Food and Agriculture Organization of the United Nations

VOLUME 1

RECARBONIZING GLOBAL SOILS

A technical manual of recommended management practices

INTRODUCTION AND METHODOLOGY

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INTERGOVERNMENTAL TECHNICAL PANEL ON SOILS

GLOBAL SOIL PARTNERSHIP

VOLUME 1

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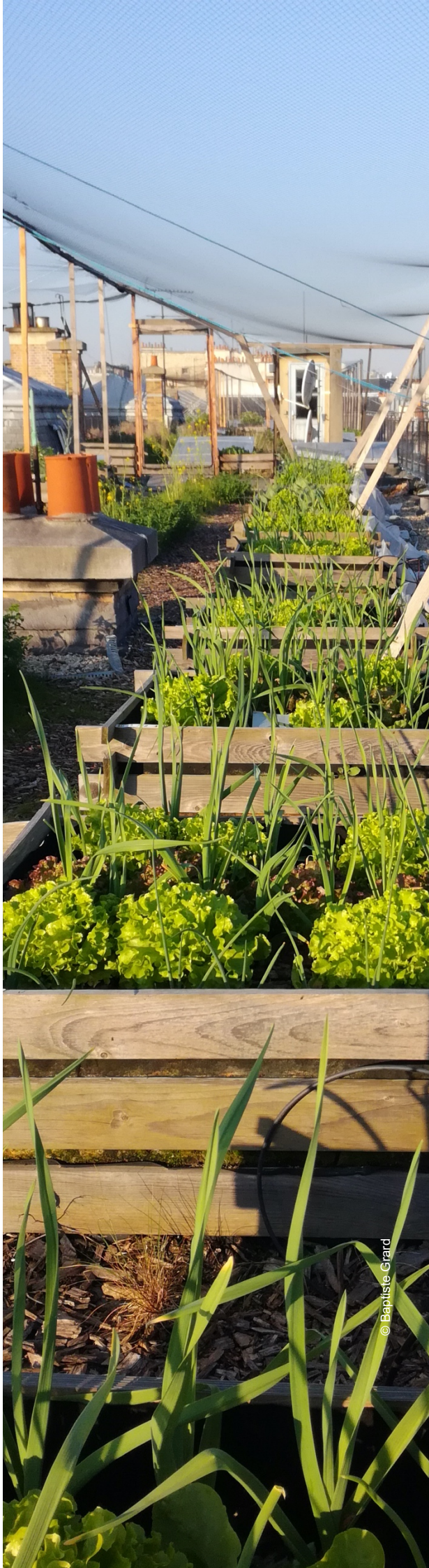

Preface

Healthy soils are those capable to sustain the productivity, diversity, and environmental services of the terrestrial ecosystems. In the agroecosystems, soil health can be maintained, promoted or recovered through the implementation of sustainable soil management practices, following the technical principles of the Voluntary Guidelines for Sustainable Soil Management (FAO, 2017c). Their application is site- and practice-specific and must take into account the socio-economic context besides the physio-chemical and biological soil properties.

The management of soil organic carbon (SOC) has always been a core sustainable practice in agriculture, since SOC is a key soil property that influences a range of soil functions from which many soil ecosystem services are derived, including: biomass production (agriculture and forestry); nutrient storage; water storage; filtering of wastes and pollutants from water; providing habitat for soil biodiversity; providing soil carbon storage which interacts with the Earth's climate and protects soil from erosion by improving soil aggregate stability. Effective soil organic matter (SOM) management, with balanced and timely inputs and outputs, also ensures an efficient macro- and micronutrient cycling. Thus, SOC is one of the most widely recognized soil quality parameters determining soil health, since SOC maintenance or increase is synergic with a great number of ecosystem services and it is also relatively easy parameter to measure compared with others.

During the last decades, soil carbon attracted the attention of a much wider array of specialists beyond agriculture and soil science, as it was proven to be one of the most crucial components of the earth's climate system which has a great potential to be managed by humans. Soils as a carbon pool is one of the key factors in several Sustainable Development Goals, in particular Goal 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" since the SOC stock is explicitly cited in Indicator 15.3.1. SOC is also affecting other SDGs, as 13 "Take urgent action to combat climate change and its impacts" (indicator 13.2.1); or 2 "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" among others.

Throughout human history, SOC has been strongly affected by anthropogenic activities, especially in the process of the conversion of soils under natural vegetation to agro-ecosytems since the onset of agriculture, starting in the Fertile Crescent about 10 000 years ago. The moldboard plow that turns the topsoil (ca 1100 y AD), favouring SOM mineralization, and the introduction of fertilizers (beginning of 20th century), with the consequent loss of importance of organic matter management for providing nutrients to crops, have been other milestones that brought about a global SOC depletion in the topsoils. It is estimated that we have released considerable amounts of CO_2 into the atmosphere caused by land use change and unsustainable agricultural practices, translated into historical SOC depletion of 115-154 (average of 135) Gt C (Lal, 2018), while the global SOC stock estimation from 0 to 30 cm is 694 Pg (FAO, 2017a). However, the SOC depletion rate shows different intensities around the globe, depending on climate, soil type, texture, initial SOC content, water status and specific management practices, as wetland drainage. Due to these processes, the decline of SOC content

and stocks is one of the major threats identified in the Status of the World's Soil Resources Report (FAO and ITPS, 2015). In spite of that, several reported soil management practices have proved beneficial regarding SOC storage, as for instance the continuous organic matter management leading to Plaggen soils in Northern Europe or to the formation of Terras Pretas do Indio in Brazil. In the latter case, one of the last field-based estimates a total pyrogenic carbon stock for the Amazon Basin of 1.10 Pg over 0–30 cm soil depth, and 2.76 Pg over 0–100 cm soil depth (Bonhage *et al.*, 2020).

This manual is one of the results of the document **"Unlocking the potential of soil organic carbon"** (FAO, 2017b), which gathers the conclusions of the **Global Symposium on Soil Carbon (GSOC17)** held at the FAO headquarters in Rome in 2017. Among the different statements this document specifically recommends to "*Identify and specify the tangible short-term and long-term benefits for farmers of management practices for SOC sequestration to trigger their adoption, and introduce mechanisms to incentivize the adoption of such practices*". This recommendation started to take shape at the end of 2017, through an open call for experts launched by the ITPS and GSP Secretariat, with the purpose of developing a technical manual of good soil management practices; and through an online survey about beneficial practices for SOC management that should be included in it. More than 200 expressions of interest and 82 responses to the survey were received. A draft of the technical manual, with about 160 authors involved, was finally submitted and reviewed by a scientific committee composed by the GSP/ITPS, STC of the 4 per 1000 initiative, CIRCASA, and UNCCD/Science Policy Interface in May 2019, who considered that in its present form it needed reshaping and improvement in order to adequately address the recommendations of the GSOC17. During 2020 the manual was reformulated and updated, more than 200 new authors were invited; and it underwent a peer review process by the scientific board and 5 special reviewers.

