Food and Agriculture
Organization of the
United Nations

Protocol for the assessment of Sustainable Soil Management

itps
INTERGOVERNMENTAL
TECHNICAL PANEL ON SOILS

GLOBAL SOIL
PARTNERSHIP

Protocol for the assessment of Sustainable Soil Management

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2020

Recommended citation:

FAO-ITPS 2020. *Protocol for the assessment of Sustainable Soil Management*. Rome, FAO.

Contents

Contributors

General coordination:
Ronald Vargas Rojas (*FAO-GSP*)

Managing Editors:
Carolina Olivera (*FAO-GSP*), Zineb Bazza (*FAO-GSP*),
Megan Balks (*ITPS*), Rosa Poch (*ITPS*)

Contributors:

- Ahmed Elgubshawi, *Bahrain*
- Alberto Origazzi, *European Union*
- Aleksi Lehtonin, *Finland*
- Alireza Moridnejad, *IRAN*
- Amanda J. Ashworth, *USA*
- Amanullah, *Pakistan*
- Andre Franco, *Global Soil Biodiversity Initiative*
- Andrea Spanischberger, *Austria*
- Anthony John Mouzas, *Cyprus*
- António Perdigão, *Portugal*
- Antonio Sanchez, *Venezuela*
- Arkadiy Levin, *Ukraine*
- Arwin Jones, *European Union*
- Bente Foreid, *Norway*
- Bernard Fungo, *Uganda*
- Bo Sun, *China*
- Bravo Peeters, *European Union*
- Cairo Robb, *United Kingdom*
- Charles Rice, *USA*
- Christian Omuto, *FAO-GSP*
- Clara Lefevre, *FAO-GSP*
- Claudia Rojas, *Chile*
- Cristina Grandi, *Italy*
- Dan MacDonald, *Canada*
- Daniella Wetten, *Malawi*
- Dardo Escobar, *Argentina*
- David B. Knaebel, *USA*
- David Lobb, *ITPS*
- Deyanira Lobo, *Venezuela*
- Diana Wall, *Global Soil Biodiversity Initiative*
- Edoardo Costantini, *Italy*
- Ekaterine Sanadze, *Georgia*
- Elmobarak Elhag, *Sudan*
- Emanuele Lugato, *European Union*
- Erica Lumini, *Italy*
- Fernando Delgado Espinoza, *Venezuela*
- Fernando garcia Prechac, *Uruguay*
- Filiberto Altobelli, *Italy*
- Gabriella Rossi, *Italy*
- Gaius Eudoxie, *Grenada*
- Generose Nziguheba, *ITPS*
- Gerardo Ojeda, *Colombia*
- Giuseppe Corti, *Italy*
- Guedon Jean, *France*
- Guillermo Peralta, *Argentina*
- Gulchekhra Khasankhanova, *Uzbekistan*
- Hans Brand, *The Netherlands*
- Hanspeter Liniger, *WOCAT*
- Hervé Guibert, *France*
- Idrissa Boubacar, *Niger*
- Ieda de Carvalho Mendes, *Brazil*
- Igor Vidal, *Brazil*
- Iman Sahib Salman, *Iraq*
- Ingeborg Bayer, *Germany*
- Jacques Tavares, *Cabo Verde*
- Jesus Viloria, *Venezuela*
- Jin Ke, *ITPS*
- Juan Carlos Rey, *Venezuela*
- Juan Comerma, *Venezuela*
- Julien Demenois, *France*
- Klaas Mampholog, *South Africa*
- Laura Bertha Reyes, *IUSS*
- Lenin Medina, *Mexico*
- Luca Montanarella, *European Union*
- Lucia Anjos, *ITPS*
- Lucrezia Caon, *FAO-GSP*
- Lydia Chabala, *ITPS*
- Manuel Carrillo, *Ecuador*
- Marc Van Liedekerke, *European Union*
- Maria Fanta, *Italy*
- Maria Konyushkova, *ITPS*
- Marija Dragovic, *Serbia*
- Martha Bolaños, *ITPS*
- Martin Yemefack, *Cameroon*
- Maya Zahavi, *Israel*
- Melissa Lis Gutierrez, *Colombia*
- Mirco Barbero, *European Union*
- Mirelys Rodriguez Alfaro, *Cuba*
- MonicaFarfan, *Global Soil Biodiversity Initiative*
- Nader Noureldeen Mohamed, *Egypt*
- Nakasi Harriet, *Uganda*
- Napoleon Ordoñez, *Colombia*
- Nat Tuivavalagi, *Micronesia*
- Natalia Rodriguez Eugenio, *FAO-GSP*
- Nopmanee Suvannang, *Thailand*
- Olga Lucia Ospina, *Colombia*
- Panos Panagos, *European Union*
- Patricia Verástegui Martinez, *Spain*
- Paul Luu, *4 pour 1000*
- Pilar Andrés, *Spain*
- Rémi Cardinael, *France*
- Reynaldo Bismarck Mendoza, *Nicaragua*
- Rosa Cuevas, *FAO-GSP*
- Rosario Napoli, *Italy*
- Samual Francke, *ITPS*
- Samvel Sahakyan, *Armenia*
- Sarkal Jyakhwo, *Nepal*
- Saud Al Farsi, *Oman*
- Serghei Corcimaru, *Moldolva*
- Sol Ortiz Garcia, *Mexico*
- Somsak Maneepong, *Thailand*
- Su Su Winowiecki, *Myanmar*
- Tarik Topcu, *Turkey*
- Tom Bruulsema, *Canada*
- Tusheng Ren, *China*
- Ummed Singh, *India*
- Vinisa Saynes, *Mexico*
- Volodymyr Ivanov, *Ukraine*
- Yuxin Tong, *FAO-GSP*

