purpose of a Forestry and Carbon Management Agreement is to provide for the imposition of management obligations in relation to any of the following—(a) carbon sequestration by vegetation; (b) carbon sequestration underground; (c) the management of vegetation.

[77] Law 12.187 of 29 December 2009.

[78] Decree No. 7390, consisting of 12 articles and 1 Annex, regulates Law No. 12.187, which institutes the National Policy on Climate Change; www.fao.org/faolex/results/details/en/c/LEX-FAOC093834 (Last access: 22 June 2022).

[79] www.fao.org/faolex/results/details/en/c/LEX-FAOC196838 (Last access: 22 June 2022).

the bodies and institutions involved in the implementation of the ABC Plan; analyze the reports of the monitoring systems established by the ABC Plan and evaluate the results, guide the implementation, strengthening and prioritization of actions to be taken by the MALS; identify and propose studies to support the implementation and review of the ABC Plan; and to support the MALS on the fight against climate change by the Brazilian agricultural sector.

4.3.5 USA: United States Mid-Century Strategy for Deep Decarbonization

The Mid-Century Strategy (MCS) aims to reduce emissions while maintaining economic growth.[80] The MCS sets out policies and strategic measures to ensure global action on climate change, with the vision to achieve greenhouse gas emissions reductions of at least 80 percent below 2005 levels by 2050. In particular, the MCS defines three policy priorities: transform to a low-carbon energy system; sequester carbon through forests, soils and CO_2 removal technologies; reduce non-CO_2 emissions.

The MCS recognizes that sequestering carbon through forests and soil will encompass actions to accelerate private land carbon incentives to support forest carbon enhancing activities and SCS, underpinned by science based carbon accounting protocols and policy frameworks.[81] It also provides for a reduction of land use competition and land use change through research and policies with the objective to increase land productivity.[82] Special attention is given to afforestation and reforestation and minimizing carbon loss due to natural disturbances. The MCS provides for the transition to a low-GHG pathway that guides the process of decarbonisation. This includes maintaining and enhancing the land carbon sink, ensuring that US landscapes continue to sequester substantial amounts of carbon and developing CO_2 removal technologies that sequester and store carbon.[83]

[80] The White House Washington (2016) United States Mid-Century Strategy for Deep Decarbonization p. 111; see—extwprlegs1.fao.org/docs/pdf/usa181125.pdf (accessed 21 September 2021).

[81] Ibid p. 69, Fig. 1 indicates that the MCS analysis estimates 2050 land sector and CO_2 removal technologies could sequester 30 to 50 percent of economy-wide GHG emissions.

[82] Ibid p. 71, says that "finding efficient ways to structure carbon-based incentives in the land sector will be important. For example, carbon-based payments to farmers, ranchers, and forest owners would incentivize many of the activities described below. Funding these incentives will be an important consideration for future climate action, as well as putting in place the appropriate institutions to administer such incentives to ensure they are efficiently supporting our long-term climate goals."

[83] Ibid p. 77 specifies that "Increasing uptake of key soil carbon-enhancing practices to more than 70 percent of U.S. cropland and ensuring that the practices are implemented to maximize carbon storage benefits could result in an increased soil carbon sink of over 270 million metric tons CO2e per year by 2050."

4.3.6 Australia, New South Wales De-carbonization Hub

The New South Wales Decarbonisation Innovation Study (DIS) investigated opportunities for meeting emissions targets and adapting to climate change while generating economic development for the state.[84] In regard to land and sustainable agriculture, it specifies the promotion of best practice sustainable land management, and expanding sustainability markets and ecosystem services to provide decarbonised income sources for landholders, including Indigenous landholders, where sustainable land management includes carbon farming and regenerative agriculture. The DIS provides for the improvement of agricultural productivity and resilience through technologies including horticulture, renewables, bioenergy, and water efficiency and recycling, gene technologies and synthetic biology. In particular, it emphasises the growth of local demand and supply chains in agricultural goods.[85]