Thus, this final technical manual has been accomplished thanks to the efforts of more than 400 specialists from all around the world, with the objective to accumulate in one compendium all practices of SOC management that proved to be efficient up to date, or can potentially be efficient in maintaining or improving the storage of organic carbon in soil, in the frame of sustainable soil management. It is structured in three sections: practices (widely applied soil management techniques), hotspots (behaviour and dynamics of those special soils crucial for soil organic carbon storage) and case studies (reporting successful specific practices in given contexts). In its present form it compiles 73 practices, 11 hotspots and 81 study cases from all around the world in all types of landscapes, from forests, wetlands, urban soils to cropland and grasslands, conveniently enriched by a great deal of illustrations and graphics provided by authors.

The need to recognize standardized and locally tailored soil management practices with proved effectiveness in maintaining/increasing SOC is still more important in the frame of global change, by which the boundary conditions (climate, land use) of soil carbon flows will change. In this context the effects of the practices that were traditionally used to foster soil fertility through SOC management may become more uncertain, and the application of sustainable soil management practices will be crucial to ensure the maintenance of soil quality and the provision of soil ecosystem services. Following these guidelines, this manual focuses on those practices or case studies maintaining or increasing SOC, but at the same time it is reporting the trade-offs, conflicts or synergies with the rest of the soil qualities and services. Due to the complexity of gathering complete information

on each practice and to the lack of enough long-term experiments with complete monitoring protocols, there are limited reports on factors such as soil organic matter quality or detailed GHG flux measurements. Indeed, any practice aimed at sequestering carbon as organic matter without an appropriate C/N ratio in the soil or in the material added to soils can lead to increased CO_2 emissions and/or depletion of available N in soils. Nevertheless, each chapter provides with valuable information that can be used in future carbon footprint, life cycle, and cost-benefit analyses regarding C sequestration.

This manual is also one of the elements of the RECSOIL toolkit (FAO, 2019). RECSOIL is a mechanism proposed to account for carbon credits and sustainable soil management practices in agriculture as one of the tools to mitigate climate change through carbon sequestration into the soil, as promoted by the Koronivia Joint Work on Agriculture in the 23rd session of the Conference of the Parties (COP 23) of the United Nations Framework Convention on Climate Change (FAO, 2018). In order to attain this goal, standard procedures and guidelines to monitor, report and verify SOC variations are necessary, and indeed the GSOC MRV Protocol: A protocol for measurement, monitoring, reporting and verification of soil organic carbon in agricultural landscapes, was launched in 2020 by FAO/GSP and its Intergovernmental Technical Panel on Soils (FAO, 2020). SOC stocks evolve in a mid and long term with continuous application of management practices, therefore it is difficult to quantify small changes even if they are significant. Total SOC stocks that are mainly made of humified SOC have a turnover of between 400 and 500 years in Black Soils. In the short term (less than 5-10 years) only the turnover of fresh SOC (within the particulate organic matter) at the surface can be accurately measured (Salvo *et al.*, 2014). This is why having recognized practices that farmers can apply with beneficial effects regarding SOC and soil quality will help in certifying management protocols and setting funding policies before the effects on SOC are noticed.

In summary, this manual is the first attempt to gather, in a standardized format, the existing data on the impacts of the main soil management practices on SOC content in a wide array of environments including the advantages, drawbacks and constraints. This exhaustive review will also be useful to identify research gaps in SOC research. As a consequence, due to the existing limited results in some of the practices, it will have to be updated in the future with results of ongoing research.

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Abbreviations and acronyms

AFS	Agroforestry
C	Carbon
CA	Conservation agriculture
CAP	Common agricultural policy of the European Union
CCF	Continuous cover forestry
CIMMYT	International Maize and Wheat Improvement Centre
DOC	Dissolved organic carbon
FAO	Food and Agriculture Organization of the United Nations
FLR	Forest landscape restoration
FOM	Fresh organic matter
GHG	Greenhouse gases (CO_2 = carbon dioxide; N_2O= nitrous oxide; CH_4 = methane)
ICARDA	International Centre for Agricultural Research in Dry Areas
IPCC	Intergovernmental Panel on Climate Change
LUC	Land use change
LULC	Land use and land cover
N	Nitrogen
N_2O	Nitrous oxide
NH_3	Nitrates
NH_4	Ammonium
P	Phosphorus
SLM	Sustainable land management
SIC	Soil inorganic carbon
SOC	Soil organic carbon
SOM	Soil organic matter
SSM	Sustainable soil management
WRB	World Reference Base

Units and measurements

MAP	Mean annual precipitations
MAT	Mean annual temperatures
m.a.s.l	Meters above sea level
SD	Standard deviation
SE	Standard error
Yr	Year

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1. Background and timeline

Land uses and management practices that maintain or increase SOC stocks are being recognized as beneficial for climate change mitigation and adaptation, food security, Land Degradation Neutrality and biodiversity conservation. Although many practices are known for maintaining and increasing SOC, responses vary depending on climate and soil, as well as type of implementation. Soil management practices should therefore be selected to suit each specific context.

Due to the urgency to unlock the potential of SOC and identify, compile and highlight management practices and land use systems that promote the preservation and/or enhancement of SOC stocks, a Global Symposium on Soil Organic Carbon was organized by the FAO's Global Soil Partnership (GSP) in 2017. Scientific evidence and knowledge gaps were included in the symposium Outcome Document, which reflects recommendations from all participants and co-organising organisations. The establishment of a working group to prepare a technical manual on SOC management at the national and local scale was highlighted as one of the key recommendations. This technical manual should include the recommendations developed in the outcome document, especially recommendations 3 and 4:

Recommendation 3: In estimates of the potential for SOC sequestration, include the full GHG balance and consider possible interactions between the carbon and nitrogen cycles that could affect the climate change mitigation potential of applied practices.

Recommendation 4: The design of implementation strategies and appropriate soil and land management practices for SOC protection and sequestration should consider land use and the local environmental, socio-economic, cultural and institutional contexts, and potential barriers to adoption.

At the end of 2017, an open call for experts was launched by the International Technical Panel on Soils (ITPS) and the GSP Secretariat, which received more than 200 expressions of interest. This call for experts was followed by an online survey aiming to identify SOC management practices at the regional and sub-regional scale. The online survey received 82 replies and contributed to the creation of the outline of the first version of the technical manual. The manual's original version was developed in 2018 by about 160 authors and first time submitted for peer-review to the scientific board (composed of the ITPS, UNCCD-SPI, 4 per 1000 initiative Science and Technical Committee and CIRCASA project) in February 2019. After peer-review, recommendations for major improvement were made: the manual should be more concise, more practical and chapters better harmonized. The GSP Secretariat took into consideration the scientific board's advice and reshaped the table of contents of the manual.