Edition and publication:
Hugo Bourhis (*FAO-GSP*)
Isabelle Verbeke (*FAO-GSP*)

Art direction:
Matteo Sala (*FAO-GSP*)

Photo credits:
Alejandro Polo, Carolina Olivera, Guillermo Peralta, Instituto Geográfico Agustin Codazzi, Javier Otero, Juan Carlos Durán, Matteo Sala

Preface

Our planet is currently facing a number of global challenges that put pressure on our natural resources; the basis for our daily lives. Urban sprawl, climate change, poverty, food insecurity, loss of biodiversity, pollution, migration, pandemics constitute some of the global issues that we need to take into account if we are to achieve our aspiration for sustainable development. Now more than ever, the role of healthy soils is globally recognized by different stakeholders, especially in the era of climate change. Soils provide ecosystem services that enable the resilience of life on Earth.

The importance of sustainable soil management (SSM) for the United Nations system and all international organizations is unambiguously stated in the Revised World Soil Charter (FAO, 2015): the overarching goal for all members is to ensure that soils are managed sustainably and that degraded soils are rehabilitated or restored.

The Intergovernmental Technical Panel on Soils (ITPS) and the Secretariat of the Global Soil Partnership (GSP) have identified the need to develop a protocol to assess if a given soil management practice is in line with sustainable soil management, as defined in the Voluntary Guidelines for Sustainable Soil Management (FAO-ITPS, 2015). A first draft was developed and presented at the 6th GSP Plenary Assembly (PA), where it was recommended to further refine the document. A new version was developed, which provides a practical method for different stakeholders to determine if current soil management practices are sustainable and, if not, to identify possible actions to improve their sustainability. This document was submitted to the 7th GSP Plenary Assembly and members expressed their request to review the indicators that were selected. After intensive and inclusive work, a final draft was submitted to the 8th GSP Plenary Assembly in June 2020 and was endorsed in principle and requested a final refinement which was welcomed at an ad-hoc session held in September 2020.

The present protocol constitutes a fundamental tool to assess if any intervention implemented in the field, such as improvement of productive systems, innovation and new technologies, ecosystem restoration and carbon sequestration, is carried out in a sustainable manner according to the definition of sustainable soil management. In practical terms, the protocol provides key indicators and a set of tools to assess soil functions based on its physical, chemical and biological properties.

This protocol is a living tool that will be improved in 3 to 5 years based on the evidence gathered from its application on the ground in the different regions of the world.


Ecosystems services
Sustainable development
Food security and nutrition
Climate change adaptation and mitigation

1. Introduction

The objective of this protocol is to provide a framework, based on a set of indicators, for government officials, NGOs, and other stakeholders involved in development projects, to determine if implemented soil management practices are sustainable and in line with the definition of Sustainable Soil Management (SSM) included in the Voluntary Guidelines for Sustainable Soil Management (VGSSM) (FAO, 2017). This protocol and its indicators, parameters, and methods should be regularly revised and updated according to the evolution of soil sciences and the results obtained during its use in the field, reflecting local, national and regional realities. The measurement of recommended indicators provides an evaluation of a soil's ability to maintain prioritized ecosystem services, and therefore improve farmers' productivity and income in a sustainable manner. This document is built on existing work of the FAO's Global Soil Partnership (GSP): the revised World Soil Charter (WSC) (FAO, 2015), The Status of the World's Soil Resources (SWSR) report (FAO and ITPS, 2015), and the previously mentioned Voluntary Guidelines for Sustainable Soil Management.

The VGSSM define Sustainable Soil Management (SSM) as:

"*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*".

Following this definition, the elements to be considered for the assessment of SSM are:

a. Supporting and provisioning services for plant growth for food, livestock, fibre and forestry;
b. Supporting services for below ground biodiversity;
c. Regulating services for water quality and quantity; and
d. Regulating services to increase carbon sequestration and limit the emission of greenhouse gases.

