Food and Agriculture Organization of the United Nations

Global Soil Partnership Plenary Assembly

GLOBAL SOIL PARTNERSHIP

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Work of the Intergovernmental Technical Panel on Soils (ITPS)

Executive Summary

- This document contains the annual progress report of the ITPS, complementing those submitted to previous sessions of the Plenary Assembly (PA). It provides a succinct overview of the main activities carried out by the Panel and the conclusions reached, since the current members were appointed by the PA at its 6th session in June 2018 for a three-year term. The ITPS Chair is also due to make an oral presentation.
- It is important to recall that, besides its formal working sessions, the ITPS often relies on the convening of smaller groups to deal with specific assignments. Their input is subsumed under the appropriate rubrics. This document also provides the revised ITPS work programme for 2019-20 for the information of the PA and addresses interface with other pertinent bodies and initiatives.
- The full report of the ninth meeting of the ITPS can be consulted at: http://www.fao.org/global-soil-partnership/intergovernmental-technical-panel-soils/ninth-working-session/en/

Suggested action by the GSP Plenary Assembly

- The Plenary Assembly may wish to:
  - review and comment, as relevant, on the range of activities undertaken by the ITPS in the last twelve month period.
  - endorse the work plan 2019-2020 and invite donors and partners to support this work by providing financial and in-kind resources.
  - endorse the planned work towards the convening of a global symposium on soil biodiversity in 2020.
  - review the progress made on the implementation of the outcome documents of the 2017 Global Symposium on Soil Organic Carbon (GSOC17) and the 2018 Global Symposium on Soil Pollution (GSOP18), and provide guidance accordingly.
  - review the outcome of the 2019 Global Symposium on Soil Erosion (GSER19) and support the preparation of similar events to be led by the ITPS in collaboration with other UN panels and organizations.
  - review the proposed concept note for the assessment of the economic benefits of Sustainable Soil Management (SSM) for farmers and other land users, and identify best practices that prevent soil degradation.

- review the protocol for the assessment of sustainable soil management practices.

3.1 Report by the chairperson on main activities and outcomes of the work programme 2018-2019

1. In June 2018, the PA endorsed the appointment of the 27 experts constituting the Intergovernmental Technical Panel on Soils (ITPS) to serve for a mandate of three years (2019-2021).

2. The present panel had it first meeting, as the Ninth Working Session of the ITPS (10 - 12 October 2018). Hence, during the first eight months of activities, the Panel carried out a number of tasks as follows:

- preparation of the Soil Pollution Guidelines;
- preparation of the concept note and working documents for the three themes of the 2019 Global Symposium on Soil Erosion;
- review of the concept notes for the global maps of Soil Salinity, Soil Erosion and Soil Organic Carbon Sequestration Potential;
- support, as appropriate, to the implementation of the GSP Plans of Action and the development of Regional Implementation Plans;
- review of the Technical Manual on Soil Organic Carbon Management at the national and local scales;
- review of the concept note for an Economical Assessment on Sustainable Soil Management;
- preparation of a Protocol for the Assessment of Sustainable Soil Management;
- review of the concept note for the Global Report of the Status of Knowledge on Soil Biodiversity;
- continued cooperation with other scientific panels, such as the Science Policy Interface (SPI) of the United Nations Convention to Combat Desertification (UNCCD), the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), the Intergovernmental Panel on Climate Change (IPCC), as well as with “4 per1000” Initiative; in addition, pursuance of the Coordination of International Research Cooperation on soil Carbon Sequestration in Agriculture (CIRCASA), and assistance in the implementation of the Sustainable Development Goals (SDGs) as appropriate;
- preparation of a joint submission on soil organic carbon for the Koronivia Joint Work on Agriculture.

A. Concept note for the Assessment of the Economic Benefits of Sustainable Soil Management (SSM)

3. At the 5th session of the PA, the ITPS was asked to prepare a study on the economic benefits of SSM for farmers and other land users, as well as to identify best practices that prevent soil degradation. The aim of this study was to highlight possible motivation and incentive measures for expanded adoption of SSM practices. A specific working group was established within the previous ITPS membership that developed a concept note which was endorsed by the 8th working session of the ITPS for consideration of the PA. Further work on

this document by the Pillar I group of the present ITPS has resulted in the improved concept note included in Annex 2.

B. Protocol for the Assessment of Sustainable Soil Management Practices

4. The objective is to provide a framework about how the sustainability of soil management can be assessed through a set of indicators. It should also provide a starting point for regional and local assessments of SSM carried out under the Pillars of the GSP. The proposed protocol can be found in Annex 2.

3.2 Work programme for 2019-20

5. The ITPS work plan until mid-2020 would include the following:

- five working groups assigned to each pillar addressing (from the perspective of the ITPS) global and regional implementation plans;
- various working groups to prepare reports on the progress made in addressing the following priorities: soil biodiversity, soil erosion, soil salinity, soil organic carbon, and soil pollution.
- to initiate joint work with the UN Convention on Biological Diversity (CBD), the Global Soil Biodiversity Initiative (GSBI), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the European Commission (EC) towards the Report of the Status of Knowledge on Soil Biodiversity to be presented in the 15th CBD Conference of the Parties (COP), also contributing relevant information to be reflected in the second Status of World Soil Resources (SWSR) report;
- lead from a scientific perspective, the organization of the Global Symposium on Soil Biodiversity (March 2019);
- develop, review and implement outcomes of the GSER19, including:
    - Global Soil Erosion map following a multi-level, bottom-up approach,
    - Policy brief to cover technical elements on soil erosion;
    - Methodology to evaluate the costs of erosion and benefits of erosion prevention, remediation and mitigation practices, following a tiered approach.
    - Study on how society could compensate farmers for public benefits (ecosystem services) stemming from the implementation of soil erosion control practices.
- advise on the implementation of the GSOC17 recommendations including updating of the GSOCmap, the finalization of the Technical Manual for Soil Organic Carbon (SOC) Management and the preparation of the Global Soil Organic Carbon Sequestration potential map;
- advise on the implementation of the GSOP18 recommendations, including the Technical Guidelines for Assessing, Mapping, Monitoring and Reporting on Soil Pollution and the global assessment of soil pollution;
- advise on the preparation of the Global Black Soils map;
- preparation of articles/comments for publication in global journals.

3.3 Global symposia and follow-up actions

3.3.1 Report of the Global Symposium on Soil Erosion (GSER19)

6. The ITPS and the GSP Secretariat led the organization of the first Global Symposium on Soil Erosion (GSER19: http://www.fao.org/about/meetings/soil-erosion-symposium/en/) as mandated by the 6th PA of the GSP. Inputs were obtained from other FAO units, including the Joint FAO/ International Atomic Energy Agency (IAEA) Programme of Nuclear Techniques in Food and Agriculture, and the Science-Policy Interface (SPI) of the United Nations Convention to Combat Desertification (UNCCD)..

7. The symposium was held at FAO headquarters on 15-17 May 2019. It was attended by roughly 500 participants from 100 countries including representatives from FAO member countries, the organizing institutions, academic and research communities, relevant panels, private sector, farmer associations and civil society, as well as scientists and practitioners working in soil erosion assessment, remediation, and related fields.

8. The GSER19 was a milestone event, based on a very collaborative and inclusive approach. The major conclusions and recommendations as well as the way forward will be available in the outcome document entitled "Stop soil erosion, save our future".

9. A summary of the main conclusions and recommendations is given below:

- it has been amply demonstrated via scientific methods that soil erosion poses a worrisome threat to agricultural productivity, the environment and urban infrastructure. Tackling soil erosion is essential to the achievement of the SDGs, therefore it requires joint efforts to prevent, minimize and remediate it;
- soil erosion is accelerated due to human activities (unsustainable soil management, improper land use and land-use changes such as deforestation, overgrazing or intensive tillage); in this light, bold actions should be pursued to control and remediate soil erosion;
- as the main soil threat, the prevention and control of soil erosion should be a top priority worldwide and when present, rehabilitation actions under the framework of Sustainable Soil Management should be implemented;
- awareness raising on the importance of soils and the risks posed by soil erosion to the food system, the environment and urban infrastructure should constitute a key activity. These efforts should cover different target groups including decision-makers and the general public (particularly children and youth);
- there is a need for case studies in the different regions to address soil erosion in a complete and holistic manner (from assessment to rehabilitation and the associated cost-benefits), to build scientific evidence for and promote solutions;
- need to implement a global assessment of the status of global soil erosion using a country-driven process;
- to establish a working group to develop guidelines for implementation of effective policies to control soil erosion, including a database of good practices for addressing soil erosion control;
- to support the development and implementation of tools and guidelines that contribute to the fight against soil erosion, for instance regional policy briefs to inform policy-makers and foster action to control soil erosion;
- to establish an expert and multi-stakeholder working group to develop feasible and regionally contextualized guidelines for assessing, mapping, monitoring and reporting on soil erosion;

- to implement capacity building and training activities covering the full cycle of soil erosion – from its assessment to its remediation - including the strengthening of facilities for data analysis and management;

10. The ITPS is to take the leading role in the implementation of the recommendations of the outcome document "Stop soil erosion, save our future".

3.3.2 Progress on the implementation of the outcome document of the Global Symposium on Soil Organic Carbon (GSOC17)

11. The outcome document (http://www.fao.org/3/b-i7268e.pdf) outlined the way forward in relation to an increasingly relevant topic under the title of 'Unlocking the potential of soil organic carbon'. The ITPS and the Secretariat, together with partners have been working on implementing these recommendations. In a nutshell, the following tasks were addressed:

a. As requested by the 6th GSP Plenary Assembly, an interpretation document of the GSOCmap (the GSOCmap activities are explained in section 4.4.3) was prepared with focus on explaining the concepts behind this map and how it can be used by policy-makers and general public (the document can be found in GSPPA: VII/2019/04).

b. Technical specifications (GSPPA: VII/2019/04) for the Global Soil Organic Carbon Potential map have been developed using a bottom-up approach based on best available data and the implementation of a widely used and validated carbon simulation model. This work will require collaboration and interaction with country-designated modelling experts, capacity development and guidance by regional modelling experts, and the supervision by a SOC advisory group. The technical specifications were reviewed during the Fourth workshop of the International Network of Soil Information Institutions (INSII) and a recognized group of top SOC experts. The technical specifications will be shared with member countries for final review and then a capacity development process will be facilitated by the Secretariat and the ITPS. It is expected that the map will be finalized by December 2020.

c. The zero draft of the technical manual on soil organic carbon management at the national and local scales was prepared by a working group (established through an open call). This draft was submitted for review by the ITPS, the Intergovernmental Panel on Climate Change (IPCC), SPI-UNCCD Science and Technology Correspondents, the "4 per1000" Initiative and CIRCASA. Based on substantial comments and suggestions (which stressed inter alia that the document was too much of a scientific nature than a manual), an improved, summarized and harmonized version will be prepared for review by the panels. The final version will be launched during World Soil Day 2019.

d. The ITPS and the GSP Secretariat supported activities under the Koronivia Joint Work on Agriculture. A joint submission of the"4 per1000" Initiative, ITPS/GSP and SPI-UNCCD was prepared regarding the topic 2c): Improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management. Furthermore, RECSOIL a facility to move the SOC agenda into concrete implementation was prepared and a document regarding the SOC potential for offsetting aviation emissions was produced.