The new structure was proposed to highlight (1) all the hot spots and bright spots of SOC, (2) all the SSM practices available in agriculture, grassland, forestry, wetlands and urban areas that positively affect SOC stocks, and (3) a collection of successful case studies regarding SOC stocks illustrating the specificity of the practices. Templates were developed to guide the authors in providing the relevant information associated to each hot spot/bright spot, practice and/or case-study dealt with. This manual has been developed thanks to an important participatory work that brought together more than 400 soil management experts from all over the world.

2. Structure and coverage of the manual

This technical manual presents different SSM practices, at different scales and in different contexts, supported by case studies that have been shown with quantitative data to have a positive effect on SOC stocks, as well as successful experiences of SOC sequestration in practical field applications. Therefore, this technical manual aims to provide general overview of (1) the important SOC stocks locations in the world, (2) the main SSM practices that positively impact SOC storage and (3) concrete evidence of successful cases in which SSM practices positively influenced SOC storage.

According to the definition given by the FAO, 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 (FAO, 2017c). The balance between the supporting and provisioning services for plant production, and the regulating services for water quality and availability and for atmospheric greenhouse gas (GHG) content is of particular concern.

Therefore, although the manual emphasizes on SOC sequestration, the sole information on carbon was not sufficient to provide the full overview of sustainability. Therefore, more information related to the other soil threats (Box 1), GHG emissions, or other socio-economic important parameters have also been included.

This manual shows the myriad of solutions that exist today and demonstrates that moving towards a new agricultural model that is more environmentally and soil friendly, productive and resilient is possible worldwide. It also shows that SSM can be adapted to the diversity of existing ecosystems, climates, soil types and people.

This manual also shows the importance of research, which provides solid scientific evidence demonstrating the benefits of SSM. These figures have been missing for some practices and/or for some regions, so in order to incorporate future advances towards MORE sustainable and resilient systems, and to include longer term experiments, this technical manual has been thought as a living document, to be updated in the medium term (10 years maximum). We hope that through this manual new research opportunities will emerge worldwide to fill the knowledge gaps and give soils the consideration and protection they urgently need.

Box 1. Soil threats considered in this manual

In all volumes, explanations are given on the potential effects of a SSM practice on the different soil threats, or the potential for a hot spot/bright spot to limit soil threats. The soil threats correspond to those identified in the Voluntary Guidelines for Sustainable Management and the Status of the World's Soils Resources Report:

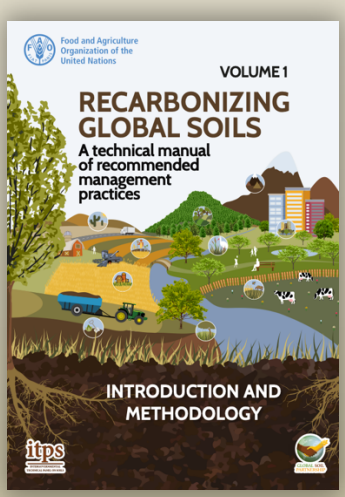
1. **Soil erosion by water, wind or tillage:** Soil erosion is the accelerated removal of topsoil from the land surface through water, wind and tillage. It affects soil health and productivity by removing the highly fertile topsoil and exposing the remaining soil.
2. **Soil organic matter content depletion:** Soil organic matter plays a central role in maintaining soil functions and preventing soil degradation. Soils constitute the largest organic carbon pool on the Earth and play a critical role in regulating climate and mitigating climate change through trade-offs between greenhouse gas emission and carbon sequestration.
3. **Nutrient unbalance and cycles**: The benefits of sufficient and balanced nutrient supply for plant needs are well-established and include production of food, feed, fibre, timber, and fuel at levels at, or close to, the optimum potential in the specific geographical context.
4. **Soil salinization and alkalinization:** Salinization is the accumulation of water-soluble salts of sodium, magnesium and calcium in the soil as a consequence of high evapotranspiration rates, inland sea water intrusion, and human-induced (e.g., improper irrigation) processes.
5. **Soil contamination/pollution:** Soil may filter, fix and neutralize, but also release pollutants when conditions change (e.g., heavy metal release with lowering pH).
6. **Soil acidification:** Human-induced soil acidification is primarily associated with removal of base cations and loss of soil buffering capacity or increases in nitrogen and sulphur inputs.
7. **Soil biodiversity loss:** Soil biodiversity refers to the variety of life belowground, from genes and species to the communities they form, as well as the ecological complexes to which they contribute and to which they belong, from soil micro-habitats to landscapes.
8. **Soil sealing:** Soil sealing refers to the result of land conversion and subsequent soil sealing for settlements and infrastructure.
9. **Soil compaction:** Compaction impairs soil functions by impeding root penetration and limiting water and gas exchange. In soils where it occurs, it can reduce crop yield but it rarely eliminates plant growth entirely.
10. **Soil water management**: Waterlogging is related to the saturation of soil with water, creates rooting problems for many plants, thereby reducing yields, and can cause contaminants to become mobile in the soil. On the contrary, water scarcity occurring in areas where water is lost by evaporation, surface runoff and percolation, can cause crop failure.

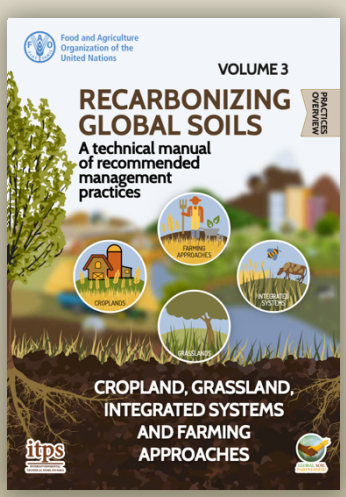
Carbon sequestration entails additionality and permanence of new carbon beyond original carbon levels at a given location. It is considered in the manual as the process by which atmospheric carbon dioxide is taken up by plants through photosynthesis and stored as carbon in biomass and soils at a given location, but sometimes, it is associated by the soil carbon increases resulting from the importation of external organic matter to a given plot (for example, manures, biochar, etc.). In the first case, the SOC increases are mainly visible after some years (usually more than four), while increases resulting from imported carbon maybe visible shortly after its addition as it is incorporated in the soil. The SOC sequestration values associated to the addition of external sources of carbon may be higher in the short term when compared to the SOC sequestration values associated to an increased organic matter (plant litter) input due to improved soil health and hence crop productivity.