The DIS recognizes that sustainability markets that encompass both carbon and biodiversity can provide greater economic and environmental benefits than separate markets. These markets can also decrease the risk of unintended consequences such as monoculture environments and land use conflicts, and provide greater capacity for protecting the land.[86] Improving decarbonisation and climate resilience will require landholders to build skills in assessing the risks and opportunities of climate change for their land. Landholders would also be required to build skills to adopt carbon sequestration technologies and services that improve productivity and resilience while reducing emissions, as well as building skills to implement sustainable land management practices. Building these skills is a particular challenge in the New South Wales land sector with its diverse range of land uses and geography.[87] Sustainable certification protects the value of sustainable products, encouraging businesses to make investments to improve their sustainability. Certification is particularly important in providing transparency and education to consumers, including through justifying price premiums on sustainable products, and avoiding perceptions of 'greenwashing.'[88]

[84] NSW Government Chief Scientist and Engineer (2020); a major outcome of the Study will be the establishment of a Decarbonisation Innovation Hub under the NSW Government Net Zero Industry and Innovation Program. The Hub will support researchers, industry and government stakeholders in critical sectors to collaborate, and increase the uptake of new technologies in decarbonising NSW, see https://www.chiefscientist.nsw.gov.au/science-in-nsw/nsw-networks/decarbonisation-innovation-hub (Last access: 22 June 2022).

[85] Ibid p. 4.

[86] Ibid p. 90.

[87] Ibid p. 92.

[88] Ibid p. 93; Greenwashing is a process where false or misleading claims are made about the sustainability of a product or service.

5 FAO Guidelines for Sustainability Assessment of Food and Agriculture Systems

The FAO Sustainability Assessment of Food and Agriculture systems (SAFA) Guidelines were derived to assess the impact of food and agriculture operations on the environment and people.[89] It is one of the most comprehensive assessment procedures available to consider the capability of an agricultural land use to sequester carbon and to ensure its benefits are fully accounted for in the supply chain. The vision of SAFA is that food and agriculture systems worldwide are characterized by four dimensions of sustainability: good governance, environmental integrity, economic resilience and social well-being. In this context, SAFA presents a framework that encompasses aspects of land used for cropping, including postharvest, processing, distribution and marketing. Governance is the process of making and implementing decisions. For SAFA, this includes corporate ethics, accountability, participation, rule of law and holistic management.[90] In a SAFA, environmental sustainability is addressed by accessing atmospheric, water, and land and biodiversity information. Economic activity involves the use of labour, land and capital to produce goods and services to satisfy peoples' needs. The four dimensions of sustainability divide into 21 themes and 58 subthemes, all with sustainability objectives.[91] The relevance of the SAFA guidelines to SCS is that it provides a broad framework in which to consider all aspects of soil carbon management within an agricultural land use system.

5.1 *SAFA and Carbon*

Theme E3 of the SAFA guidelines covers soil resources,[92] and specifies that "no land is lost due to surface sealing or mismanagement of arable lands and pastures, and soil fertility is preserved and enhanced".[93] The main objective of this theme is that soil characteristics provide the best conditions for plant growth and soil health, while chemical and biological soil contamination is prevented. An important aspect of soil quality is monitoring and managing soil biological quality include the macro and microorganisms present in soils; soil organisms provide a multitude of benefits for soils and ecosystems, including breakdown of organic matter leading to nutrient and carbon release, improving soil structure and water holding capacity, providing a sink for GHG emissions. Content and quality of soil organic matter also affect the

[89] FAO (2014).

[90] Ibid. p. 79.

[91] Ibid. Section 3, pp. 75–208.

[92] Ibid. FAO (2014), pp. 121–125.

[93] Ibid p. 122.

nutrient cycling and gas, including CO_2, exchange in soils, and are related to soil life, soil fertility and the functioning of ecosystems.[94] Examples of positive conditions and practices that fulfil this objective include:[95]

- Soil physical structure is in excellent condition on all land used by the enterprise, with no signs of soil compaction of structural degradation.
- Soil chemical quality is in excellent condition on all land used by the enterprise, with no signs of chemical soil degradation.
- Soil biological quality is in excellent condition on all land used by the enterprise, with no signs of biological soil degradation, i.e. a reduction of soil life.
- Soil organic matter content and quality are in excellent condition on all land used by the enterprise, with no signs of quantitative or qualitative losses.
- Adopting soil improvement practices to improve the physical, chemical and biological properties of the soils used by an enterprise and tackling all problematic aspects for soil quality by effective measures on all areas concerned.