3.3.3 Implementation of the outcome document of the Global Symposium on Soil Pollution (GSOP18) including the Assessment of the Global Status and Regional Trends of Soil Pollution

12. The GSOP18 gathered more than 500 participants from 100 countries, including representatives of FAO member states, organizing institutions, the private sector and civil

society, as well as scientists and practitioners working on soil pollution assessment and remediation. Participants engaged actively in presenting the results of studies on soil pollution covering in particular: the sources and risks posed to food production and safety, human health and the environment; risk assessment approaches; and state-of-the-art techniques to remediate polluted sites. They also worked on the key messages to be reflected in the outcome document.

13. The eight recommendations of the outcome document http://www.fao.org/3/ca0362en/CA0362EN.pdf under the heading 'Be the solution to soil pollution' address the development of policies and actions to encourage the implementation of soil and land management practices that foster the prevention, minimization and remediation of soil pollution, as well as improving measurement, mapping, monitoring and reporting on soil pollution. The ITPS and the GSP Secretariat are currently addressing these recommendations with several activities as follows:

- a Global Assessment of the Status of Soil Pollution is to be conducted using a country-driven process in line with the United Nations Environment Assembly (UNEA-3) resolution "Managing soil pollution to achieve sustainable development" of December 2017, and the decision adopted by the 6th meeting of the GSP Plenary Assembly (page 7)[1], the GSP Secretariat has initiated the preparation of this global assessment together with ITPS, UN Environment and the World Health Organization (WHO). A questionnaire (https://goo.gl/forms/6lRX5oHweHTCEM352) has been developed to facilitate data collection on policies to prevent, control and remedy soil pollution; the number and extent of polluted sites; and the identification and location of potentially polluting activities. This approach will allow: 1) to better understand the problem of soil pollution at national and regional levels, 2) to build a global picture of the status of soil pollution, and, 3) to identify the main knowledge and legal framework gaps. To facilitate participation of countries in the development of this assessment, regional workshops are planned to discuss the main findings and recommendations that will be included in the final report, which will be presented at the 5th session of the United Nations Environment Assembly (March 2021), where decisions will be made on future actions to address soil pollution.

- tools and guidelines for contributing to the prevention and remediation of soil pollution are to be developed. The International Code of Conduct for the Sustainable Use and Management of Fertilizers has been prepared and discussed internationally and will be submitted to the FAO Conference for final endorsement in June 2019 (see section 4.1.3.). Training activities and workshops are to be organized to implement the Fertilizer Code at the national and regional level, including the development of regulations, awareness raising programs and other relevant tools for the dissemination of the main principles addressed in the Code.

- soil pollution assessment and minimization measures to be included in the Soil Doctors programme to support land users to maintain healthy soils under local conditions for long-term benefits.

[1] "The PA appreciated the positive outcomes of the Global Symposium on Soil Pollution and supported the preparation of a Global Assessment of Soil Pollution to be led by the ITPS in collaboration with other UN panels and organizations. The PA recommended the need to involve member countries in this global assessment following the successful approach of the GSOCmap. The PA also expressed that soil pollution needs to be addressed now starting at the political level and when doing so, the ITPS should explore not only the prevention and remediation, but also the adaptation to soil pollution"

- an expert and multi-stakeholder working group is to develop guidelines for assessing, mapping, monitoring and reporting on soil pollution. In September 2018, the GSP Secretariat launched an open call for experts to establish the working group. The working group is formed by 64 international experts. While a number of guidelines, books and scientific journals related to the scope of this technical manual have been published over the years, none covers all the aspects to be dealt with in this manual, which is intended to be a compendium of the latest information available in a single document. The final guidelines are expected to be ready by December 2019.

- a working group will develop guidelines for the management of polluted soils, including a database of good practices for remediating soil pollution. In September 2018, the GSP Secretariat launched an open call for experts to establish the working group. Fifty international experts now form the working group. The database will facilitate the search of soil remediation techniques by technicians, remediation workers, public and private agents, farmers and all other interested parties. This tool can help inform the preparation of polluted soil remediation projects, technical recommendations for companies, municipalities, environmental and legal licensing bodies, as well as students, professionals from different areas, gardeners and nursery owners. For developing countries, in particular, it may assist recovery projects in degraded areas; for example, implementing management and adaptation practices such as selecting crops that do not absorb contaminants or hyperaccumulators in certain areas to mitigate pollution.

- Implementation of the activities of the Global Soil Laboratory Network (GLOSOLAN), including harmonized methods to identify and measure soil contaminants. As part of the technical guidelines mentioned in GSPPA: VII/2019/04, a chapter on soil sampling and analytic methodologies for soil contaminants is to be prepared. This chapter will serve as a basis for discussion within the GLOSOLAN network on the harmonisation of methodologies related to the assessment of soil pollution.

- Actions to implement recommendation 3 and 6 of the GSOP18 outcome document are to be taken in a successive phase.

3.3.4 Preparation of the Global Symposium on Soil Biodiversity (GSOBI20)

14. As per the recommendation of the 6th GSP Plenary Assembly, the Global Symposium on Soil Biodiversity (GSOBI20) will be organized on 10-12 March 2020 at FAO headquarters. The ITPS and the Secretariat are working on the preparation of a concept note to guide the implementation of the symposium. The visual identity of the symposium was already prepared http://www.fao.org/global-soil-partnership/resources/highlights/detail/es/c/1183872/. The slogan which is in line with the World Soil Day theme 2020 is proposed as “Keep soil alive, protect soil biodiversity”. The Convention on Biodiversity (which welcomed this symposium in the recent COP13 https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-30-en.pdf), the UN Environment, the Intergovernmental Platform on Biodiversity and Ecosystem Services and the Global Soil Biodiversity Initiative will be invited to co-organize this important event.

3.4 Interface with other pertinent bodies and initiatives

15. The ITPS has been explicitly mandated to provide scientific and technical advice to other UN organizations and bodies with an interest in soils.

16. Therefore, the GSP Secretariat has worked towards continuing fruitful collaboration between the ITPS and other relevant panels, such as the IPCC, IPBES and the SPI of

UNCCD. In particular, the ITPS can enhance the work of these panels by providing specific knowledge and expertise in soil related issues. As evidenced above under various rubrics, the GSP Secretariat and the ITPS succeeded in establishing structured collaboration arrangements with the SPI of UNCCD, IPBES and the IPCC, especially via joint work for the symposia on Global Soil Organic Carbon, Soil Pollution, Soil Erosion, and the co-organisation of the next symposium on Soil Biodiversity. More information is given below.

17. **Collaboration with the SPI of UNCCD**

A work plan 2019-2020 was agreed among the two panels on the following topics: the scientific review of the Technical Manual on Soil Organic Carbon Management at national and local scale; the scientific review of the guidelines for the measurement, mapping, reporting, and monitoring of soil organic carbon; and the organization of the Global Symposium on Soil Erosion.

18. **Collaboration with IPBES, CBD and GSBI**

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, the Convention for Biological Diversity and the Global Soil Biodiversity Initiative will participate in the elaboration of the report entitled: “The Status of Knowledge on Soil Biodiversity” and will be co-organizers of the Global Symposium on Soil Biodiversity 2020.

19. **Collaboration with IPCC**

Given the increased attention to the role of soils within the climate change debate and negotiations, the ITPS is an observer organization within the IPCC structure and is therefore empowered to propose experts for the various IPCC assessments relevant to soils. In particular, the IPCC Special Report on Climate Change and Land was finalized by three ITPS members that were nominated as experts within the on-going IPCC reporting cycle.

20. **Collaboration with the 4pour1000 initiative**

The ITPS is a permanent observer in the Science and Technology Committee of the 4pour1000 initiative. Its Scientific and Technical Committee has been active in a thorough revision of the Technical Manual on Soil Organic Carbon Management, one of the outcomes of the GSOC17. A joint submission of the “4 per1000” Initiative, ITPS/GSP and SPI-UNCCD was prepared regarding the stream on soil organic carbon, soil health and soil fertility.

Annex 1: Concept note on the Economic Assessment of Sustainable Soil Management Practices

Concept note for the preparation of a study on the "Economic benefits of sustainable soil management for farmers and other land users"

1. Summary

Soil degradation, and the resulting effect on agricultural productivity, has a major impact on food security and nutrition. Food availability relies on soils: nutritious and good quality food and animal fodder can only be produced if our soils are healthy. A healthy living soil is therefore a crucial ally to food security and nutrition. Numerous and diverse farming approaches promote the sustainable management of soils with the goal of improving productivity. As a response to the need for sustainable soil management (SSM) worldwide, the Global Soil Partnership (GSP) developed the Voluntary Guidelines for Sustainable Soil Management (VGSSM). The latter focus on technical and biological aspects of soil, while facilitating potential choices and practices. However, there is a need for farmers and other land users to understand the benefits of adopting SSM practices, and this is what the forthcoming study aims to do. This concept note explains the need for assessing the economic benefits of sustainable soil management, provides examples of SSM practices, their potential benefits and possible consequences if they are not adopted, and gives a brief background of the economics of soil management and of cost-benefit analyses.

2. Introduction

Sustainable soil management (SSM) is critical to long-term human survival, as stressed in the revised World Soil Charter (FAO, 2015). The framework for SSM application in agriculture is further outlined in the Voluntary Guidelines for Sustainable Soil Management (VGSSM), a broad document that is voluntary in nature that was endorsed by the 155th session of the FAO Council in 2016. The VGSSM address sustainable management of soils in all types of agriculture systems and the maintenance or enhancement of the ecosystem services they provide, such as food production, climate regulation, and the regulation of water quality and quantity.

Though the necessity for SSM is widely recognized, its practical application may be limited by higher costs of crop production under SSM. Extra costs are incurred for additional measures to protect soils including for new/alternative/improved farming equipment, (Section 4). In many regions, farmers do not have available capital to cover up-front costs of SSM, especially if their investment would not be recompensed over time. There are three questions to be answered if we want to make SSM attractive for farmers:

1) Is it possible for the cost/benefit of SSM to be improved, compared to that of current soil management, through measures such as advanced technology application and more efficient use of agrochemicals?
2) Could the cost of SSM implementation be compensated in the future by higher or more profitable production and/ or better ecosystem services provision?
3) Could farmers and other land users be compensated by society for public benefit of SSM implementation?

Each of these questions needs to be addressed using the best available science and expertise.

On the other hand, soil degradation is also linked to high additional costs, and as part of the Global Erosion on Soil Erosion and this year's World Soil Day theme "Stop Soil Erosion, Save our Future", the GSP is looking at the economics of soil erosion prevention, management and remediation. The expected outcome of the symposium working group on the economics of soil erosion is to propose a cost-benefit analysis of erosion and erosion prevention, remediation and mitigation practices. This will be done by first providing guidance on the evaluation of the costs of erosion and an economic assessment of soil erosion management practices as a flowchart. The second part is to provide an erosion-specific template with an on-line (and off-line) tool and guidance for people to calculate the cost-benefit of erosion management activities in their specific situation.