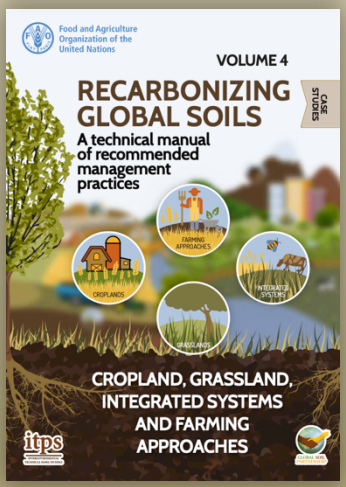
This technical manual is a not a catalogue of certified practices. This collection of practices and case studies are site-specific, and report on published results and expert knowledge around the world, but the manual is not advising on adopting a given practice without knowing the environment.

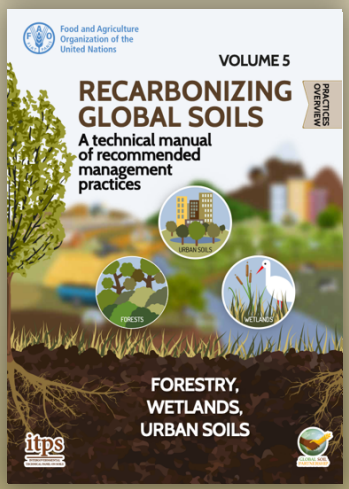
The manual is organized in six volumes:

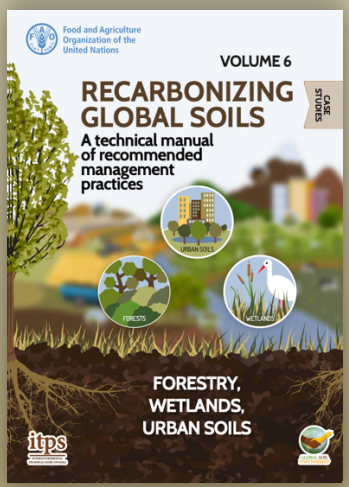
- **Volume 1:** Introduction and methodology
- **Volume 2:** Hot spots and bright spots of soil organic carbon
- **Volume 3:** Cropland, Grassland, Integrated systems and farming approaches - Practices overview
- **Volume 4:** Cropland, Grassland, Integrated systems and farming approaches – Case-studies
- **Volume 5:** Forestry, Wetlands, Urban Soils – Practices overview
- **Volume 6:** Forestry, Wetlands, Urban Soils – Case-studies











3. Selection of hot-spots, practices and case studies

The selection of hot-spots, bright spots and practices to be included into this manual has been intended to be as exhaustive as possible taking into account a geographical and land use balance, as this manual is intended to become a reference document. However, this manual is by no means inclusive of all existing practices in all contexts due to the lack of research on SOC sequestration in some environments and will therefore be revised over time.

3.1 Selection of hot-spots and bright spots of soil organic carbon *(Volume 2)*

Volume 2 includes a description of major areas for consideration for the maintenance or improvement of SOC stocks. Hot spots of SOC are defined in this manual as areas that represent a proportionally little of the global land surface but on which SOC storage is highly effective. Hot spots are very sensitive to climate change and can easily become sources of GHG emissions due to their high SOC content. On the other hand, bright spots correspond to large land areas with low SOC stocks per km^2 that represent a potential for further carbon sequestration.

The hot spots and bright spots as considered in this manual include peatlands, permafrost, black soils, drylands, forests, grasslands, tropical moist forests, mangroves, wetlands, Technosols and urban soils, and mountain soils.

3.2 Selection of practices *(Volumes 3 and 5)*

Practices that have a direct impact on SOC sequestration and maintenance were prioritised over other practices related to improved genetic varieties and pest management, which are known to be an important component of sustainable agriculture, but which have a lower direct impact on SOC stocks.

Relevant soil management practices to be included in the manual were selected after an extensive literature review and a crosschecking with the practices listed in the Voluntary Guidelines for Sustainable management. This technical manual includes a total of 49 practices available in Cropland, Grassland, Integrated systems and farming approaches (Volume 3), and 24 practices available in forestry, wetlands and urban soils (Volume 5)

3.3 Selection of case studies *(Volumes 4 and 6)*

The idea of integrating case-studies to this manual came along with the fact that single practices are seldom applied by farmers, and the successful application of practices is very much site-dependant as well as on the wider context (for example, technologies available).

The selection of case studies to be inserted in the manual has been made taking into account the trade-off between regional equilibrium and scientific evidence. That is to say, on the one hand, to ensure that all regions and topics are equally represented, and on the other hand, that the duration of experiments was sufficient, - as SOC changes cannot be visible in the short term- and that the results shared were statistically significant. Having all these four criteria (geographical balance, topics balance, duration and statistical significance) some concessions needed to be made. That is why, in some cases:

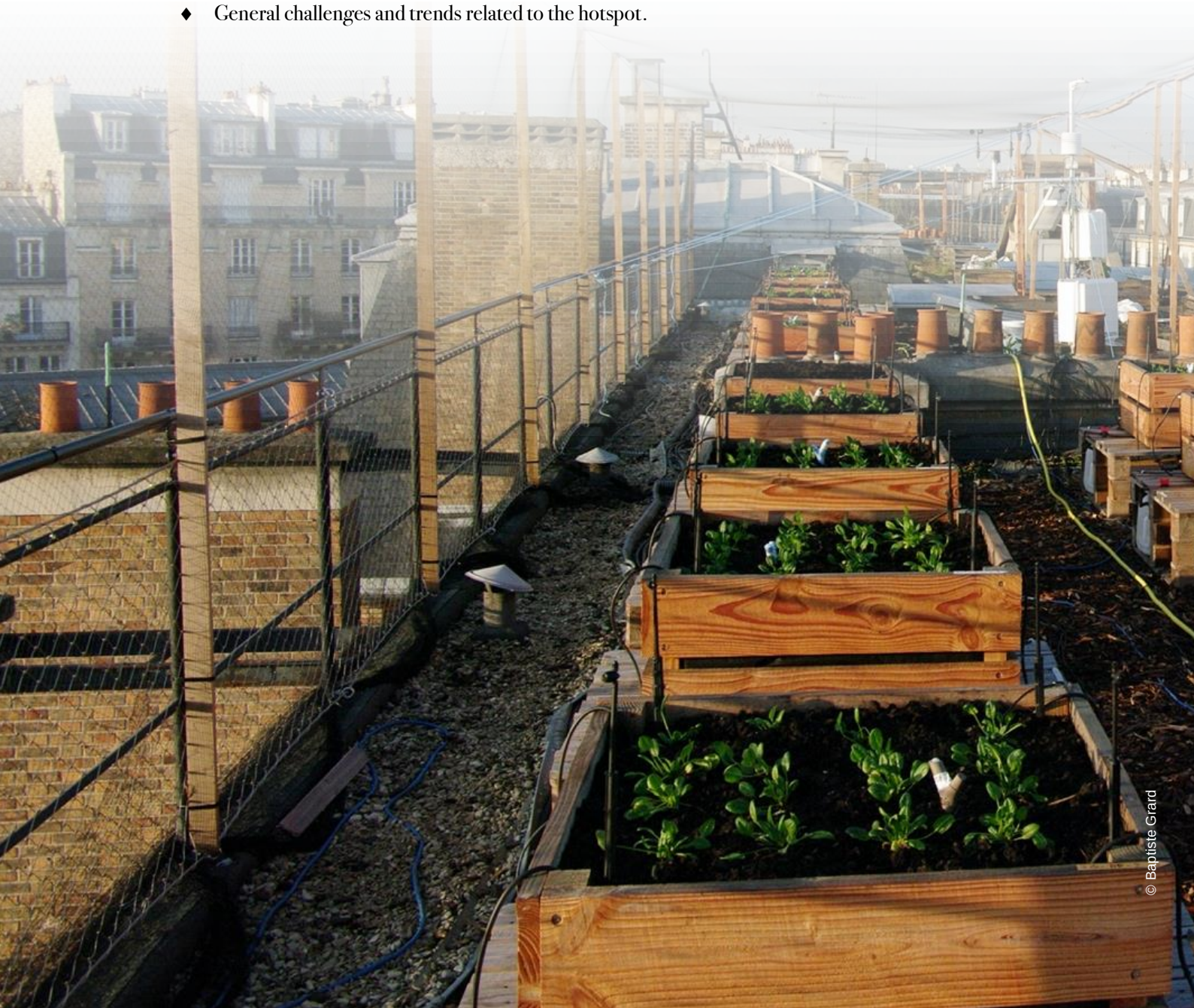
- Case studies with a duration of less than 4 years were accepted to be included in the manual, and
- Studies with no statistical significance ($p<0.05$) but showing trends were accepted.

The manual includes 51 case studies dealing with cropland, grassland, integrated systems and farming approaches, and 30 case studies dealing with forestry, wetlands and urban soils management.

4. Structure of the factsheets on hot-spots and bright spots of soil organic carbon

The factsheets presented in this volume aim to bring general information on important locations in the world for SOC stocks, and/or potential for SOC sequestration in specific areas. They are organized as follows:

- A short definition and description of the hot spot and/or bright spot, importance as a carbon sink.
- World repartition of the hot spot and/or bright spot.
- Quantitative estimations of global SOC stocks and sequestration potential of the hot spot and/or bright spot at global and regional scales: non-exhaustive list of different estimates of global carbon stocks contained in hot spots and bright spots and when available, their SOC sequestration potential and associated GHG emissions.
- Importance of the hot-spot or bright spot:
  - On minimizing soil threats
  - For production and food security
  - For climate change mitigation and adaptation
- General challenges and trends related to the hotspot.



5.Structure of the practices

The factsheets presented in volumes 3 and 5 aim to give an overview of the main practices with a positive impact on SOC stocks and sequestration at the global level. The structure of each practice overview is the following:

- Definition and short description of the practice.
- Context of application of the practice, including the geographical and pedo-climatic conditions of application of the practice(s).
- Quantitative summary of SOC increases after application of a given practice. Values of SOC sequestration are provided in stocks according to a baseline.
    - Values mainly come from meta-analysis, models, reviews or in some case (where information is scarce) from local studies.
- Associated improvement of soil chemical, physical and biological properties.
- Positive and negative impacts on minimizing soil threats (other than soil organic carbon loss).
- Effects of the practice on sustaining crop yields.
- Effects of the practice on greenhouse gases emissions and therefore on the capacity to adapt and mitigate climate change. When possible, an estimation of the net GHG balance is proposed.
- Positive or negative effects of the practice on socio-economic aspects.
- Any conflict that may arise between the practice described and a concurrent practice.
- Recommendations to practitioners before applying the practice, taking in account the possible drawbacks and conflicts.
- Potential biophysical, cultural, social, economic, institutional, legal or knowledge barriers that could hamper the adoption of the practice.

6.Structure of the case studies

The case-studies presented in volumes 4 and 6 aim to provide examples of practical applications of selected practices on the field, and their positive effects on soil health and carbon sequestration. The structure of each case study is the following:

- Definition and short description of the case study.
- Context of application of the case study, including the geographical and pedo-climatic conditions of application of the practice(s).
- Quantitative summary of SOC increases after application of a given practice. Values of SOC sequestration are provided in stocks according to a baseline.
    - These values correspond to the measurements made over time in the given study
- Associated improvement of soil chemical, physical and biological properties.
- Positive and negative impacts on minimizing soil threats (other than soil organic carbon loss)
- Effects of the practice on sustaining crop yields.
- Effects of the practice on greenhouse gases emissions and therefore on the capacity to adapt and mitigate climate change. When possible, an estimation of the net GHG balance is proposed.
- Positive or negative effects of the practice on socio-economic aspects.
- Any conflict that may arise between the practice described and a concurrent practice.
- Recommendations to practitioners before applying the practice, taking in account the possible drawbacks and conflicts.
- Potential biophysical, cultural, social, economic, institutional, legal or knowledge barriers that could hamper the adoption of the practice.

Glossary

Afforestation	Conversion from other land uses into forest, or the increase of the canopy cover to above 10 percent.
Agrisylviculture	Agroforestry practice in which trees are associated with crops on the same piece of land, either simultaneously (each component occupies a separate space, but both exist at the same time) or sequentially (one component replaces another in rotation).
Agrosylvopastoralism	The integration of crops/pastures, livestock and woody perennials into the same farming system.
Agroforestry	Also refers to: **Agrisylviculture, Sylvopastoralism, Agrosylvopastoralism**. Collective term for land-use systems and technologies in which woody perennials (e.g., trees, shrubs, palms or bamboos) and agricultural crops or animals are used deliberately on the same parcel of land in some form of spatial and temporal arrangement.
Aggregate stability	A measure of the proportion of the aggregates in a soil which do not easily slake, crumble, or disintegrate.
Animal manure	Materials from livestock production operations used for fertilization purposes, including faeces, urine, straw and other bedding materials.
Afforestation	Establishment of forest through planting and/or deliberate seeding on land that, until then, was under a different land use, implies a transformation of land use form non-forest to forest.
Biochar	Relatively stable, carbon-rich material produced by heating biomass in an oxygen-limited environment. Biochar is distinguished from charcoal by its application: biochar is used as a soil amendment with the intention to improve soil functions and to reduce greenhouse gas (GHG) emissions from biomass that would otherwise decompose rapidly.