In other words, a sustainably managed soil has the ability to grow food, fibre or energy crops, or undertake other human activities that have an impact on soil, in such a way as to avoid adverse effects on the soil or the wider environment, including waterways and biodiversity.

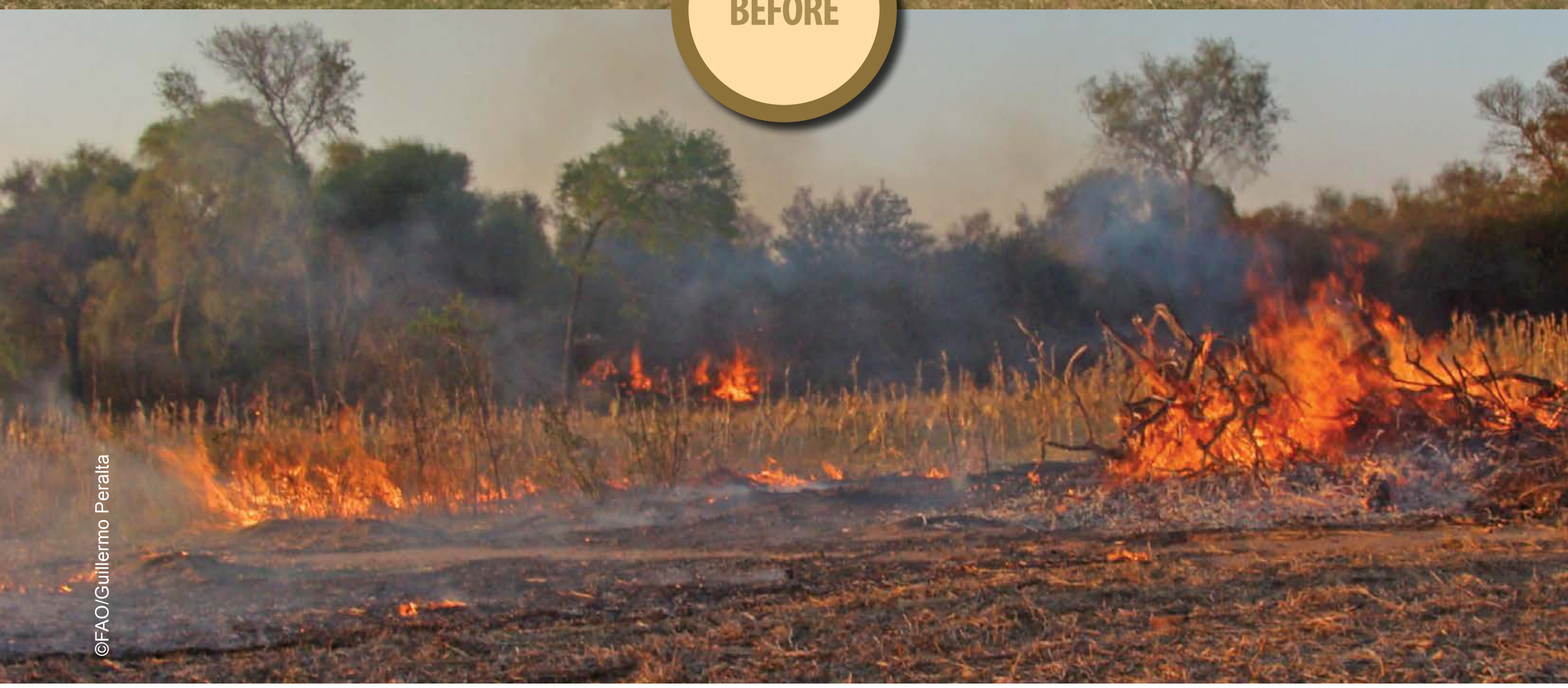
SSM supports a number of Sustainable Development Goals (SDGs):

- Sustainable productivity (SDG 2: ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, and that progressively improve land and soil quality).
- Soil water availability (SDG 6: freshwater withdrawal as a proportion of available freshwater resources).
- Soil pollution (SDG 11: Make cities and human settlements inclusive, safe, resilient and sustainable)
- Sustainable use of agricultural inputs (SDG 12: achieve the management of chemicals and all wastes, and significantly reduce their release to air, water and soil).
- Soil carbon capture (SDG 13: Take urgent action to combat climate change and its impacts).
- Soil degradation (SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

2. Sustainable Soil Management indicators

Sustainable Soil Management indicators were selected, after consultation with stakeholders working in the field of soil science and agricultural development, to assess the effectiveness of implementation of selected SSM practices in varying circumstances, including different soil types, climate, and food production systems.