While this concept note provides a general way forward, it was determined that a discussion will be held on this assessment during the Global Symposium on Soil Erosion. This discussion will help determine, with the help of environmental economists and other experts, whether the proposed methodology for the specific case of soil erosion could be up-scaled to cover the main soil threats and associated SSM practices, and a concrete way forward on how to proceed with this study.

3. Background

The revised World Soil Charter defines SSM as follows:

"Soil management is sustainable if the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced without significantly impairing the soil functions that enable those services or biodiversity." In other words, soil management is sustainable if food production, or other land use, can be maintained in the long term without adverse impacts on the soil, or wider environment, including downstream effects on water quality and biodiversity.

The issues to be addressed for maintaining the services listed in the VGSSM include soil erosion control, soil structure preservation, soil cover maintenance, soil nutrient management, soil water regulation, soil contamination prevention or reduction, prevention or remediation of salt accumulation, soil carbon content maintenance or enhancement, soil biodiversity maintenance, and minimizing the degradation of agricultural soils. Each of these issues requires careful management - and monitoring to ensure that ongoing sustainable soil management is achieved. Therefore, as a first step in assessing the economic effects of SSM, soil management practices need to be assessed against the definition of sustainable soil management and a set of suitable practices listed. A preliminary set of measures is summarized in Table 1.

Table 1. Examples[2] of sustainable soil management practices, their contribution to soil-related ecosystem services and functions, and the consequences of ignoring them[3]

SSM practices	**Benefits**	**<u>Possible</u> consequences of no-action**
Soil Erosion Prevention		

[2] It is important to note that the table only provides examples of SSM practices and not an exhaustive list of all existing SSM practices

[2] The Table does not include political actions or prerequisites for SSM implementation such as soil monitoring

No-till or conservation tillage application[4]	Reduced erosion, nutrient retention, prevention of SOC losses, improved physical soil properties, increased soil biodiversity	Decreased crop production, soil erosion, soil organic carbon and nutrient loss, increased greenhouse gas emissions, decreased soil biodiversity, decreased soil water holding capacity, increased sediment and nutrients in waterways, increased dust in atmosphere
Strip cropping	Reduced erosion, enhanced crop production/pest control, facilitates crop rotation	
Terrace formation and maintenance (associated with no-tillage)	Erosion control, soil water regulation and run off control	
Grass waterway formation	Traps sediment and nutrients to protect waterways, increased infiltration	
Manage livestock to prevent overgrazing and pugging	Retain vegetation cover to prevent erosion	
Wind breaks – lines of trees	Reduced wind erosion	
Sowing or planting cover crops	Soil cover maintenance, nutrient enrichment, organic carbon accumulation, biological activity and diversity maintenance, lower fertilizer use	
Improved fallow plants application		
Less use of fire to burn off plant cover		
Soil structure preservation or enhancement		
Reduction of heavy machinery use or keeping machinery to “tram lines”	Soil structure preservation, compaction prevention and increased infiltration.	Decreased crop production, excessive and/or “deep reach” compaction, decreased root penetration, decreased water holding capacity, increased surface water runoff, increased erosion, increased sediment and nutrients in waterways
Managing livestock to prevent excessive trampling and pugging		
Minimization of soil disturbance and restoration of disturbed topsoil	Soil structure preservation and biodiversity maintenance, erosion control, carbon and nutrient retention.	
Including crops with dense and fibrous root systems in crop rotations	Soil structure preservation, erosion prevention	
Improved soil nutrient management		
Optimizing fertilizer application methods and timing	Nutrient enrichment, contamination reduction, limit losses and promote crop nutrient uptake	Decreased crop production, greenhouse gas emission, loss of nutrients to groundwater or waterways, soil organic carbon loss,
The use of nitrification and urease inhibitors	Prevent loss of N to groundwater	
The use of slow release fertilizers	Nutrient enrichment, lower nutrients loss	

[3] Consider the potential risk of soil and water contamination through increased pesticide application

The use of inoculants that promote atmospheric nitrogen fixation or phosphorus solubilization	Nutrient enrichment, less use of fertilizers	deterioration of soil physical properties, increase in surface water runoff, decrease in soil biodiversity
The use of organic amendments and agricultural by-products	Nutrient enrichment, biodiversity maintenance, lower fertilizer use	
Effective liming (including the application of gypsum).	Soil pH increase, increased nutrient availability, decreasing Al toxicity, improved soil physical properties	
Crop rotations with legumes	Nitrogen enrichment, lower fertilizer use	
Crop rotation improvement	Increased nutrient availability, increased soil carbon, improved pest control/ management.	
Improved soil water management		
Improved irrigation water delivery and field application (e.g. drip irrigation) to reduce evaporation, match water application to crop needs	Soil water regulation, increased water use efficiency, reduced erosion and reduced contamination.	Decreased crop production, soil loss, soil organic carbon and nutrient loss, decrease in soil biodiversity, soil salinization, less efficient water use
Manage previous crops, forages, and fallows to increase soil water availability at sowing	Improved plant water availability and thus productivity, erosion control, run-off control, and biodiversity maintenance.	
Installation and maintenance of surface and sub-surface drainage systems	Soil water regulation, reduced erosion, salinization prevention	
Contaminant prevention or remediation in soils and water		
Best practice pesticide use	Improved crop production, Biodiversity maintenance, contamination reduction, improved soil and water quality	Productivity decline, adverse health effects, biodiversity decline, water eutrophication and pollution, Nutrient loss from productive land.
Minimization of outflows of irrigation water from paddy fields after fertilizer and pesticide applications	Soil water regulation, contamination reduction	
Utilization of riparian buffers and protecting wetlands	Reduction in sediment, contaminants, and nutrients reaching waterways	
Minimizing loss of agricultural lands		
Constrain urban development to less productive land or prevent urban sprawl.	Retains productive land in food production.	reduction in food production

4. Economic background

The broad concept of the Economics of Land Degradation (ELD) is based on the contrast between "action" that is implementation of SSM practices, and "inaction" that is the current farming or "business as usual" (von Braun et al., 2013). Though in this concept note we concentrate mainly on soils and on the management practices that benefit soil productivity and health, for economic assessment we have to include into the calculation the entire cycle of land management including; machinery and fuel cost, insurance, other costs a farmer has to pay, downstream environmental costs and benefits such as improved production, improved water use efficiency, and so on. It is often considered that "action" costs more than "inaction", which in practice is not necessarily true: for example, the recommendation to avoid soil disturbance does not lead to direct costs, though possibly leads to lost profit. Nonetheless, the perception of extra costs of SSM may be the main barrier for the implementation of the practices recommended for sustainable farming and land use.

To convince farmers and other land users to apply recommendations for SSM, we need evidence to show that investment in operations to combat soil degradation, and decline in soil-related ecosystem services, will be compensated by profit from increased crop productivity, better market performance, and/or the improvement of other ecosystem services. It makes no difference whether we show the benefit of SSM application as an increase in yield (and/or other ecosystem services) or a decrease in income due to unsustainable practices. The main benefit of SSM implementation is the increased sustainability of farming: non-sustainable farming practices may increase yields on a short-term basis, but over the long-term, the yield may decline, or additional investment would be required to maintain soil productivity at the same level. That is why it is important to assess the cost and benefit of SSM using a long-term planning horizon, at least 20-30 years.

Another important benefit of SSM is the increase in food quality. Balanced use of fertilizers and plant protection products will benefit food quality. Agricultural products of higher quality may be sold on a higher price, thus compensating the cost of SSM application. The consumption of more healthy food benefits human health, thus contributing to improvement in quality of life that may be regarded as an indirect added value of SSM.

According to the concept of total economic value (TEV) the cost of any action includes not only direct market cost of the output products, but also indirect values such as ecosystem functional benefits, future direct and indirect use values, values for leaving use and non-use values for posterity, and value from knowledge of continuing existence. The ELD approach widely uses the TEV concept to show the importance of reducing the rate of land degradation: the contribution of indirect use plus non-use values in many cases exceeds direct use value of an agroecosystem. However, the beneficiary of the profit other than direct use value is humankind and not the particular farmer who bears all the expenses. Thus, the mechanisms of transferring some part of the public goods produced due to SSM to the farmer should be discussed. The discussion of payment for SSM is not strictly private but of public order. Lands and soils have social functions and we cannot forget the role of governments in the implementation of economic and institutional mechanisms promoting land conservation.

5. Low-cost SSM practices

The implementation of SSM may vary in cost. "Passive" SSM may include, for example, the rejection of conversion of agricultural land to urban or industrial use, or avoiding the use of heavy machinery. However, just avoiding management that is potentially destructive for soils is only a prerequisite for farming sustainability and should be followed by additional activities to maintain soil productivity, which do have a cost. The rejection of a land use change such as

urban development commonly has economic consequences such as lost profit for the landowner. In places awareness rising might be enough for preventing farmers from application of soil-destructive practices, but a common challenge is that even a minor change in management practice can lead to additional costs. For example, rejection of burning stubble residues commonly favors soils carbon accumulation, biodiversity, and protects soil from erosion. However, if burning is avoided additional measures may need to be taken for weed and disease control. Thus, SSM cannot be regarded as completely free of cost, even if no formal action is taken.

Another situation where minor investment is required is the use of specific crop rotations, e.g. including legumes. The cost of such rotations may not exceed the cost of other, less sustainable rotation schemes by much.

Some SSM practices, especially those related to reduced tillage and accompanied by adequate rotations, are currently widely advertised to be both sustainable and profitable in any temporal scale, leading to "win-win" results. Reduced tillage is promoted as less expensive, favoring higher productivity, and protecting soils from erosion and organic carbon loss, while improving the pore continuity and soil strength. Lighter but sophisticated tools may be necessary for sustainable soil management. The equipment required for the no-till or minimal tillage techniques may be less expensive than conventional agricultural machinery. Recognizing the positive effect of practices such as no-tillage, at least in some environments, their use still requires further scientific and economic analyses. The results of application of minimal tillage approaches needs to be investigated under different biophysical and economic conditions and over time. Where the use of innovative practices requires acquisition of special machinery, the cost should be taken into account in the overall economic calculation.

There are some practices that require significant investment at the first stage, but the benefit from the initial investment may continue for decades. For example, terracing is an expensive practice, but it leads to a long-term reduction in water erosion, increased water-use efficiency, and may facilitate machinery use. When long-term planning is applied, the cost divided by the number of years is commonly lower than the benefits obtained. However, the cost and benefit of such practices may vary in a broad range depending on the available machinery, infrastructure, climate, type of crop grown, and on the geology and geomorphology of the slopes.

6. Cost-benefit analysis

Cost-benefit analysis is an important technique that is used to compare the streams of costs and benefits in order to determine the economic efficiency of a project and its associated management practices. The three ways that can be used to perform a cost-benefit analysis using the same input data and assumption are the following:

1. Net present value or net present worth (NPV or NPW): this measure is used to determine the difference between the present value of the stream of benefits and the present value of all the costs. A project (or certain component of a project) may only be accepted if this difference is zero or positive ($B - C \geq 0$).