Biofertilizer	Broad term used for products containing living or dormant micro-organisms such as bacteria, fungi, actinomycetes and algae, alone or in combination, which on application help in fixing atmospheric nitrogen or solubilize/mobilize soil nutrients.
Biomass burning	Burning of living and dead vegetation.
Biodynamic agriculture	View of agriculture based on a holistic and spiritual understanding of nature and humans' role in it, which considers a farm as a self-contained evolving organism, relying on home-produced feeds and manures with external inputs kept to a minimum. Biodynamic agriculture utilizes preparations made from herbs, manure, and silica to affect manure and compost, soil life, crop growth and product quality. Biodynamic production and products are certified under the Demeter trademark.
Blue carbon	Carbon stored in coastal and marine ecosystems. Coastal ecosystems - mangroves, salt marshes and seagrass meadows - sequester and store large quantities of blue carbon in both the plants and the sediment below.
Buffer strips	Areas of natural vegetation cover (grass, bushes or trees) at the margin of fields, arable land, transport infrastructures and water courses. They can have several different configurations of vegetation found on them varying from simply grass to combinations of grass, trees, and shrubs.
Carbon	Non-metallic chemical element with symbol C and atomic number 6, essential building block of all living matter. Occurs in a variety of forms (e.g., coal and diamonds). Constituent of fossil fuel and carbon dioxide.
Carbon sequestration	The process of storing carbon in a carbon pool.
Climate-smart agriculture	Agriculture systems that aim to increase agricultural productivity and food security in the face of climate change, enhance adaptive capacity at multiple levels, and mitigate climate impacts where possible. Broadly, CSA is not a new set of practices, but rather an integrated approach aiming to 1) increase crop productivity, 2) develop resilient food production systems under climate change, and 3) reduce greenhouse gas (GHG) emissions. Consideration of all three objectives, which recognizes the trade-offs arising from each of those objectives are important to apply locally acceptable CSA practices.

Community forest management	Use, management, and conservation of forests by communities. Communities can have full, partial, or no ownership of such forests, and their management is often practiced in various degrees of collaboration with state forest agencies, donor organizations, knowledge institutions and/or companies.
Compost	A mixture of decaying organic matter (from plant litter and animal manure), produced to reduce volume/mass, eliminate pathogens and organic contaminants, reduce odour, and stabilize nutrients. It is used as organic amendment and fertilizer.
Compost (bis)	Organic residues, or a mixture of organic residues and soil, that have been mixed, piled, and moistened, with or without addition of fertilizer and lime, and generally allowed to undergo thermophilic decomposition until the original organic materials have been substantially altered or decomposed. Sometimes called ″artificial manure″ or ″synthetic manure″. In Europe, the term may refer to a potting mix for container-grown plants.
Composting	A controlled biological process which converts organic constituents, usually wastes, into humus-like material suitable for use as a soil amendment or organic fertilizer.
Conservation tillage	A method of tillage that consists on reducing the ploughing depth occasionally or continuously, replacing mouldboard ploughing by shallower tillage with other implements and/or reducing the intensity of seedbed preparation. The aim of this practice is to minimize soil disturbance as well as to reduce losses of soil and water, for which ≥ 30 percent soil surface is covered by crop residues.
Continuous cover forestry	Forest management that works with the characteristics of the site and with tree species that are well adapted to the location, and which maintains forest cover permanently. It respects the processes inherent to the site, rather than imposing artificial uniformity, and will normally involve a mixture of tree species and ages. Management is based on the selection and favouring of individual trees (of all sizes) rather than the creation of areas of uniform tree size and spacing.
Controlled traffic farming (CTF)	System which confines all machinery loads to the least possible area of permanent traffic lanes. CTF is a tool; it does not include a prescription for tillage. The permanent traffic lanes are normally parallel to each other, and this is the most efficient way of achieving CTF, but the

Controlled traffic farming (CTF) *(cont).*	definition does not preclude tracking at an angle. The permanent traffic lanes may be cropped or non-cropped depending on a wide range of variables and local constraints.
Cover crop	Close-growing crop, that provides soil protection, seeding protection, and soil improvement between periods of normal crop production, or between trees in orchards and vines in vineyards. When plowed under and incorporated into the soil, cover crops may be referred to as green manure crops.
Crop rotation	A planned sequence of crops growing in a regularly recurring succession on the same area of land, as contrasted to continuous culture of one crop or growing a variable sequence of crops.
Cryogenic soil	Soil that has formed under the influence of cold soil temperatures.
Dissolved Organic Carbon (DOC)	Portion of soil organic carbon which can pass through a 0.45 µm filter. It is largely a product of decomposition of litter and humus, but it may also originate directly from exudates from plant roots. The concentration of DOC in soils is dependent on the rates of production from vegetation and soil organic matter and consumption by soil organisms as well as water movement through the soil and sorption by mineral particles.
Drainage	Artificial lowering of the surface and sub-surface soil water from an area that leads to lowering of the water table causing the drying of the soil.
Earth movement (for soil preparation)	Common practice before planting specialized tree crops aimed at creating smooth slopes through land levelling, to ease the mechanized management of the crop, and is accompanied by deep ploughing, backhoe delving, or ripping, to loosen soil compaction and ensure optimal conditions for root and plant growth.
Fertilizer	A substance that is used to provide nutrients to plants, usually via application to the soil, but also to foliage or through water in rice systems, fertigation, hydroponics or aquaculture operations.
Fertigation	The application of soluble fertilizers through an irrigation system, which facilitates nutrient plant uptake.

Forest	Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.
Grazing exclusion	Total ban on grassland grazing by livestock.
Green manure	Also refers to: **cover crops, green cover.** Plants that are grown in order to provide soil cover and to improve the physical, chemical, and biological characteristics of soil.
Green roof	Roof that is partly or completely covered by plants and has an impermeable layer underneath.
Greenhouse gas	A gas in the atmosphere that prevents heat (longwave infrared radiation) from being radiated into space. A driver of global climate change
Healthy soil	Soils capable to sustain the productivity, diversity, and environmental services of the terrestrial ecosystems. In the agroecosystems, soil health can be maintained, promoted or recovered through the implementation of sustainable soil management practices, following the technical principles of the Voluntary Guidelines for Sustainable Soil Management.
Integrated soil fertility management	Application of soil fertility management practices and the knowledge to adapt these to local conditions, which optimize fertilizer and organic resource use efficiency and crop productivity.
Intercropping	Intercropping is the practice of growing two or more crops in proximity.