The measurement of recommended indicators evaluates a soil's ability to maintain the ecosystem services identified above (points a) to d) above). The selected indicators (Table 1) can be analyzed in order to obtain an assessment of Sustainable Soil Management.



2.1 Comparison to a baseline reference or to an adjacent control

Given the great variability of soil properties, even within the same area, soil indicator measures cannot be compared to those evaluated in a different site. For each SSM assessment, a baseline or control must be identified, to determine the differences with the study area. This means that value(s) obtained, must be compared with values measured before SSM practices were implemented (baseline), or eventually with an adjacent area where SSM measures have not been applied (control).

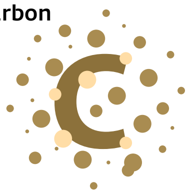
The baseline or control area samples must be taken in the same conditions and during the same period (same weather conditions, same stage of crop cycle). The soil samples must also be analyzed using the same laboratory methods and sampling protocols.

2.2 Recommended set of SSM indicators

The recommended set of indicators for the assessment of SSM (Table 1) can be measured in the laboratory. These indicators were chosen as they are sensitive to change following the implementation of SSM, and can therefore assess, by proxy, the changes in selected soil properties that are crucial in sustainably managed soils.

The recommended indicators were also chosen as they are widely developed, and rely on internationally established and harmonized measurement methods. They are considered as reference indicators for all the additional indicators that might be implemented, as needed, by protocol users.

Table 1. Recommended indicators that can be monitored to assess Sustainable Soil Management [1]

Indicator	Parameter/ metric	Measurement methods[2]	Sample characteristics[3]
Soil productivity 	Agricultural productivity or biomass in dry matter ($t\ ha^{-1} year^{-1}$)	Dry weight of vegetation quadrats, or yield measurements	Quadrat method or yield measurement
Soil organic carbon 	Organic carbon (%)	Walkley- Black method *http://www.fao.org/3/ca7471en/CA7471EN.pdf* or Dumas method *http://www.fao.org/3/ca7781en/ca7781en.pdf*	Representative soil sample
Soil physical properties 	Bulk density ($kg\ dm^{-3}$) In some cases, bulk density can be complemented by available water capacity, or other relevant soil physical properties *(See additional indicators)*	The Core Method	Undisturbed representative sample with known volume
Soil biological activity 	Soil respiration rate ($gCO_2\ m^{-2}\ d^{-1}$) Ideally combined with at least one other biological indicator *(See soil biological activity p. 4 and 5)*	Laboratory based soil respiration measurement (static or dynamic) The most common methods will be presented in the annex.	Representative soil sample to be analyzed within hours or refrigerated

1 This is not an exhaustive, exclusive or mandatory list, and other parameters can be adopted according to national prevailing scientific knowledge and capacities.
2 The Global Soil Laboratory Network (GLOSOLAN) is working on developing standard and global methodologies for soil tests. For more information visit the following website: http://www.fao.org/global-soil-partnership/pillars-action/5-harmonization/glosolan/en/
3 For sampling instructions for all the indicators cited, please refer to Annex 1.

Soil productivity is the soil's ability to produce biomass, whether for agricultural, forestry or environmental purposes. While productivity is an indirect indicator of the status of a soil, it is a critical indicator of the overall impact of SSM practices. For the assessment of SSM, agricultural productivity should be measured using the same product (e.g., maize yield, forest biomass etc.) and input conditions (fertilizer input, type of farming etc.), through total yield weight or an estimation of dry biomass per surface unit.

Soil organic carbon (SOC) is a commonly recognized indicator that reflects the chemical, physical and biological status of a soil, responding to change through the implementation of SSM practices. SOC has a direct relationship with soil nutrient availability, soil structure and aggregate stability, soil porosity, water retention capacity, and the presence of macro, meso and micro soil fauna. For the assessment of SSM, SOC can be measured in the topsoil (30 cm) as a percentage of organic matter in the soil.

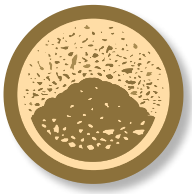
Soil physical properties are represented by soil bulk density (BD), which measures the mass of oven dry soil per unit volume. Changes in BD give an indication of changes in soil structure, porosity and compaction, and indicate how readily water, air and plant roots can move through the soil.

Soil biological activity is a good indicator of life in the soil. Soil biological activity is affected by edaphoclimatic conditions, also including salinity and pollution, and can reveal the persistence of soil degradation if the activity is low despite non-limiting nutrients, moisture and temperature. Soil respiration is a reliable method for measuring biological activity in the soil and is used in both laboratory and field-based assays. However, it is important to follow sampling indications, as biological parameters are very sensitive to external conditions. **For a better interpretation of the results obtained from the soil respiration rate measurement, it is recommended to include at least one complementary analysis of soil biological activity and/or biodiversity (see additional indicators).**

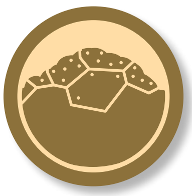
2.3 Additional SSM indicators for specific cases

If soil degradation is caused by specific and identified threats, the latter should be measured through the use of additional indicators to more specifically assess the impact of the implemented management practices. For the measurement of additional indicators, this protocol does not recommend any specific laboratory or field methods, but it is important to be consistent and to use the same method for the comparison between baseline and control areas.