2. Benefit and cost ratio (B/C ratio): Used to determine a ratio using present value of all the benefits in the numerator and the present value of the costs in the denominator. A project is considered to be economically sound or acceptable when the calculated value is larger than or at least equal to 1 ($B/C > 1$).

3. Internal rate of return (IRR): this is the discount rate, which, when applied to the stream of benefits and costs, produces an equal present value of both or a net present value of zero (A

discount rate when B = C, or B - C = 0). This particular rate is called IRR and represents the average earning power of the project's investment to be compared with other investments.

Each measure has its pros and cons. NPV shows the magnitude of the net benefit of a project and associated management practices but indicates nothing about returns per unit. B/C ratio and IRR give no indication of the magnitude of net benefit. Since they use the same set of data, all three measures could be used to obtain a more holistic picture.

7. Cost-benefit analysis of SSM implementation

At first glance, the calculations of the economic value of SSM practices seems simple: it is the difference between the monetary benefits of SSM and conventional practices. In turn, in a simplified way these benefits should be calculated as the difference between the direct use values of the agroecosystem under study and the costs of soil management. In this simplified calculation the direct use value equals the price of the yield obtained at the farm, and the cost includes that of labor, fuel, machinery and its depreciation, rent, fertilizers, pesticides, seeds, etc.

SSM may require the use of additional innovative equipment, and though such equipment may be less expensive than conventional heavy machinery, it needs to be purchased by the farmers, while regular tools are generally already available. Thus, the price of SSM introduction may be compensated only in the long term and creates an important barrier for SSM implementation for small farmers. Reduced used of machinery for tillage and farm management may require an increase in the use of pesticides at additional cost. Finally, labor costs need to be taken into account, because many SSM practices may require more intensive, and more qualified, labor. The cost of training of farmers and workers should be also considered, as well as other costs that are often disregarded such as the cost of soil or plant analyses for fertilizer optimization, or the cost of soil surveys and of environmental analyses for proper design of the SSM.

We can potentially calculate the difference in cost between implementation of a range of SSM practices and current farming methods for the individual practices listed in Table 1. However, several complications exist for the cost-benefit analysis of these practices, namely:

1. The economic parameters of each of the practices vary widely between countries and even regions depending on the crops, varieties, climatic and soil conditions, local/regional/national prices for the agricultural products and the cost of supplies, etc.
2. Each of the practices has numerous modifications due to historical traditions, as well as technical and economic facilities of each farm that may significantly modify the cost of application of these practices.
3. The list of possible practices is not complete and has to be tested against the definition of SSM.

Thus, cost-benefit analysis of SSM implementation may be achieved for an individual farm or site, if all the data is available, but scaling to a regional or level is challenging. Any universal calculation is hardly possible. It is therefore proposed that a template be provided as part of the study for the calculation of the cost-benefits of selected SSM practices at the farm/ site level. This template would be accompanied by examples/ case studies from around the world to provide the users with a better understanding of how it can be completed for the farm/ site of their interest.

8. Benefits of ecosystem services: may/should they be included?

Soil-related ecosystem services are not limited to the production of food, feed and fiber for humans. Several other services are also of major importance, the most significant of which include organic carbon storage, biodiversity maintenance, and water regime and quality regulation. Recent studies allow the assessment of the cost even of such non-market services as biological diversity (Robinson et al. 2009), implying that TEV for the benefits of SSM can be potentially assessed.

There are two main obstacles for the inclusion of multiple complimentary ecosystem services in the cost-benefit analysis of SSM. Firstly, the abovementioned soil-related ecosystem services have a big range of variation depending on the approach to cost assessment. The only universally established method exists for soil carbon accumulation cost, which is calculated on the basis of greenhouse gas emission prices on world stock-markets. Good progress was made for erosion cost estimation based on the loss of nutrients that is proportional to soil loss amount. For biodiversity and water filtering, multiple approaches exist. Secondly, farmers and other land users generally have little interest in the benefits of their management practices for ecosystem services until these benefits have an economic effect for themselves. It does not mean that land users are indifferent to public benefits, but they are not ready to pay for them out of their pocket. The inclusion of complimentary ecosystem services in the calculation would be possible only if their cost would be compensated to farmers by the local authorities. Another approach is the "Polluter pays principle", which makes the party responsible for producing pollution responsible for paying for the damage done to the natural environment. In this case, pollution is only one of the many threats to soil, and all soil degradation would be taken into consideration.

9. The case of soil erosion (the Global Symposium on Soil Erosion 2019)

The Global Symposium on Soil Erosion, or GSER19, 15-17 May 2019, tackles the economics of soil erosion prevention, management and remediation through the following proposed methodology:

Handling cost-benefit analysis of soil conservation measures is a major challenge. Indeed, in the literature very variable values can be found, depending on the characteristics of the case studies, on the general approach used, on whether on-site or off-site impacts are assessed, and on the scale of the assessment. Estimates of the costs of soil erosion are highly dependent on the methodologies and assumptions made in its valuation (Adhikari and Nadella, 2011). Estimating the marginal benefits and costs of such changes would assist investment decision making. The outputs of "theme 3" of the GSER19 will lead to a preliminary cost-benefit analysis of soil erosion management practices at the global level. The outcome will be reached following a two-step methodology:

1) Development of a flowchart and explanatory document:

The document produced will consist of a flowchart and an explanatory document which could be seen as a first option, a non-quantified (or roughly quantified, using estimates) way of identifying possible alternatives. A document will aim to provide guidance on using the flowchart, explaining specific terms and giving more details or examples when needed.

2) As a second choice, a tool will be set-up based on case studies and will include guidance for evaluating the costs of erosion. The tool will contain more precise calculations than the previous flowchart. It would be a "second choice" when information is available at the local scale. Some case examples of application of such a tool could be provided in a range of different situations, environments and practices. A database compiling all available case studies following the flowchart should be compiled, referencing all the possible information available. Then, all the required information should be assembled, and the process automated in order to provide the cost-benefit analysis at a specific position. GSER19 will be a first step in gathering case studies, referencing the relevant indicators and getting suggestions from participants on (i) the needs for such a tool and (ii) the resources needed.

At the symposium, a discussion will also take place on the economic benefits of sustainable soil management. This discussion will help determine, with the help of environmental economists and other experts, whether the abovementioned methodology for soil erosion can be up-scaled to tackle the main soil threats and associated SSM practices.

10. Conclusion

Economic assessment of SSM implementation is possible, but difficult and implies certain conventions. Since SSM has economic, technical and cultural barriers, we should assume in any economic analysis that policies for SSM implementation exist at national and regional levels, and that bank loans and technological solutions are available to farmers and other land users.

The economic benefit of SSM implementation should be calculated in the simplest way as the mere difference between the cost and benefit of any given management practice. The proposed analysis should take into account which SSM practices are more suitable for each site. A database should be developed of SSM management practices and the associated economic effect of each management practice. The assessment would be valid only if based on a location-specific basis taking into account the biophysical conditions, historical traditions and current socioeconomic conditions, which strongly affect the applicability and cost of SSM practices. Since the outputs of SSM widely range depending on multiple factors, the recommendations for the use of these practices should have a probabilistic character: the farmer or land user would see the upper and lower limit of benefits received by other agriculturalists compared with the invested costs. Science is expected to provide as much factor-related information as possible to guide the land users and/or local governments on the suitability of management for different climatic conditions, landscapes, soils, crops and varieties. Only a framework assessment of economic benefits of SSM is possible, while the major part of the work should be done at the farm/site level.

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Annex 2: Protocol for the Assessment of Sustainable Soil Management (SSM) – Guidance document

Prepared by Intergovernmental Technical Panel on Soils

Summary

Sustainable management of soil is a critical step in ensuring sustainable food production and thus human health and global security. The main objectives of this protocol are to provide a framework for land managers, farm advisors, and local government officials to use to help determine if current soil management practices are sustainable and, where practices are recognised as not sustainable, to identify potential actions to improve the sustainability of soil management. The protocol also seeks to assist in the establishment of a set of indicators to provide ongoing monitoring to ensure sustainable soil management (SSM) is achieved.

Guidance is provided to assess each of the eleven conditions or guidelines for a sustainably managed soil that were identified in the Voluntary Guidelines for Sustainable Soil Management (VGSSM) published by FAO in 2017. Six Key Steps are outlined that give a means to assess the sustainability of soil management. The Six Key Steps assess the important features of the site, potential natural and off-site threats, current management practices, selection of indicators to determine if current management practices are sustainable, collection and interpretation of indicator data, and implementation of improved management, where needed, along with the establishment of longer term monitoring to assess effectiveness of any changes in soil management. As many changes in soil are gradual, undertaking a monitoring programme, using indicators to assess changes over time, will assist in determining if soil conditions are improving, declining, or remaining stable.

1. Introduction

Sustainable management of our soil resource is key to sustainable food production, which is critical for human health, and food and nutrition security**.** The importance of sustainable soil management (SSM) is stated in the revised World Soil Charter (FAO, 2015):

> "The overarching goal for all parties is to ensure that soils are managed sustainably and that degraded soils are rehabilitated or restored."

The definition of Sustainable Soil Management in the revised World Soil Charter (FAO 2015) is as follows:

> "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"

In other words, Sustainable Soil Management means being able to grow food, fibre, or energy crops, or undertake other human activities that impact on soil, in such a way as to avoid adverse effects on the soil or the wider environment, including waterways, and biodiversity. If an activity is sustainable, that implies that it could be continued indefinitely.

In many cases, determination of whether current land management practices sustain the soil resource requires that the condition of the soil in relation to management is observed. For this

purpose, a set of soil indicators has been identified (Section 2, Table 1) which may be used to determine whether soil conditions are improving, remaining the same, or worsening. Selected indicators need to be practical, affordable, repeatable, and easily understood and interpreted. More sophisticated indicators may be used depending on available knowledge and resources.

Three key FAO documents refer to, and promote, sustainable soil management: the Revised World Soil Charter (WSC) (FAO, 2015), The Status of the World's Soil Resources (SWSR) report (FAO and ITPS, 2015), and the Voluntary Guidelines for Sustainable Soil Management (VGSSM) (FAO, 2017).

Sustainable Soil Management (through supporting sustainable food, fibre and fuel production while preventing adverse downstream effects and sustaining biodiversity) supports a number of Sustainable Development Goals (SDGs), including sustainable agricultural management (2.4) and sustainable forest management (15.2), as well as preventing land degradation (15.3) (UN General Assembly, 2015).

This document seeks to build on the existing work to provide a simple guideline to determine if current practices are achieving SSM. The overall intent of this protocol is to provide a starting point for regional and local assessments of SSM. The specific objectives are:

1. To provide a framework for practitioners, farm advisors, and local government officials to determine if current soil management practices are sustainable and, where practices are recognised as not sustainable, to identify potential actions to improve the condition of soils; and
2. To provide guidance to select and apply appropriate soil quality indicators to develop an ongoing assessment of the sustainability of soil management practices for any particular site or area.