Irrigation	The application of water to soil to provide better moisture conditions for crop growth. Flood and furrow irrigation practices pond the soil with water for a limited time and allow it to infiltrate. Micro-irrigation, including drip, trickle, and micro sprinkler irrigation, refers to a set of practices that apply localized irrigation water at low rates through small tubes and emitters and are generally water conserving. Supplemental irrigation refers to a practice used in humid regions where rainfall provides most crop water needs, and irrigation is primarily used to maintain adequate soil moisture levels during limited drought periods. Deficit irrigation refers to a water-conserving practice whereby water supply is reduced below maximum levels and mild crop stress is allowed, with minimal effects on yield.
Legume	Plants—including beans, peas, clovers, and alfalfa—that form a symbiotic relationship with nitrogen fixing bacteria living in their roots. These bacteria help to supply the plants with an available source of nitrogen.
Lime	A soil amendment containing calcium carbonate, magnesium carbonate and other materials, used to neutralize soil acidity and furnish calcium and magnesium for plant growth.
Managed forests	Forests subject to human interventions (notably silvicultural management such as planting, pruning, thinning), timber and fuelwood harvest, protection (fire suppression, insect suppression) and management for amenity values or conservation, with defined geographical boundaries.
Mangroves	Forest and other wooded land with mangrove vegetation.
Manure	Waste materials produced by domestic livestock. The term 'manure' is used to include both dung and urine (i.e., the solids and the liquids) produced by livestock.
Micronutrient	An element, such as zinc, iron, copper, boron, or manganese that is needed by plants in only small amounts.
Mulch	Material which is applied to the soil surface in order to reduce water loss and soil erosion, suppress weeds, reduce fruit splashing, modify soil temperatures and generally improve crop productivity.

No-till	A system of planting crops without preparing the soil with a plow, disk, chisel, or other tillage implement.
No-till (bis)	*Other definition:* A procedure whereby a crop is planted directly into the soil without ploughing after the harvest of the previous crop
Non-inversion seed bed preparation	Also known as: **non-inversive tillage.** Tillage operations which do not mix (or minimizes the mixing of) soil horizons or does not vertically mix soil within a horizon.
Nutrient	Essential element needed by plants and animals to build biomass. Classed as macronutrients if needed in large quantities (primarily nitrogen, phosphorus, potassium, calcium, magnesium and sulphur) or micronutrients if needed in very low quantities (primarily boron, chlorine, copper, iron, manganese, molybdenum and zinc).
Nutrient balance	An undefined theoretical ratio of two or more plant nutrient concentrations for an optimum growth rate and yield. Nitrogen and sulphur is a classic example that can be defined because both nutrients are metabolically related in the protein fraction.
Organic farming	A form of agriculture in which no synthetic chemicals such as inorganic fertilisers or herbicides are used.
Organic fertilizer	A carbon-rich fertilizer derived from organic materials, including treated or untreated livestock manures, compost, vermicompost, sewage sludge and other organic materials or mixed materials used to supply nutrients to soils.
Organic mulch	Any material such as straw, leaves, loos soil, etc. that is spread or formed upon the surface of the soil to protect the soil and/or plant roots from the effects of raindrops, soil crusting, freezing, evaporation, etc. Also see: **mulch**
pH	A measure of acidity, measured from 1 (acid) through 7 (neutral) to 14 (alkaline). Most soils fall in a range between pH 4 and 8.

Paludiculture	Biomass production from wet or rewetted peatlands under conditions that maintain the peat integrity, facilitating peat accumulation and ensuring the provision of peatland ecosystem services.
Permanent grassland	Permanent grasslands are defined as land being used for several consecutive years (normally 5 years or more) to grow grass or other herbaceous fodder, forage or energy crops, either through cultivation (sown/reseeded) or naturally (native/autochthone, self-seeded).
Phosphorous (P)	A highly reactive, non-metallic element with symbol P and atomic number 15. Phosphorus is never found as a free element on Earth. Essential for life as it is a component of DNA and cell membranes. Low phosphate levels limit growth in plants.
Potassium (K)	Chemical element with symbol K and atomic number 19. Essential for life and occurs in high concentrations in plants and fruits. Intensive crop production rapidly depletes soils of potassium.
Reduced tillage	A tillage practice in which the total number of tillage operations preparatory for seed planting (in herbaceous crops) or for soil aeration and decompaction (in perennial crops) is reduced from that normally used under conventional (intensive) tillage on that particular field or soil. This practice is also called minimum tillage.
Reforestation	Re-establishment of forest through planting and/or deliberate seeding on land classified as forest.
Regenerative agriculture	System of farming principles and practices that seeks to rehabilitate and enhance the entire ecosystem. It is a method of farming that improves the resources (soil, water, biodiversity, etc.) it uses and place a heavy premium on soil health.
Revegetation of peatland	Re-establishment of vegetation that is adapted to wet soil conditions.
Rewetting	The deliberate action of changing a drained soil into a wet soil, e.g., by blocking *drainage* ditches, disabling pumping facilities or breaching obstructions.

Semi-natural grassland	Grassland of natural origin, under minimum human influence vegetation dominated by grasses.
Slurry (manure)	Manure that is between solid and liquid; it flows slowly and has the consistency of a very thick soup.
Soil carbon sequestration	Land management (including crop and soil management practices) that result in a net increase in soil organic carbon content, resulting in removal of carbon dioxide (CO_2) from the atmosphere.
Soil amendment	Any material such as lime, gypsum, sawdust, compost, animal manures, crop residue or synthetic soil conditioners that is worked into the soil or applied on the surface to enhance plant growth. Amendments may contain important fertilizer elements, but the term commonly refers to added materials other than those used primarily as fertilizers.
Soil organic carbon	Carbon contained in soil organic matter.
Soil organic matter	The organic component of soil, comprising plant and animal residue at various stages of decomposition, and soil organisms.
Strip cropping	Alternation of strips of closely sown crops such as hay, wheat, or other small grains with strips of row crops, such as corn, soybeans, cotton, or sugar beets. Strip cropping helps to stop soil erosion by creating natural dams for water, helping to preserve the strength of the soil.
Superficial tillage	Tillage practice that is performed at the upper soil layer, which is annually or periodical loosened.
Sustainable Forest Management	A dynamic and evolving concept that is intended to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations.
Sustainable Soil Management	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

Sustainable Soil Management *(cont.)*	regulating services the soil provides for water quality and availability and for atmospheric greenhouse gas composition is a particular concern.
Silvopastoralism	Integration of trees with pastures and livestock husbandry.
Tillage	The mechanical manipulation of the soil profile for any purpose; but in agriculture it is usually restricted to modifying soil conditions and/or managing crop residues and/or weeds and/or incorporating chemicals for crop production.
Urban green infrastructure	Public and private green spaces, including remnant native vegetation, parks, private gardens, golf courses, street trees, urban farming and engineered options such as green roofs, green walls, biofilters and raingardens.
Urban and peri-urban agriculture	The cultivation of crops and rearing of animals for food and other uses within and surrounding the boundaries of cities, including fisheries and forestry.
Water table	The upper surface of ground water or that level in the ground where the water is at atmospheric pressure.
Wetland	Land that is covered or saturated by water for all or part of the year (for example, peatland).