1) Soil nutrients are essential for high agricultural productivity, which can only be obtained when all nutrients are in the optimal supply range. **Plant available phosphorus** can be used as an indicator of chemical soil nutrients as it is a stable element, and its mobility in the soil is limited. When measuring soil nutrients, laboratories may provide a complete analysis containing values for nitrogen (N), phosphorous (P) and potassium (K). Plant available phosphorus was chosen given the nature of its mobility, but N and K can also be considered.



2) Soil erosion is the displacement of the upper layer of soil and can be caused by wind, water or anthropogenic activities such as soil tillage. It can be measured in the field, by observing visible evidence of soil loss, in complement to the measure of topsoil soil organic matter. In identified cases of soil erosion, it is recommended to implement different assessment methods, such as the USLE method, the synthesis of satellite imagery and its metadata, or **direct measurement of erosion in gullies, rills, sheet wash, landslides** using erosion pins, **sediment yield downhill or in drains** using Gerlach boxes, **or undercutting of the soils around trees and fence-lines.**

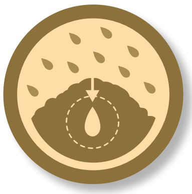


3) Soil Salinity can be a natural phenomenon (reflecting the geological/lithological/climatic conditions of the area, or proximity to a coastal marine environment), or the result of anthropogenic activities such as the use of salt-rich water for irrigation or the adverse impacts of poorly managed irrigation in dry regions. Halophytic plants, white scabs, an oily appearance or lack of plant growth are all signs of salinity in the field. Salinity can be estimated using **electrical conductivity (EC).**

4) Soil biological activity. The most recommended additional methods to estimate soil biological activity are soil microbial biomass, specific enzymatic activity methods and the Bait-Lamina method. For this protocol, it is recommended to associate at least one of these methods to the respiration rate mentioned in the recommended indicators (table 1), in order to better interpret the values obtained.

5) Soil biological diversity reflects the variability among living organisms including a myriad of organisms not visible to the naked eye, such as microorganisms (e.g., bacteria, fungi, protozoa) and meso-fauna (e.g., nematodes, acari and springtails), as well as the more familiar macro-fauna (e.g. earthworms, ants and termites). The most recommended methods for soil biodiversity include the counting and identification of macro and meso-organisms by a trained person, following extractions in the laboratory (e.g., Berlese funnel, Baermann funnel or pitfall traps in the field). A regular genomic analysis also enables biodiversity to be assessed more accurately at the microbial level. It is recommended to associate at least one of these methods with the respiration rate mentioned in the recommended indicators (table 1) in order to better interpret the values obtained.

6) Soil pH (acidity and alkalinity) gives an important indication of plant nutrient availability, and different crops thrive at different pH values. Soil pH may change in response to management activities such as liming, fertilizer addition, irrigation that leads to salt accumulation, and some forms of soil pollution. Soil pH may be measured in the field with simple indicators, or with standard laboratory measurements. It is relatively cheap, quick, and easy to determine. Amending a low (acidic) pH can lead to greatly improved crop yields.



7) Available water capacity refers to the water held in the soil between its field capacity and permanent wilting point. It represents the ecosystem service of regulating water quality and availability in the landscape (easily available water is held between -10 and -200 kPa). This parameter can also help assess the physical condition of a soil (porosity and structure) as water availability is highly dependent on it.

Field parameters for evaluation of **soil physical properties** can be a good complement to the recommended set of indicators and proposed parameters.

8) Soil infiltration rate is a measure of how fast water enters the soil under non-saturated conditions. Water entering too slowly can reflect ponding conditions, soil compaction or erosion risk (surface runoff).

9) Soil penetration resistance can be useful in estimating soil compaction. It gives an indication of root-impeding layers in the soil and can be used to compare relative strengths among similar soil types. Penetration resistance can also be used to identify hardpans, zones of compaction, or dense soil layers.

10) Soil pollution refers to the presence of contaminant(s) in the soil whose nature, location, or quantity produces undesirable effects in the environment or human health. The laboratory analysis will depend on the results of the preliminary pollution risk assessment (in many cases this is not related to stakeholder management), after which the contaminants of major concern could be identified, and the specific method implemented. The contaminants of major concern considered in this document are trace elements, different types of pesticides, excess nutrients, hydrocarbons, and plastics. For an accurate assessment, it is therefore recommended to compile the necessary information related to the possible pollution risks, such as the proximity to a factory or a mining area, the source of irrigation water; the type and frequency of supplies and equipements used; and the use of agroplastics and its management. In addition, if a soil management practice is known to (potentially) introduce contaminants into the soil, the additional measurements of soil pollution for such substances need to be performed.