2. What is a "sustainably managed soil"?

According to the Voluntary Guidelines for Sustainable Soil Management (FAO, 2017), sustainable soil management is associated with the following characteristics:

1) Minimal rates of soil erosion by water, wind, and tillage;
2) The soil structure is not degraded (e.g. soil compaction) and a stable physical context for the movement of air, water, and heat, as well as for root growth, is provided;
3) Sufficient surface cover (e.g. from growing plants, plant residues) is present to protect the soil;
4) The store of soil organic matter is stable or increasing and ideally close to the optimal level for the local environment;
5) Availability and flows of nutrients are appropriate to maintain or improve soil fertility and productivity, and to minimize their loss to the environment;
6) Soil salinization, sodification, alkalinisation and acidification are minimal;
7) Water (e.g. from precipitation and supplementary water sources such as irrigation) is efficiently infiltrated and stored to meet the requirements of plants and ensure the drainage of any excess;
8) Contaminants are below toxic levels, i.e. those which would cause harm to plants, animals, humans, and the environment;
9) Soil biodiversity provides a full range of biological functions;
10) The soil management systems for producing food, feed, fuel, timber, and fibre rely on optimized and safe use of inputs; and
11) Soil sealing (due to urban expansion etc.) is minimized through responsible land use planning.

3. Six Key Steps to assess Sustainable Soil Management

Six key steps have been identified to assess SSM. For each step, the key areas of information required are briefly discussed here. A series of templates (Appendix 1) have been provided that may be used to guide the collection of the information needed in each key step of assessing the limits to SSM. The templates are a guide and could be adapted or changed to suit the specific requirements of any given site. Collating all the relevant information using the templates provides a basis for making decisions on how to improve SSM. An example of completed templates is given in Appendix 2.

This document can provide only general guidelines, so where areas of concern are identified it may be necessary to undertake further research or consult appropriate experts to ascertain the best options for any specific site or conditions.

Step 1: General description of the location, soil, and land use

The objective of Step 1 is to gain an overall understanding of the site and any conditions that may support or hinder SSM, and to establish a site record. Important things to note include climate, topography, soil and soil variability, main farming activities, number of people supported, destination of products (food, fuel, fibre etc.), availability of labour, access to the site for both farming activities and to move produce out, and any particular problems or opportunities that people are aware of.

A template to support the development of an appropriate record and to give a guide to the features that need to be considered is included as Table A1 in Appendix 1. It is suggested that a map or diagram also be prepared that shows the key features of the site/area under consideration.

Step 2: Identification of natural and off-site threats

The local situation, both in terms of natural hazards and off-site threats, needs to be considered in deciding how best to manage a site/soil sustainably. Local events that may lead to, or exacerbate, soil erosion or exceed other limits to SSM, should be recorded and considered. Threats or conditions to consider include weather-related effects such as monsoon weather, tropical cyclones, and the frequency of storms and droughts. Topography and soil parent materials should be considered as steep slopes and weakly consolidated materials are more prone to erosion. Are there local pests or diseases that may limit SSM? Does the area have dry conditions that make soils susceptible to salt accumulation? Are there naturally high levels of potentially toxic metals in the soil/geological materials? Is the area prone to flooding or waterlogging?

Are there industrial activities in the region that have an adverse impact on the soil through air or water discharges? Do upstream activities such as irrigation or deforestation impact the site?

A template to guide the features that need to be considered is included as Table A2 in Appendix 1.

Step 3: Description of current soil management practices

Consideration of current soil management practices will provide insight into whether best practice is being utilised and whether current soil management is likely to be impacting, either positively or negatively, on SSM. What are the main activities? Is there any overall plan?

What is grown/harvested? What fertilisers/pesticides are used? What practices (if any) target protection of soil with respect to erosion, fertility, prevention of pollution, maintenance of soil organic matter, and others?

The main objective of Step 3 is to evaluate the effectiveness of current practices and prioritize to amend or avoid practices that are having the most negative effects and continue or enhance practices that are having a positive effect.

A template to guide the features that need to be considered is included as Table A3 in Appendix 1. Likelihood ratings of never or rare (zero or one), and severity ratings of Nil or minor (zero or one) imply that reasonable SSM is occurring. Likelihood ratings or severity ratings of three or four imply that actions should be considered to improve the SSM of a site.

Step 4: Selection, measurement, and recording of Sustainable Soil Management indicators

Potential indicators for assessing SSM, for each of the 11 characteristics of a sustainably managed soil (listed in Section 2 above), are included in Table 1. Carefully consider the list in Table 1 and determine which indicators are important to assess SSM at the site under consideration. They have been divided into simple indicators that can be readily recorded with minimal skills and equipment, and others that require laboratory access or more specialised field skills and equipment. The best indicators are those that can be applied with the existing knowledge of practioners, and which are affordable and easily repeatable by different operators (e.g. to re-measure at later dates to assess change over time). If resources allow, a wider range of indicators may be used to build a more detailed picture and provide improved confidence in the SSM assessment.

Which indicators are practical to measure at a given site? The selection chosen will depend on the resources and skills available as well as the likely factors that may be limiting SSM at any particular site. It may be necessary to undertake some research, or seek expert advice, to determine the best method to measure a selected indicator.

Once a set of suitable indicators, and the most practical methods to measure them, have been identified, the field and laboratory measurements will need to be undertaken to establish a baseline for the current soil conditions.

A suggested template to guide the recording of indicators is included as Table A4 in Appendix 1.

Complete the assessment form (Table A4) with a record of actual measurements and ratings of good, fair, or poor, for monitored values as appropriate. A rating of “good” would imply that the value is within the range expected for the area, and that no limitations to SSM are identified for that indicator. A rating of “fair” would imply that there is some room for improvement, but the indicator value does not suggest a major limitation to SSM. A rating of “poor” suggests that there is much room for improvement and that actions should be considered that could improve the SSM for that indicator.

Table 1. Possible Indicators to monitor the effectiveness of SSM (from VGSSM[1], FAO, 2017). Indicators marked in bold are a suggested priority minimum data set.

Characteristics of sustainably managed soil	**Indicators**		
	Easily undertaken	**Lab measurements and more specialized tests**	**Tools, knowledge and further suggestions to support the assessment**
1. Minimal rates of soil erosion	**General observation of loss of soil from site** - Evidence of erosion e.g. rills, sheet wash, landslides, sediment runoff to waterways **Frequency of wind or rain storms that result in erosion** **Frequency of field operations that result in soil movement** **Depth of topsoil and/or solum**	% Soil organic carbon **Turbidity and/or suspended solids in runoff water**. Soil erosion monitoring using erosion pins or Gerlach boxes	Imagery (satellite, aerial photographs) to determine vegetation cover and bare ground. Local knowledge about the management conditions (crop type, seasonality, machinery, mechanical operations) which favour or mitigate soil erosion Crop performance using indices
2. Soil structure not degraded	**Occurrence of surface seals/crusts or plough pans** **Density of living roots in the topsoil and subsoil** **Depth to which plant roots extend** Dispersibility and slaking Soil compaction	Soil penetration resistance Topsoil/plough pan porosity Description of Soil structure/aggregation **Dry bulk density of topsoil and/or plough pan**	Lack of aggregation (proportion of single grain structures e.g. from SOC loss) and block building (from tillage) as compared to expected natural soil structure Local knowledge about the stability of soil:
3 Sufficient surface cover to protect soil	**Estimate % bare ground during each season**		Remote sensed vegetation cover. Mulch or crop residue use to protect soil surface.
4. Soil organic matter stable or increasing	**Depth of A horizon** **Compare top soil colour to baseline** **Variability of colour across field**	**Topsoil organic carbon content**,	% field area with subsoil exposed Signs of soil water deficiency compared to SOC-rich soils
5. Adequate nutrient availability with minimal loss to environment.	**Crop yield/crop vigour** **Nutrient balances** (content of N, P, K and others, crop need, harvest loss) **Field soil pH test** **Symptoms of nutrient deficiencies in crops – leaf colour**	**Symptoms of nutrient deficiencies in crops or animals**. **Topsoil N, P, K, pH** Soil and plant trace elements and essential nutrients,	Some nutrients can be monitored by spectroscopy sensors (N, P), remote sensing Fertiliser managed to meet crop needs No nutrient loss in runoff or drainage Crop performance using indices
6. Minimal or absent soil salinization, Na accumulation, alkalinisation, acidification	**Visible salt on soil surface or in the soil profile** Presence of salt or acid tolerant plants **Low structural stability due to salt/sodium effects** **Field soil pH test.**	**Soil pH.** **Soil electrical conductivity** Soil ESP (exchange. Na %), SAR, Sodium Absorption Ratio	Knowledge about (ground-)water quality: current well depth compared to knowledge about the depth of salt-free aquifers Chlorides/ sulphates Irrigation water quality.
7. Water managed to ensure efficient infiltration, plant requirements met, and excess water drained effectively.	**Symptoms of plant moisture stress** **Availability of irrigation water if required** **Presence/absence of soil saturation or surface ponding** Irrigation application rate and method avoid runoff, ponding or excessive evaporation	Soil moisture % Total and readily available soil water holding capacity (0.1 bar – 1 bar, 15 bar) Accumulation of reduced mineral forms (NH_4^+)	Remotes sensed soil moisture status and vegetation status Assessment of soil moisture status as adequate for crop. Remote sensing of water ponding, saturated soil Signs of surface water accumulation, and stagnic properties Evidence of acid sulphate soils

	Drainage installed if needed **Soil colours that indicate lack of O_2 – blue/grey or mottles**		
8. Contaminants maintained below toxic levels.	**Potential contaminant sources – from atmospheric fall-out, industrial wastes, pesticides, fertilisers** etc. **Symptoms of plant toxicity**	Analysis of potential identified contaminants in soils and plants – metals, organic chemicals	Pollutants in soils require knowledge of previous activities, soil analysis, and the correct timing and dosage of products, minimizing harmful effects on accompanying vegetation and animals
9. Soil biodiversity maintained or enhanced.	Soil fauna (e.g. earthworm) counts. Use a light trap to catch and describe soil fauna.	Soil respiration rate Soil biodiversity (DNA). Microbial biomass/activity Entomology numbers and identification	Diversity of herbal flora (compare field margins with neighbouring less disturbed areas)
10 Safe use of inputs e.g. pesticides	**Pesticide use follows best practice guidelines**	Pesticide residues in soils. Cu and other potentially toxic elements that may be used for best control.	Integrated pest management Avoid non-specific broadcast pesticides where possible
11. Minimized soil sealing by concrete etc.	**Area (%) of land sealed under buildings, concrete, etc.**		Urban/paved extent determined from air photos or satellite images

[1] VGSSM = Voluntary Guidelines for Sustainable Soil Management.

It can be seen in Table 1, that knowledge about the local soil properties is beneficial to assess soil indicators. For this, the Guidelines for Soil Description (FAO, 2006) can be consulted ; it is an easy-to-comprehend manual which describes key soil properties. For some indicators, it is recommended to contact extension services and other advisors or laboratories. For several countries, soil analysis in support of planning fertilizer applications is supported, and the information received there helps to assess the nutrient and acidification status.

Some of the indicators require some training (e.g. soil animals, soil biodiversity, soil structure), or manuals (plant health, pests). The authors of this protocol envision that some additional material and guidance will be developed, which views and integrates existing manuals and training materials.