5.2 International Reference

One of the benefits of the SAFA guidelines is that they can be applied to assess sustainability along food and agriculture value chains. It establishes an international reference for assessing trade-offs and synergies between the different dimensions of sustainability and has been prepared so that enterprises involved with the production, processing, distribution and marketing of agricultural goods have a clear understanding of the respective components of sustainability. SAFA creates opportunities for enterprises to use existing data and combine it with other tools and sustainability initiatives. It was developed as an international reference document, a benchmark that defines the elements of sustainability and a framework for assessing trade-offs and synergies between all aspects of sustainability.[96] Global trade and the governance of inter-state externalities on public goods (e.g. climate, biodiversity, food safety), compounded by the proliferation of sustainability schemes, call for a multiparty cooperation that must be supported by "common rules" in order to reduce fragmentation, prevent conflicts, mitigate uncertainty and build capacities for effective sustainability. More accurate data and sound guiding principles to establish a common basis for assessing sustainability is needed. While there is now a wide awareness of the sustainability concept, there is also wide interpretation of the definitions and components of sustainability based on different disciplines and political beliefs and values. By providing a transparent and aggregated framework

[94] Ibid p. 122.
[95] Ibid p. 123.
[96] Ibid pp. 1–2.

for assessing sustainability, SAFA seeks to harmonize sustainability approaches within the food value chain, as well as furthering good practices.

5.3 General Application

The SAFA system is constructed so that different users with different purposes can enter at different levels of the SAFA Framework;[97] the themes comprise 21 universal sustainability goals; sub-themes comprise 58 sustainability objectives specific to supply chains; and there is 116 indicators for crops, livestock, forestry, fisheries and aquaculture enterprises. These themes can be implemented at any level, national, supply chain or operational unit and thus, provide a common understanding of what "sustainability" means in a practical context. Each of the 21 sustainability themes is detailed into sub-themes, or individual issues within SAFA themes, with associated explicit sustainability objectives. This level, which comprises 58 sub-themes, is relevant for supply chain actors doing an analysis which identifies risk, as well as gaps in existing sustainability efforts. The SAFA guidelines aim at rendering approaches and results of sustainability assessments in the food sector more transparent and comparable. This is in line with the call for disclosing the values and assumptions behind sustainability.[98] They establish a comprehensive, widely accepted language for sustainability in agriculture and food; facilitating comparisons of the sustainability performance of companies; and emphasizing the need to take the varying scope of influence of enterprises into account, which may stretch beyond the physical borders of a production site and even include suppliers and stakeholders outside the supply chain. Although the guidelines provide a standard set of sustainability themes and goals that all enterprises in the sector should pursue, they allow for flexibility in selecting indicators for measuring sustainability performance.

However, although the SAFA guidelines aim for being globally applicable for all food, their practical applicability must be evaluated under a diversity of environmental conditions.[99] While they define a hierarchically structured and sound set of sustainability topics, and corresponding objectives, which allow the assessment of enterprises against an objective and transparent set of criteria, pilot applications of the tool have shown that sustainability assessments according to the guidelines can provide a detailed picture of the sustainability performance of an enterprise. Jawtusch says that applying the SAFA guidelines to get meaningful, valid and communicable answers requires both a large amount of resources in terms of time and data needs and a profound expertise of the analysts in a wide range of thematic

[97] Ibid p. 3, Fig. 1.

[98] Gasparatos (2010) explores the implications that arise with the selection of specific sustainability evaluation tools and says that in most cases the choice of the evaluation tool is made by the analyst (s) without taking into consideration the values of the affected stakeholders.

[99] FAO (2014).

areas.[100] The examples described below apply different approaches but each would have the ability to provide information on land management practices that provide for improved soil carbon sequestration.

5.3.1 Paraguay

A study in Paraguay[101] analyzed the sustainability of agricultural systems through the use of SAFA indicators, in a comparative way, for identifying critical issues and improvement strategies for enhancing rural sustainability. As regards the evaluation of the sustainability level within Paraguayan agricultural systems, peasant family farming, as well as agro-ecological, conventional, neo-rural, and indigenous agriculture proved to be substantially similar at the time of the sustainability assessment, exhibiting excellent results in the four dimensions of SAFA.