Any additional indicators that are relevant for the type of soil, crops, implemented SSM practices or local conditions can also be included as part of this SSM assessment.

©FAO/Matteo Sala

3. How to plan a SSM assessment

Planning a SSM assessment (Figure 1) includes the consideration of the study area, the purpose of measurements, budget, people responsible for the assessment, location and timing of sampling, and record keeping requirements. The SSM assessment must necessarily include the recommended set of indicators, as well as any relevant additional indicator(s), given the location, soil type, land use, types of SSM practices used, and natural and off-site threats. The time lapse between two measurements will depend mainly on the nature of the practice to be assessed. For most SSM practices, where the objective is to obtain long-term results, the positive impacts may be observed within a time frame of 4 to 8 years after implementation. More information on the planning of a SSM assessment can be found in the annexes.

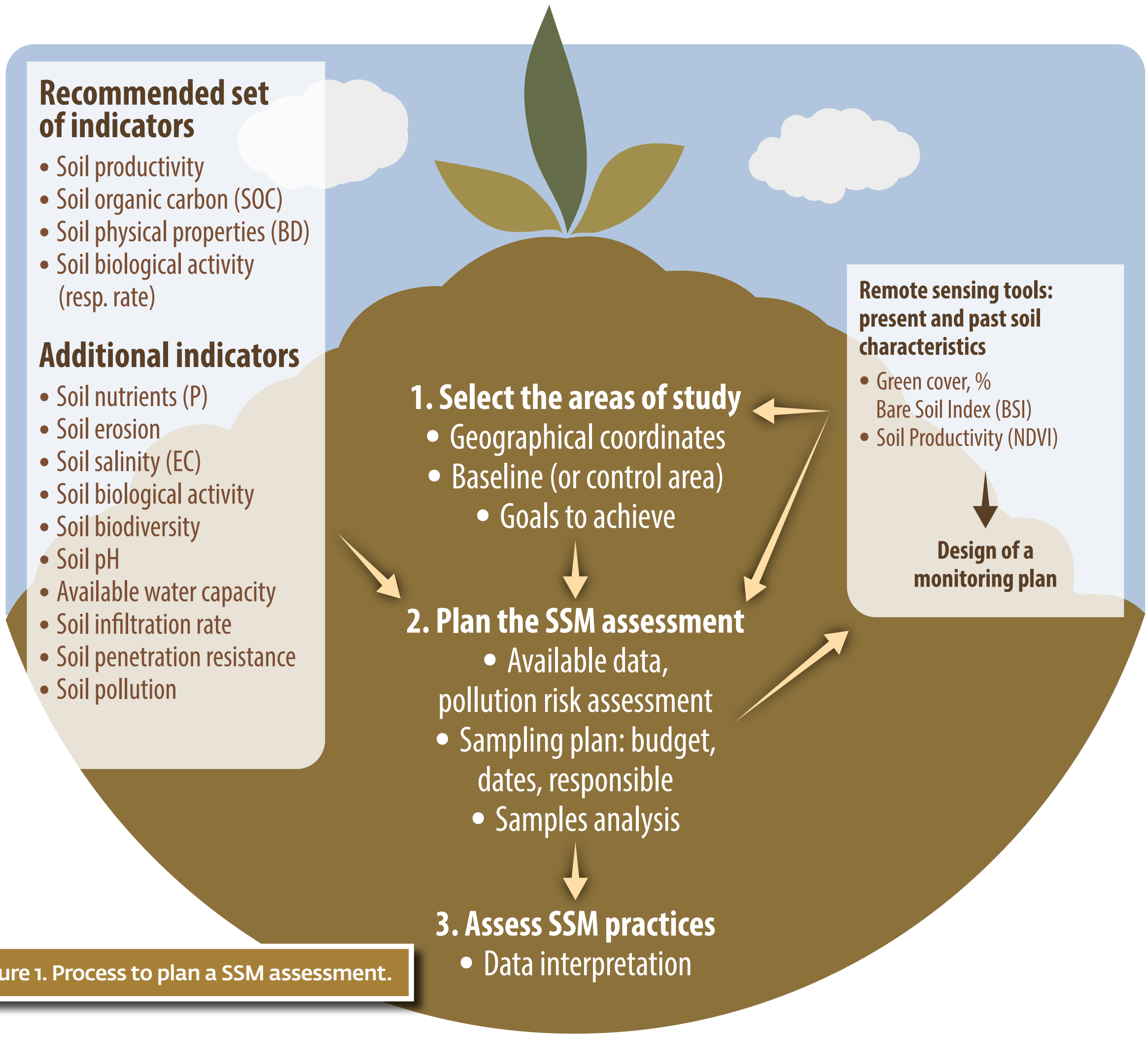
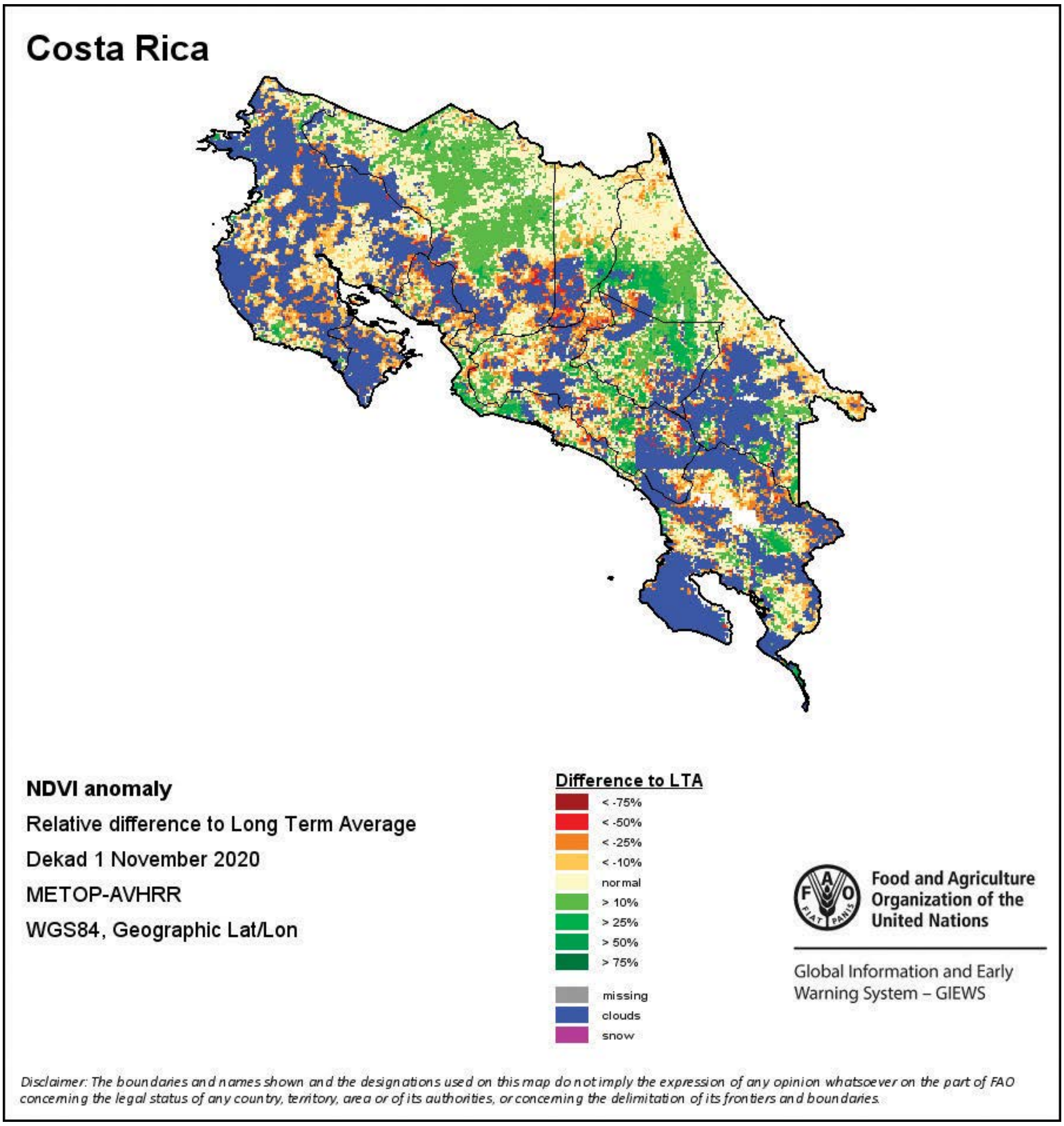


Figure 1. Process to plan a SSM assessment.

3.1 Select the areas of study

- The selected areas must be representative of the management practice to be assessed. For example, in a productive area: select a representative area of the main crop (do not include secondary crops or living fences).
- The assessment must include a baseline (measured prior to implementation of the SSM practice(s) that are being assessed) and/or at least a control area.
- Include remote sensing tools if possible, to delimit the study areas and design the sampling method (Vegetation cover, soil moisture estimation, Normalized Difference Vegetation Index (NDVI) or Bare Soil Index (BSI).