Step 5: Interpretation of the results and recommendations of improved practices to promote SSM

The objective in step 5 is to bring together the results from the previous steps to give an overview of the situation with regard to SSM of the site under consideration. With the identification of threats in steps 1 and 2, the characterization of current practices in step 3, and the data from indicators collected in step 4, we can then identify the main limitations to SSM. Where observations or monitoring indicate that there is a limit to SSM, it is important to consider what factors (both natural and management induced) are limiting sustainability.

Consider which of the 11 characteristics of a sustainably managed soil (Section 2, above) are being met? Which areas need more work to ensure that the soil is sustainably managed?

Where there is a need to improve SSM consider what new measures could be implemented. Table 2 provides a summary of possible SSM practices that may be usefully employed. What practices can be undertaken to improve the sustainability of the soil management? What are the limitations or barriers in doing so? What are the highest priority actions?

In identifying limits, or ways to enhance SSM Table 2 is intended as an initial guide. It may also be necessary to consider other activities (not included in Table 2) that are important in a

local area. As every situation is different, it may also be necessary to undertake further research to identify appropriate management practices, or to seek expert advice. The Voluntary Guidelines for Sustainable Soil Management (VGSSM) (FAO, 2017) provide an important source of information to help in improving practices.

It is important is to prioritize the practices that will provide the best improvement in SSM. The best practices will:

- be practical and affordable to implement,
- address the main threats to SSM, and
- provide the greatest improvement in SSM for the effort undertaken.

Where natural factors such as weather-related events impact SSM consideration should be given to what management techniques could be used to minimise the adverse effects. For example, ensuring that there is good vegetation cover to protect soils during the rainy season, preventing overgrazing during drought, and not ploughing soils on steeper slopes.

A suggested template to guide the determination of improvements in SSM practices is included as Table A5 in Appendix 1.

Table 2: Management practices that may adversely impact, or enhance, SSM for the 11 conditions/ guidelines for a sustainably managed soil (from VGSSM[1], FAO, 2017).

Characteristics of sustainably managed soil	**Management factors that may adversely impact Sustainable Soil Management**	**Management practices that may enhance Sustainable Soil Management**
1 Minimal rates of soil erosion	Intensive or inadequate tillage practices, bare-ground fallow periods (lack of vegetation and residues), over-grazing that leaves bare ground exposed. Poorly managed irrigation	No or reduced till crop establishment, terraces and waterways, contour ditches, vegetation cover maintained, contour ploughing, strip cropping, hedges, mulching, wind breaks, tree planting to prevent hillslope movement, live barriers[2]
2 Soil structure not degraded	Heavy machinery, vehicle traffic, livestock trampling, human trampling. Intensive or inadequate tillage practices, bare-ground fallow periods,	Ensure vehicles/people keep to main paths. Avoid stock trampling wet soil, avoid overstocking. Practices that enhance soil carbon accumulation including no-till, crop residue and compost incorporation. Vegetation cover maintained, Crop rotation, deep or strongly rooted plants.
3 Sufficient surface cover to protect soil	Ploughing Stock trampling Bare ground fallow	Mulch crop residues, Plant fallow season cover crop, No-till cropping
4 Soil organic matter stable or increasing	Tillage, excess N use enhances biodegradation of soil C, soil erosion leaving organic-poor horizons at the surface, and no addition of organic inputs	No-till, crop residue incorporation, compost or organic matter addition,
5 Adequate nutrient availability with minimal loss to environment	Fertiliser use too low to support crop growth. Crop harvested without nutrient replacement. Fertiliser in excess of crop requirements so nutrients are lost to environment.	Fertilisers managed in accordance with International Code of Conduct for the Sustainable Use and Management of Fertilizers Soil tests used to determine crop nutrient availability. Fertilisers balanced to meet crop requirements Minimal loss to runoff or groundwater, Legume crops to enhance soil N. Nutrients removed via crop harvest replaced. Organic matter/compost and crop residues added.
6 Minimal or absent Salinization, sodium accumulation, nor alkalinisation, nor acidification.	Irrigation with poor quality water, Irrigation without adequate drainage, Insufficient irrigation water applied to remove salts to drainage. Dryland salinity due to rising water tables maybe result of irrigation elsewhere or of tree removal. Use of acidifying fertilizers in soils with low pH buffer capacity, Drainage of coastal (acid sulphate) or inland (acid peat, bog) soils	Ensure well-managed irrigation with good quality water supply. Drainage installed if needed. Plant trees to lower groundwater table. Use gypsum as amendment to avoid sodification. Avoid excess drainage of peat, bog, & coastal lands; Use of non-acidifying fertilizers, Monitor pH and add lime (or alternative Ca source) if needed to increase soil Ph
7 Water managed to ensure efficient infiltration, plant requirements met, and excess water drained effectively.	Low efficiency irrigation (as surface flow irrigation methods, Irrigation at rates in excess of soil infiltration rate, excess irrigation water applied), Lack of drainage in slowly permeable soils, Practices that lead to unnecessarily high soil water tables.	Increase irrigation efficiency, Irrigation managed to avoid surface water ponding, drainage installed if needed to prevent water logging, soil surface managed to avoid compaction and low infiltration rates. Water added only to meet crop requirements. Soil coverings that allow greater infiltration and water retention in areas of low rainfall
8 Contaminants maintained below toxic levels.	Use of fertilizers, including manures, with high levels of contaminants. Using pesticides that are not readily biodegraded (e.g. Cu). Use of contaminated water for irrigation of crops Inadequate management of industrial contaminants Inadequate waste disposal	Ensure inputs and soil quality monitored – change fertiliser or pesticide regimes if necessary. Encourage regional pollution controls of air emissions etc. Use good quality water for irrigation – treat if necessary

9 Soil biodiversity maintained or enhanced.	Intensive or inadequate tillage practices (ploughing, use of heavy machinery), Inappropriate use of pesticides, Excessive application of chemical fertilizers	Ensure all pesticides used are safe for use in soil, pesticides only used on target organisms where necessary to ensure crop survival. Integrated pest management. Activities that enhance soil organic matter content.
10 Food, fibre, fuel production with optimised, safe use of all inputs.	All of the management practices listed above.	All of the management practices listed above.
11 Minimized soil sealing by concrete etc.	Uncontrolled urban sprawl loss of areas with fertile soils	Planning to provide city intensification and protect productive soils from urban or industrial sealing. Prevent rapid floodwater runoff, maximise water infiltration/groundwater recharge.

1. VGSSM = Voluntary Guidelines for Sustainable Soil Management.
2. There is always a need to consider trade-offs - for example installing such measures as contour ditches may lead to an increase in tillage erosion.

A.

Step 6: Design and implementation of ongoing management and monitoring plans

To ensure SSM, it is important to that improved management practices are identified, selected, planned and implemented. Ongoing monitoring also needs to be undertaken to determine the effectiveness of change, and to assess the sustainability of management over the long term.

Step 6 thus includes the development of a management and monitoring plan so that actions are planned and committed to in order to improve the sustainable soil management of the site. Consider the improved practices identified in Step Five, and their priorities. Which ones are currently affordable and have resources available to enact them? Consider both short and longer term changes. Develop a list of actions, in priority orde,r that need to be undertaken, who needs to do them, and when. Consider both actions to improve sustainable soil management, and indicators that will be most be useful for an ongoing monitoring programme. A suggested template to guide your decision making is included in Appendix 1, Table A6. Check out the example in Appendix 2 for ideas on how you might proceed.

4. Discussion and conclusion

It is unlikely that many sites can claim to be entirely sustainable in their soil management, so application of the protocol in these guidelines is intended to help raise awareness and lead to ongoing improvements over time. Any SSM practice must be site-specific as there are no universal solutions for the same problem. A management practice may be sustainable at one site but not at another. For example, crop residues on the soil surface may be sufficient to protect a soil from raindrop splash erosion at one site, but not at another. Practices need to be socially and economically sustainable, as well as environmentally sustainable. In the example in Appendix 2, the templates and Tables 1 and 2 provided a useful guide, but some alternative indicators and management practices were identified that better matched the environmental, social, and economic conditions of the site.

While an experienced farmer with some technical training may be able to complete the assessment, in many regions there is likely to be a need for some expert advice and technical input for identifying suitable indicators and for the observation of soils and their degradation processes.

The guidelines provided are likely to have the maximum effectiveness, and support an ongoing programme of improvement, if the indicators are kept simple, affordable, and do-able

by the land-owner. If the ongoing monitoring and record keeping is too onerous it is likely to be forgotten and not followed up.

At each level of operation, this protocol could be implemented by

- Farmers voluntarily, to optimise their own planning
- Farmers of a certain region and/or farm type
- Farmers operating under certain market and environmental conditions (e.g. in a water shed, or village, or other community or administrative region)
- Farmers advised by local experts or extension services
- Farmers of a demonstration network, or farmers who want to become demonstrators

Farmers, local community, and national government stakeholders will all benefit by working together to develop incentives to implement this protocol at farm level and to compile statistics (based on indicators) to use for policies and reporting.

5. References

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II. Appendix 1. Templates to guide SSM decision-making

Table A1. Step 1: General description of the location, soil, and land use

Site Information	Site name & address:	Location description:	Latitude: Longitude: Altitude: Area:	Other site info.
Assessor information	Names of assessors:	Date of assessment	Organisation	Contact email/phone
Climate	Mean annual rainfall	Mean annual temperature	Seasonal variability/conditions that may impact SSM	
Landform(s)	General description of landscape noting factors that influence SSM.			
Physical conditions	Topography, slope, aspect:	Underlying geological materials:	Soil Order(s) or other soil descriptor:	Soil variability:
Main farming activities	Activities undertaken:	Destination of products:	Opportunities for new or alternative crops?	Issues or problems with current land use?

Human activities	Number of local people supported:	Availability of labour and/or equipment	Opportunities/problems for local people? E.g., Site access…	

Make a diagram of the plot/field/ farm/region indicating different land use systems, topography, access roads, rivers, etc. If available, you might use a Google Earth base map.

Table A2. Step 2: Identification of natural and off-site threats

Threat	**Nature of threat**	**Likelihood of problem** **0=never,** **1= rare** **2=common,** **3 = frequent.**	**Severity of problem** **0=no problem** **1=minor,** **2=moderate** **3=disastrous**	**Comments**
Climate related	Drought Flood Intense rainfall Wind-storm Other climate event (specify)			
Physical site-related	Steep slope Soil drainage Salt accumulation Soil acidity Other Soil condition (specify)			
Off-site – industrial impacts	Contamination from air pollution Industrial waste Water pollution Other (specify)			

Upstream or other issues	Specify issue:			

Table A3. Step 3: Description of current management practices. *A copy of this table may be needed for each crop that is produced to differentiate between activities and management practices used for different crops in the same area.*

Activity	**Current Management practice**	**Effectiveness for crop production** **0= excellent** **1= moderate** **2=poor** **3=often crop failure**	**Effectiveness for Sustainable Soil Management** **0= excellent** **1= moderate** **2=poor** **3=severe soil damage**	**Comments**
Crops produced				
Fertiliser use				
Organic material use (including manure)				
Tillage methods				
Vegetative cover				
Weed and Pest control				
Water management and accessibility				

Soil conservation practices				
Other activities (e.g. grazing by livestock)				

Table A4. Step 4: Selection, measurement, and recording of SSM indicators

Characteristics of sustainably managed soil	**Selected indicator(s)**	**Measured value(s)**	**Sustainable Soil Management rating** **0= good** **1= fair** **2=poor**	**Comments and actions that could address any SSM issues identified (i.e. where ratings are 1 or 2).**
1 Minimal rates of soil erosion				
2 Soil structure not degraded				
3 Sufficient surface cover to protect soil				
4 Soil organic matter stable or increasing				
5 Appropriate nutrient availability				

6a Minimal or absent soil acidification				
6b Minimal or absent salinization, sodium accumulation, nor alkalinisation				
7 Water managed to ensure efficient infiltration, plant requirements met, and excess water drained effectively				
8 Contaminants maintained below toxic levels.				
9 Soil biodiversity maintained or enhanced				
10 Food, Fibre, Fuel production with optimised, safe use of all inputs				
11 Minimized soil sealing by concrete etc.				