5.3.2 Europe

A livestock sustainability assessment in Europe[102] advocates an approach for the selection of indicators and sustainability tools that lead to the creation of a rapid, but effective, assessment tool. It consolidated information and data collected through an industry partner survey, workshop discussions and literature review and the most appropriate indicators in all dimensions (i.e. social, economic, environmental, governance) were identified in addition to the best tool for assessing sustainability of sheep and goat farms ensuring adaptability to a range of farm types. The assessment concluded that the Public Goods Tool (PG Tool)[103] was the most appropriate framework for adaptation as it was the first to fulfil all the key selection criteria (i.e. ease of tool use; the coverage of a range of sustainability criteria as defined within the SAFA framework and; the possibility and ease of adapting the tool to include new indicators).

[100] Jawtusch et al. (2013), p. 5.

[101] Soldi et al. (2019), p. 26, as regards the evaluation of the sustainability level within Paraguayan agricultural systems, peasant family farming, as well as agro-ecological, conventional, neo-rural, and indigenous agriculture proved to be substantially similar at the time of the sustainability assessment, exhibiting excellent results in the four dimensions. The levels of sustainability achieved by agribusiness, on the other hand, deviate from those of other agricultural systems, resulting in moderate scores in the dimensions of good governance and environmental integrity, and good scores in the economic and social dimensions. Agribusiness represents the most widespread model in terms of cultivated area, thanks to its profitability and orientation to the market.

[102] Ibid. Zaralis et al. (2017), p. 633.

[103] Ibid p. 638.

5.3.3 Brazil

Commercial integrated crop-livestock-forest systems (ICLF) using beef cattle, eucalyptus and cash crops like soybeans and maize are increasing in Brazil, especially in the central part of the country, and broad ranging sustainability assessments of such systems is crucial for local development policies.[104] The Brazil study emphasises that the SAFA framework can be applied to address local ICLF systems but a prior evaluation of the framework is important for checking its suitability for the local context. It concludes that even though the indicators might be considered relevant in a sustainability assessment, many proposed indicators would be difficult to acquire in a given situation. It cautions that users of SAFA for ICLF systems should carefully evaluate each indicator when designing the scope of a study in order to produce good quality results.

6 Conclusion

This chapter has considered that sustainable land use including practices that maintain or improve the sequestration of carbon in the soil of agricultural land is critical for ongoing surety of the production of safe and healthy food. One of the essential aspects of sustainability of agricultural systems is the maintenance or improvement of SOC. The role of SCS in the management of climate change within the safe levels advocated by the IPCC is a key aspect of this objective. The most pressing need is the development of an agenda that includes information on soil distribution and degradation status, matching of sustainable management practices to each soil group and its degradation status, and stopping the carbon loss from specific soils that have the potential to significantly affect the global carbon balance. However, developing and implementing an integrated approach for the analysis of different sustainability dimensions, for SSM in particular, and integrating it in agricultural land use strategies that provides for SCS, remains a major challenge.

There are various ways to frame legislation to control the impacts of agricultural land use on soil carbon levels. However, the ability of legislation to achieve effective soil carbon management will depend on the legal and institutional elements that protect physical processes associated with SCS and the establishment, maintenance and protection of carbon sinks and reservoirs. Such elements should be incorporated within procedures that regulate and manage the land use activities that cause the loss of soil carbon, lead to land degradation and contribute to the atmospheric CO_2 and global warming. In this regard, while the SAFA methodology represents a useful

[104] Bungenstab et al. (2015) show that even though they might be considered relevant in a sustainability assessment, many proposed indicators should be difficult to acquire in a given situation. Therefore, users of SAFA for ICLF systems should carefully evaluate the inclusion of each indicator when designing the scope of their studies in order to have good quality results.

tool to support policy makers in designing and evaluating policies that include the management of SOC, the SAFA guidelines can be applied for comparing different types of agricultural systems and identifying the critical issues for preparing effective intervention policies to achieve sustainable soil management.

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