NDVI map

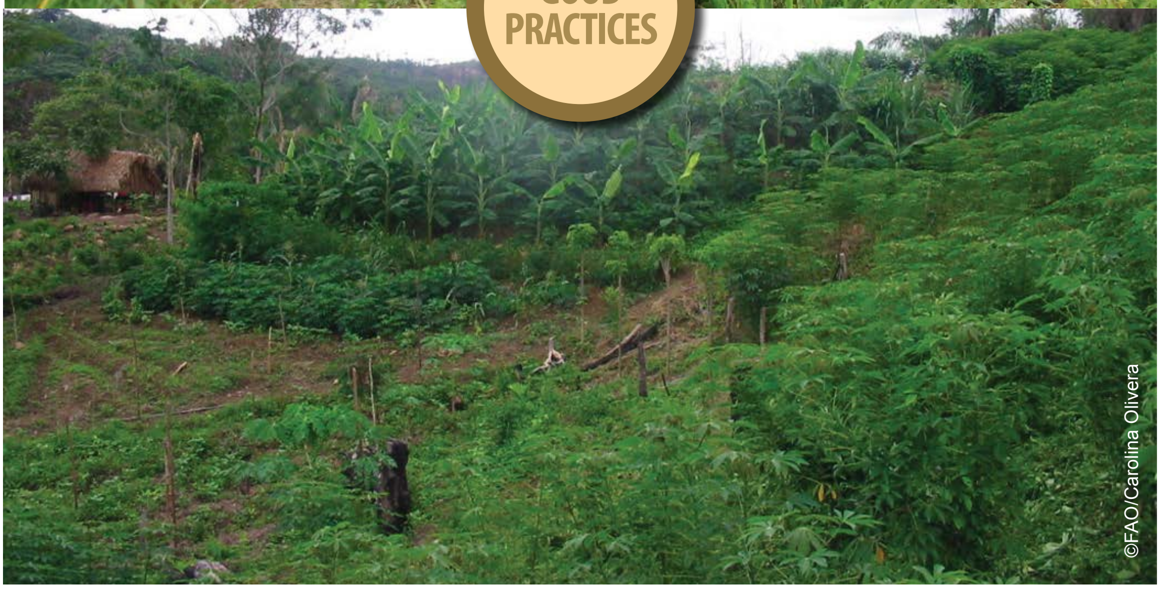
3.2 Plan the SSM study or assessment design

- Specify the location of each point to assess (geographic coordinates).
- Define the timeline for the field sampling.
- The sample analysis can be completed with additional laboratory parameters and field observations. These can be, for example, soil pH or soil resistance to penetration.

SSM assessment can determine the effectiveness of changes generated by the implementation of SSM practices and evaluate the impact of soil management for sustainability in the short, medium and long-term.

- Identify reference areas for comparison (baseline or control area).
- Define the monitoring plan: frequency, indicators, specific goals and monitoring tools.
- Implement remote sensing tools (if relevant and/or available). Previous estimation of biomass and soil moisture in different periods is needed.

Plan the field missions (sampling + field observations) and provide improved information in the SSM assessment. Some parameters obtained by remote sensing or simple field observations can be combined within the assessment indicators, to quickly obtain intermediate measurements that can, in some cases, provide early warnings and allow adjustments to the SSM.



3.3 SSM assessment, step by step

The SSM assessment requires to first compile the soil information following a series of instructions and methodologies:

- Fill a general information form.
- Include information about management practices for each field unit.
- Include observations and characteristics of each soil sample. The baseline or control area samples must be taken during the same period (same weather conditions, same stage of growing year for baseline or between-year comparisons).
- Send the soil samples to the laboratory and compile the results.

Soil sampling

4. Assess the Sustainable Soil Management

The results from the parameters/metrics of the recommended set of indicators need to be compared to baseline or control values in order to determine whether the change is considered as a positive impact on soils. A soil management practice will be considered as sustainable if the four indicators maintain their values or show a positive change. For the first indicator of soil productivity, the value needs to increase or remain the same for it to be considered as a positive impact on the studied soil. For soil organic carbon, the values should increase, for bulk density, they should decrease. For the soil respiration rate, an increase is considered to be a positive impact on soils, but the nature of the soil needs to be carefully considered.

The final result is the assessment of sustainable soil management

GLOBAL SOIL PARTNERSHIP

The Global Soil Partnership (GSP) is a globally recognized mechanism established in 2012. Our mission is to position soils in the Global Agenda through collective action. Our key objectives are to promote Sustainable Soil Management (SSM) and improve soil governance to guarantee healthy and productive soils, and support the provision of essential ecosystem services towards food security and improved nutrition, climate change adaptation and mitigation, and sustainable development.

Thanks to the financial support of

Ministry of Finance of the Russian Federation

European Commission

Federal Ministry of Food and Agriculture