Table A5. Step 5: Interpretation of the results identification of potential changes to improve SSM

Characteristics of sustainably managed soil	**Threat or practice that may cause concern**	**Level of concern: high, moderate or low?**	**Management practices that may improve sustainable soil management**	**Priority: high, medium or low?**
1 Minimal rates of soil erosion				
2 Soil structure not degraded				
3 Sufficient surface cover to protect soil				
4 Soil organic matter stable or increasing				
5 Appropriate nutrient availability				
6a Minimal or absent soil acidification,				
6b Minimal or absent salinization, sodium accumulation, nor alkalinisation.				
7 Water managed to ensure efficient infiltration, plant requirements met, and				

excess water drained effectively.				
8 Contaminants maintained below toxic levels.				
9 Soil biodiversity maintained or enhanced.				
10 Food, fibre, fuel production with optimised, safe use of all inputs.				
11 Minimized soil sealing by concrete etc.				

Table A6. Step 6: Design and implementation of ongoing management and monitoring plans

Improved practice (in priority order from Table A5 above)	Who is responsible	When to be implemented	Comments
Monitoring Plan			
Indicator	Who is responsible?	When?	Comments

Further comments – how good is the overall sustainable soil management at this site?			

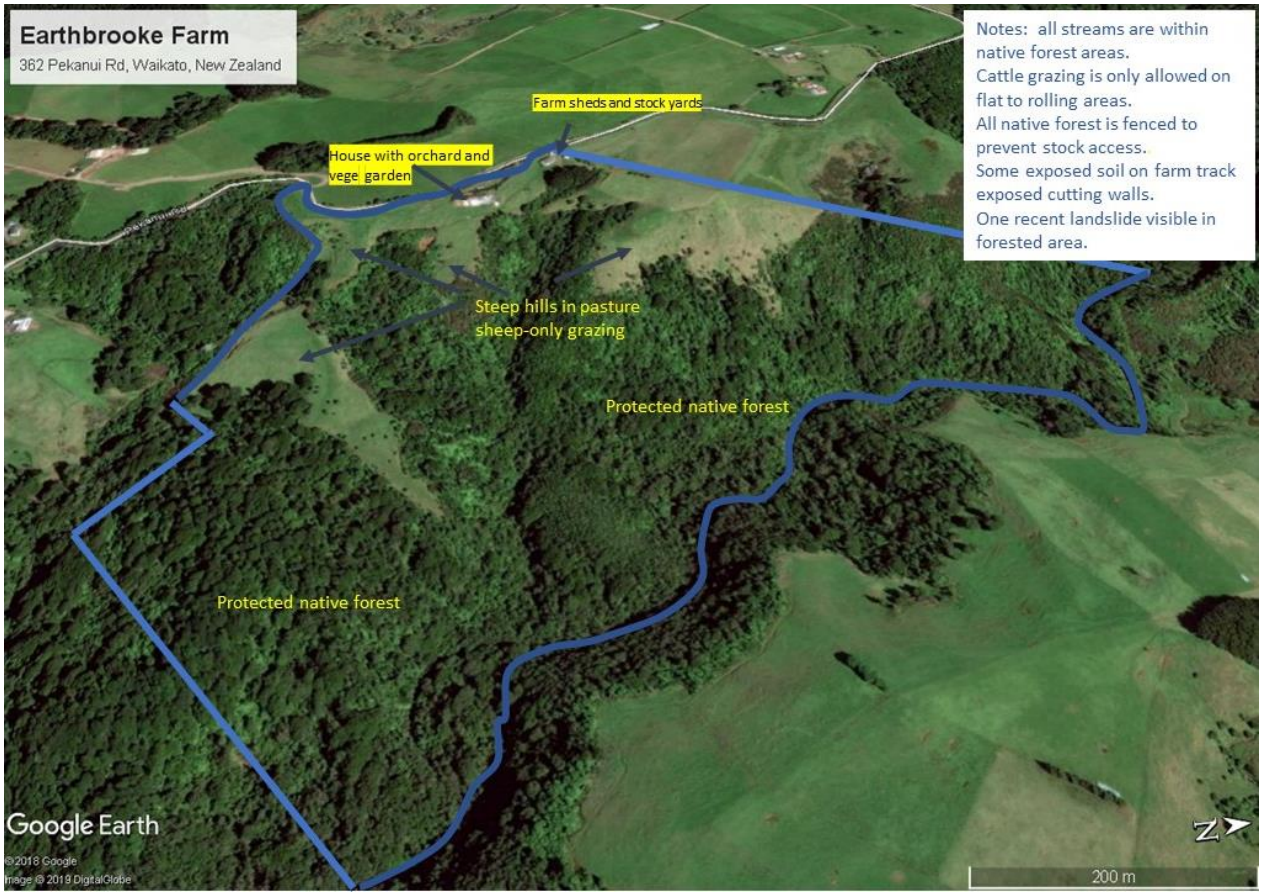
III. Appendix 2. Example of Templates in use

Site Information	Site name & address: Earthbrooke Farm, 362 Pekanui Road, Waikato, New Zealand	Location description: Lower slopes of Mt Pirongia, 3.6 km from junction of Pekanui and Ngutunui Roads.	Latitude: Longitude: Altitude: 150-300 m Area: 90 acres (36 Ha)	Other site info. Site is accessed by rural road and farm tracks, some steep areas have no vehicle access.
Assessor information	Names of assessors: Megan Balks	Date of assessment April 2019	Organisation University of Waikato	Contact email/phone M.balks@waikato.ac.nz
Climate	Mean annual rainfall 2 200 mm	Mean annual temperature 14 C°, few winter frosts, summer in 20s.	Seasonal variability/conditions that may impact SSM Area prone to high intensity rainfall, rainfall evenly distributed through year, occasional summer drought.	
Landform(s)	General description of landscape noting factors that influence SSM. On lower slopes of an extinct volcano, long ridges are interspersed with steep-sided river valleys. 2/3rds of the area is protected native forest that covers steeper slopes and stream/river margins providing protection from erosion. Forest areas are managed to support native flora and fauna, fenced to prevent access from grazing animals. 1/3rd of area comprises ridges and less steep hill slopes, which are in pasture used for grazing sheep with a few cattle on flatter areas.			
Physical conditions	Topography slope, aspect: Slopes range from very steep to rolling. Small flat areas on some ridge shoulders. Aspect: east and north	Underlying geological materials: Basalt rock overlain by Andesitic and rhyolitic tephra layers, deeper layers are strong clays.	Soil Order(s): Andosols and Ultisols (USDA), Allophanic Soils and Granular Soils (NZ).	Soil variability: Andosols on rolling slopes where younger tephras have accumulated. Granular soils on steeper areas.
Main farming activities	Crops grown: Sheep, beef and wool plus fruit and vegetables for home consumption.	Destination of products: Lambs and wool sold in local market. Beef mainly for home consumption.	Opportunities for new or alternative crops? Limited opportunity as hilly land is best suited to pasture or forest. Potential	Issues or problems with current land use? Farmed area too small for economic pasture farming or commercial forestry. Current

			for tree crops such as avocado on small areas. Niche value-add to wool. Eco-tourism.	incentives for C sequestration forestry are only for much larger areas.
Human activities	Number of local people supported: Two	Availability of labour and/or equipment Limited only by cost/benefit	Opportunities/problems for local people? E.g. Site access Owners could be self-sufficient in food (if needed) and fuel - firewood (heating), wind and solar power, but some off-site income is needed to pay for other living costs. Limits imposed by current planning rules that forbid any form of intensification such as increased horticulture. Tourism is current best opportunity for becoming self-sufficient without off-site income.	

Step 1: General description of the location, soil, and land use: Earthbrooke farm example.

Make a diagram of the plot/field/ farm/region, indicating different land use systems, topography, access roads, rivers, etc. If available, you might use a Google Earth base map.



Threat	**Nature of threat**	**Likelihood of problem** **0=never,** **1= rare** **2=common,** **3 = frequent.**	**Severity of problem** **0=no problem** **1=minor,** **2=moderate** **3=disastrous**	**Comments**

Step 2: Identification of natural and off-site threats Earthbrooke farm example.

Climate related	Drought	1	1	Floods occur reasonably often but do not affect our site due to high elevation.
	Flood	2	0	
	Intense rainfall	3	0-3	Usually intense rainfall has no detrimental effect, but potential to trigger large landslides that could be devastating if impacted house site.
	Wind-storm	2	1	Some treefall occurs with high winds, area recognised as high wind area and building laws require extra strengthening to ensure resilience.
	Other climate event (specify)			
Physical site-related	Steep slope	2	1	Steep slopes limit land to pasture or forestry and while generally stable, occasional landslides occur, even under natural forest cover.
	Soil drainage	0	0	
	Salt accumulation	0	0	Soil pH is low due to high leaching environment – free draining soils and high rainfall. Lime has been applied to amend and can be used again when needed.
	Soil acidity	2	1	
	Other Soil condition (specify)			
Off-site – industrial impacts	Contamination from air pollution	0	0	
	Industrial waste	0	0	
	Water pollution	0	0	
	Other (specify)			
Upstream or other issues	Specify issue: Occasional heavy runoff from neighbouring up-hill farm and road.	1	0-2	Runoff from neighbouring dairy farm and the road in intense rainfalls has potential to cause gully erosion, trigger landslides, and bring in sediment and nutrients. Road is low use rural road so minimal pollutants from road runoff.

Step 3: Description of current management practices: Earthbrooke farm example.