Soils and soil types

Histosol	Also refers to: **peat soils.** Organic soils that have organic soil materials in more than half of the upper 80 cm, or that are of any thickness if overlying rock or fragmental materials that have interstices filled with organic soil materials.
Humus	The well decomposed, more or less stable part of the organic matter in mineral soils.
Latosol	A suborder of zonal soils including soils formed under forested, tropical, humid conditions and characterized by low silica-sesquioxide ratios of the clay fractions, low base-exchange capacity, low activity of the clay, low content of most primary minerals, low content of soluble constituents, a high degree of aggregate stability, and usually having a red color.
Ordinary chernozem	Soil with moderately deep humiferous profile, clayey dusty-sandy texture, poorly insured with mobile phosphorus, moderately insured with exchangeable potassium that requires the balanced application of the respective chemical fertilizers every year. Parental rock of soil genesis - loessoid deposits of wind origin.
Organic soil	Also refers to: **histosol and peat soils.** A soil in which the sum of the thicknesses of layers containing organic soil materials is generally greater than the sum of the thicknesses of mineral layers.
Oxisols	Mineral soils that have an oxic horizon within 2 m of the surface or plinthite as a continuous phase within 30 cm of the surface, and that do not have a spodic or argillic horizon above the oxic horizon.
Pasture	Area covered with grass or other plants used or suitable for grazing of livestock; grassland.
Peat soil	Soil that is mainly composed of organic matter from partially decomposed dead plant material that has accumulated in wet and oxygen-deficient soil conditions caused by a high water table. In their natural, water-saturated status, most peatlands are slow carbon sinks that sequester soil organic carbon (SOC), provide

Peat soil *(cont.)*	numerous ecosystem services, and are key in climate change mitigation and adaptation efforts.
Peatland	Also refers to: **organic soils, bogs, fens, swamps or mires.** World's most carbon-dense terrestrial ecosystems and store most of the carbon in the soil, also called peat.
Permafrost	Ground (soil or rock and included ice and organic material) that remains at or below 0 °C for at least two consecutive years
Technosol	Also refers to: **artificial soils.** Soils whose development are dictated by human-created origin conditions. This could be the inclusion of foreign artifacts or soils which are isolated from the rest of the lithosphere by some sort of liner or constructed hardscape which is dissimilar to natural rock.
Topsoil	Generally dark-coloured uppermost layer of soil containing decomposing organic matter, usually high in nutrients.

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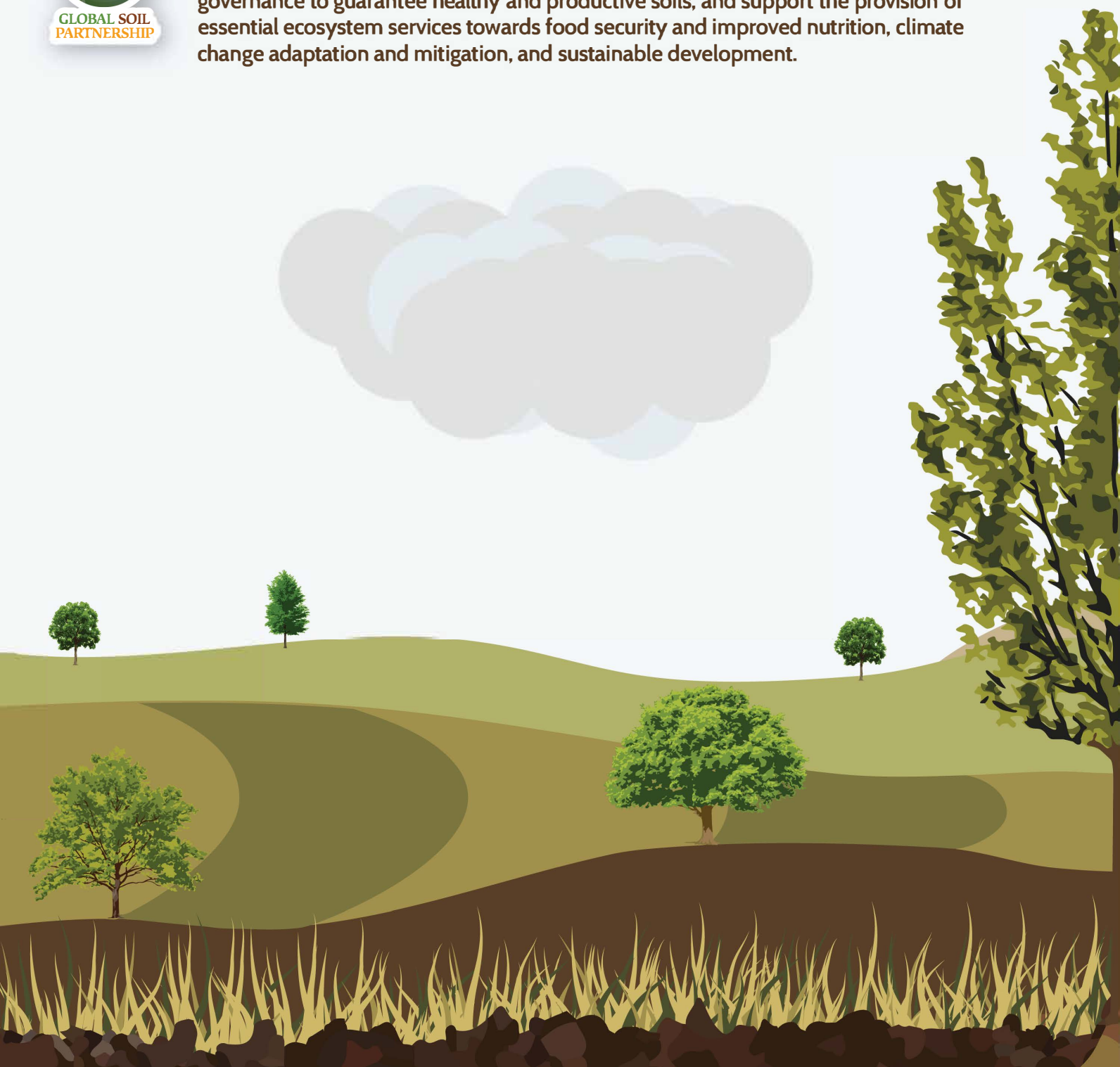
GLOBAL SOIL PARTNERSHIP

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.



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