Activity	**Current Management practice**	**Effectiveness for crop production** **0= excellent** **1= moderate** **2=poor** **3=often crop failure**	**Effectiveness for Sustainable Soil Management** **0= excellent** **1= moderate** **2=poor** **3=severe soil damage**	**Comments**
Crops produced	Wool, lambs, beef			
Fertiliser use	P and K applied about every third year, lime applied when pH indicates needed – about once every 5-10 years, Co applied as trace to counter Co deficiency. Some hay brought in to feed cattle in winter.	1	1 – No off-site impacts – P levels are lower than ideal for farm productivity.	Soil tests are used to determine fertilizer application. Due to marginal economics of site P levels are lower than ideal for maximum production. Allophanic soil requires frequent P addition due to high P retention (about 99%). Clover encouraged to fix Nitrogen. Minimal off-site impacts from fertiliser use due to low inputs and large forest buffers to stream.
Organic material use (including manure)	Most sheep and cattle manure returned directly to pastures as animals are free-range. Sheep dung and compost on vegetable garden	0	0	All animal manure returned to pasture or used in home garden. Not economic to import organic fertilisers. Temperate climate permanent pasture means soils have high levels of organic matter in topsoil.
Tillage methods	No ploughing except small area of vegetable garden.	1	0	The farm has never been ploughed. Pastures are improved by over-sowing. No loss of soil from small sheltered vegetable plot.
Vegetative cover	Permanent pasture, native forest, some small areas of pine and gum trees for firewood.	1	0	Continuous vegetative cover maintained on most of the farm. A couple of very small areas adjacent to tracks would benefit from fencing to prevent stock, and revegetation.

Weed and Pest control	Animal health products control lice and intestinal worms. Zn to prevent facial eczema. Herbicides for weed control. Snail bait in vegetable garden	0 1 1 1	0 1 1 1	Applied directly to animals, used sparingly and only when necessary to ensure animal health, no measurable effect on environment. Potential for Zn to accumulate in soil, used rarely in small quantities. Weed control is necessary to maintain pasture. Hand spot spray rather than broadcast. Products that biodegrade rapidly and that are specific to target weeds are used.
Water, accessibility	Rain collected from roof and stored in tanks to supply household and stock drinking water plus irrigation of vegetables in dry periods.	0	0	Rainfall generally adequate to support non-irrigated pasture production. Occasional summer dry periods (1/8years) lead to early selling of surplus stock for lower return.
Soil conservation practices	Steepest areas and river margins in protected native forest. Pasture cover maintained at all times. No cattle grazed on steep slopes (sheep only). Some spaced poplar and other tree planting to help stabilise steep hillsides.	0	0	Need to undertake some work to prevent frittering of soil on excavated cuttings on edge of farm tracks, More spaced tree-planting to further stabilise hillslopes especially above track-cuttings would be beneficial.
Other activities	Predator pest control in native forest with careful use of approved poisons that are proven to be effective, biodegrade rapidly, and cause minimal	0	0	We have an extensive bait station programme to control introduced Australian Opossums and rats, as well as controlling wild pigs and goats. This is necessary to prevent extinction of native flora and fauna and thus maintain biodiversity. Regional Council also undertakes widespread Opossum control over our farm

	environmental harm and great benefit.			about once every 5 years for biodiversity control and to prevent TB in cattle that is spread by the Opossum.

Step 4: Selection, measurement, and recording of SSM indicators: Earthbrooke farm example.

Characteristics of sustainably managed soil	**Selected indicator(s)**	**Measured value(s)**	**Effectiveness for Sustainable Soil Management** **0= good** **1= fair** **2=poor**	**Comments and actions that could address any issues identified (i.e. where effectiveness ratings are 1 or 2).**
1 Minimal rates of soil erosion	Visible evidence of soil erosion.	One landslide (3 years old) in native forest, Cracks on two hill-side indicating potential slope instability, Soil falling off track cuttings, especially after dry periods.	1	Some hillslope movement in this environment (e.g. landslide in native forest) is a natural event. Increased spaced tree planting on unstable slopes could help stabilise. Fencing off stock from track margins and planting to get vegetation cover on steep cuttings. We sometimes observe sheet erosion on neighbours' properties when they have ploughed or had heavy stock trampling. We need to continue to avoid such practices.
2 Soil structure not degraded	Depth to which plant roots extend Excavation to check for compact layer in topsoil.	Grasses – 20-30 cm, gorse and trees >50cm. Minor area on tracks where unavoidable vehicle travel.	1 0	Grass root depth may be limited by low pH in subsoil. Need to monitor pH and add lime if needed.
3 Sufficient surface cover to protect soil	Visual observation plus google earth latest photo.	98 % - one small area on landslide in forest and one small area adjacent to a track.	1	Forest landslide area mainly left to naturally regenerate though we did add some "manuka slash" to provide some surface protection and introduce seed from a pioneering native plant. Area adjacent to track needs to be fenced to exclude stock and revegetated.
4 Soil organic matter	Depth and colour of A horizon	Dark blackish brown colour, about 15-20 cm.	0	There is no evidence of decrease in soil OM under present management.

stable or increasing				
5 Appropriate nutrient availability	Standard soil fertility tests – Olsen P, Soil pH, Ca, Mg, K, Na, Co, Mn, Fe, Cu, Zn,	Olsen P and Co very low, K low, others in good to high range. P retn 99%. pH 6.5 Details available on request.	1	Fertiliser with P, K, Co and Se was applied in response to tests in 2018/19. Next tests due in 2020/21.
6a Minimal or absent soil acidification,	Soil pH	5.5 in 2015, 6.5 in 2018 following lime.	0	High rainfall/leaching and fertiliser use means on-going pH monitoring needed.
6b Minimal or absent salinization, sodium accumulation, nor alkalinisation.	Not applicable			Not applicable no monitoring needed in this high rainfall environment.
7 Water managed to ensure efficient infiltration, plant requirements met, and excess water drained effectively.	Observe any incidence of ponding Ensure stock water reticulation maintained	None seen All trough and pipe system working well.		Rainfed agriculture on well drained soil so no water management issues.
8 Contaminants maintained below toxic levels.	Cd monitored with fertiliser soil tests.	Very low	0	No sources of contaminants identified. Cd is an issue in NZ where there has been high fertiliser inputs in the past, but not applicable here as history of minimal fertiliser inputs.
9 Soil biodiversity maintained or enhanced.	Earthworm presence/absence Starling population and breeding success	Earthworms are evident in pasture and garden areas. Starlings were successful in fledging chicks this year, not last year when dry spell meant no earthworms near soil surface at hatching time	0	Some bird species (starlings, king fisher, blackbird) rely on earthworms, along with other soil pasture pests such as grass grubs and Porina for food – observing bird breeding success and general numbers/presence is a good indicator of availability of soil fauna.
10 Food, fibre, fuel production with optimised,	Use of weed control herbicides	No issues identified.	0	

safe use of all inputs.	follows best practice.			
11 Minimized soil sealing by concrete etc.	Sealed area.	< 1 %		House, sheds, and main driveway are the only impermeable and non-productive areas. Unlikely to increase under current management.

Step 5: Interpretation of the results and identification of potential changes to improve SSM: Earthbrooke farm example.

Characteristics of sustainably managed soil	Threat or practice that may cause concern	Level of concern: high, moderate or low?	Management practices that may improve sustainable soil management	Priority: high, medium or low?
1 Minimal rates of soil erosion	Hillslope movement Track cuttings	Moderate Low	Space plant erosion control tree species such as poplar in areas of highest risk. Fence off and revegetate small affected areas	High Medium
2 Soil structure not degraded	Vehicle traffic on paddocks	Low	Ensure vehicles only on paddocks in dry conditions, and use only when strictly necessary.	Ongoing
3 Sufficient surface cover to protect soil	No current issues	Low	Watching brief to ensure no decline in vegetation cover.	Ongoing
4 Soil organic matter stable or increasing	Apparently stable	Low	Watching brief to ensure no change	Ongoing
5 Appropriate nutrient availability	Low P content limits productivity.	Low	Soil fertility tests every third year, maintenance fertiliser to replace nutrients removed with products sold.	high
6a Minimal or absent soil acidification,	High rainfall and fertilizer inputs could lead to decline in Soil pH over medium term	Low	Soil pH is monitored along with soil fertility tests.	Ongoing
6b Minimal or absent salinization, sodium accumulation, nor alkalinisation.	Not a risk in this environment	Low	No action needed.	
7 Water managed to ensure efficient infiltration, plant	Rely on rainfall, reduce stock numbers in dry periods if necessary	Low	Watching brief so action can be taken if necessary	Ongoing

requirements met, and excess water drained effectively.				
8 Contaminants maintained below toxic levels.	No issues	Low	No action needed	
9 Soil biodiversity maintained or enhanced.	No issues	Low	Observe bird populations as bioindicator. Pest control to maintain forest biodiversity.	Ongoing
10 Food, Fibre, Fuel production with optimised, safe use of all inputs.	Use of herbicides	Low	Herbicide matched to target plant, use of spot-spraying so avoid wide broadcast. Follow best practice guidelines. Operator certification as required.	Medium
11 Minimized soil sealing by concrete etc.	Avoid excess expansion of buildings or paved areas	Low	Watching brief	Ongoing

Step 6: Design and implementation of ongoing management and monitoring plans: Earthbrooke farm example.

Improved practice (in priority order from Table A5 above)	Who is responsible	When to be implemented	Comments
Erosion control tree planting on steeper hills in pasture	Land owners	Winter - staged over next five years.	Trees will need protection from browsing animals for first few years. Poplars are likely to be most effective for erosion control but other species should be considered for aesthetic, wildlife, tree crop production, wood production, and stock fodder potential.
Ongoing monitoring and management of soil fertility	Land owners	At least once per three years, more frequently if finances allow.	Updated soil fertility tests done and appropriate fertiliser applied.
Fencing and revegetation of track margins where bare soil is exposed	Land owners	Winter of 2019 with ongoing maintenance.	This is a relatively small job, so could be implemented readily. If earthworks are decided to be used to recontour, to remove steep banks, small areas will need to be done each year to avoid breach of planning rules. Appropriate sediment runoff controls will have to be implemented.
Investigate potential for increased plantation exotic forest	Land owners	2020	Undertake once new government rules related to forestry and carbon sequestration are clear.
Monitoring Plan			

Indicator	Who is responsible?	When?	Comments
Visible evidence of soil erosion.	Land owners	Monthly – record annually	Ongoing vigilance is needed
Depth to which plant roots extend Excavation to check for compact layer(s) in topsoil.	Land owners	Annually Annually	
Visual observation of bare ground plus google earth latest photo.	Land owners	Seasonal, record annually	
Depth and colour of A horizon	Land owners	annually	
Standard soil fertility tests – Olsen P, Soil pH, Ca, Mg, K, Na, Co, Mn, Fe, Cu, Zn, plus Cd and Soil pH.	Land owners - use accredited laboratory for analyses.	At least every 3 years	
Observe any incidence of ponding	Land owners	After heavy rain	
Earthworm presence/absence	Land owners	Annually in spring	
Starling bird population and breeding success	Land owners	Annually in early summer	
Sealed area.	Land owners	Annually.	
Further comments			
This farm has been managed for low intensity pastoral agriculture and because of its small size (by NZ standards), it is not an economic unit for sheep farming alone. Overall, it demonstrates a high level of sustainable soil management with some small concerns for hill slope mass movement. While there is potential to improve soil fertility to increase stock carrying capacity, and thus food production, this is currently forbidden under local planning rules (which are aimed at our much more intensively farmed neighbours). For sustainable soil management, cattle need to be kept off the steeper slopes, as is currently the case. Potential for horticultural development is limited by current planning rules that prevent intensification. There is potential for exotic forest planting but small areas are unlikely to be economic and do not qualify for current carbon sequestration incentives. Eco-tourism is an option for increasing on-farm income.			