United Nations
Convention to Combat Desertification

UNCCD SPI Science - Policy Interface

SCIENCE-POLICY BRIEF

Tools for Soil Organic Carbon Estimation and Management

Why manage soil organic carbon?

Land degradation neutrality (LDN) is achieved if land degradation is avoided or reduced, and new degradation is balanced by reversing degradation elsewhere in the same land type through restoration or rehabilitation. The primary instrument for avoiding and reducing degradation is the application of sustainable land management (SLM) approaches and technologies. Because of its multifunctional roles and its sensitivity to land management, soil organic carbon (SOC) is one of the three global indicators for LDN, so predicting and monitoring change in SOC is vital to achieving LDN targets. Measuring SOC is challenging because SOC stock is highly variable across landscapes, even within the same soil type and land use, and SOC stock fluctuates over time. Predicting the potential change in SOC stock due to changes in land management is also a challenge. Accurate evaluation of SOC stock change resulting from SLM interventions is often limited by the availability of data and the performance of tools/models for SOC assessment. Therefore, targeted investment in SOC estimation is vital. Guidance on harmonized methods that provide accurate estimations of changes in SOC stocks resulting from SLM interventions is required. Software tools and biophysical models for SOC assessment can help "fill the gaps" in measured datasets for SOC estimation. The following decision trees will guide efforts to predict change in SOC under alternative SLM practices, and monitor SOC change in response to SLM interventions, and thereby support decision-makers to pursue the right SLM interventions in the right locations, at the right time, at the right scale with the overall goal to increase or maintain SOC and improve soil health in support of LDN achievement.

The importance of sustainable land management for soil organic carbon

SOC is an important component of the global carbon cycle and is a major constituent of soil organic matter (SOM), which plays a critical role in soil productivity and a wide array of ecosystem services. Preserving or increasing SOC brings along with it, multiple co-benefits which support not only the SDG 15.3 – striving to achieve a land degradation neutral world, but also SGDs 2 (Zero Hunger), 3 (Good health and well-being), 6 (Clean water and sanitation) and 13 (Climate action), and 5 (Gender equality). Improvements in SOC through SLM have strong beneficial impacts on soil properties and processes.

Beneficial impacts of SOC/SOM on soil health and functionality	
Constraint	Impact of increasing SOC through SLM
Drought	Water conservation, soil temperature moderation, root system proliferation, improved green water supply
Soil fertility	Nutrient retention and availability; reduced losses by leaching, volatilization, and erosion; high nutrient use efficiency
Soil health	Disease-suppressive soils, high soil biodiversity, improved plant growth and vigour, soil resilience
Soil tilth	Low risks of crusting and compaction; better soil aeration, water infiltration and plant germination due to favourable bulk density and pore size distribution
Production	Sustainable agronomic production, increased yield, better nutritional quality, improved resilience.

MAINSTREAMING GENDER INTO LAND RELATED ACTIVITIES

The UNCCD Gender Action Plan provides an agreed framework for the full and effective participation of both women and men in planning, decision-making and implementation at all levels, in order to empower women, girls and youth. The incorporation of gender-responsive actions* into project activities, pro-actively addresses gender differences and promotes gender equality and women's empowerment. This equitable participation in LDN/SLM initiatives improves prospects for socio-economic development and environmental outcomes.

* More details on the benefits of including gender-responsive actions are found in table 4 in the corresponding UNCCD-SPI technical report

GUIDANCE FOR DECISION-MAKERS

DECISION TREE 1

When is investment in SOC monitoring recommended?

Assessment of LDN achievements requires monitoring SOC change as one of the three global LDN indicators. However, limited data often hinders SOC monitoring, suggesting the need to invest in such an assessment. Yet, how do you know if an investment is necessary? To assist in this decision-making process, decision tree 1 provides guidance on where investment in SOC assessment and monitoring are recommended, to track the impact of SLM implementation and to support monitoring of LDN achievement in terms of SOC change in 2030. Decision tree 1 guides selection of SLM practices to increase or maintain SOC stocks and deliver other benefits, using information ranging from local knowledge to global datasets. The first step involves the evaluation of land health, which includes an assessment of land potential and land degradation status, which are preparatory steps of LDN planning.

Next steps: SLM requires a combination of measured data and tool/models for SOC assessment (go to decision tree 2). Investment to improve tools/models may be required to scale up SOC estimation to support LDN achievements (go to decision tree 3a and 4). Additionally, Table 6 in the corresponding technical report shows, for broad groups of SLM practices applicable to different land use systems, the degree in which they influence SOC.

If you identify potential SLM options where SOC is necessary to verify LDN achievment, **>> follow this arrow <<**

Scan the QR codes to download each decision tree!

If investment in comparative assessment is recommended, **>> follow this arrow <<**

To monitor SOC, **>> follow this arrow <<**

DECISION TREE 2

How to estimate the change in SOC due to SLM

Decision tree 2 guides the establishment of SOC monitoring and investment in measurement schemes that most effectively contribute to national-scale LDN assessment. Using direct measurement or tools/models for SOC assessment (or a combination of both) contributes to the efforts of national-scale LDN assessment. This decision tree is intended for repeated use throughout the LDN process as SLM practices are deployed.

Next steps: Decision tree 2 provides guidance on alternative steps to follow depending on whether you have the capacity to measure baseline stocks or will use the "space-for-time substitution" measurement approach, or will use tools/models for SOC assessment. Go to decision tree 5 for guidance on measuring SOC and decision tree 3a for guidance on the use of tools/models.

To improve or develeop your capacity to assess SOC, **>> follow this arrow <<**

Target groups:
- Technical representatives
- Policy-makers

DECISION TREE 3a

What is your required level of certainty?

The level of certainty required depends on how the data will be used. For example, to guide the selection of SLM practices, moderate certainty is needed, whereas, for emission trading, high certainty is needed. LDN practitioners may invest in a comparative assessment of SOC based on the lowest level of certainty required to yield results useful for SLM decision making. Decision trees 3a and 3b provide guidance for obtaining SOC data for different levels of certainty. They guide you through which steps to take in the cases when high, medium or low certainty is required.

Next steps: As data are not always available at the required level of certainty, additional SOC measurement (go to decision tree 5) or model development may be required (see Framework to manage soil organic carbon for land degradation neutrality).

DECISION TREE 4

Where is SOC monitoring a priority?

For some LDN interventions, the change in SOC will be closely linked with a change in land productivity and/or land cover, so SOC stock change can be estimated using the indicators for land productivity and land cover. However, for SLM technologies and approaches that do not change land cover or productivity markedly, monitoring SOC will be a high priority. Decision tree 4 can assist to define where tracking and monitoring of SOC is necessary for verifying LDN achievements.

Note: Low intensity SOC monitoring is suitable over larger/relatively uniform areas, whereas more intensive SOC monitoring is needed in lands that are more variable.

If your data is complete, **>> follow this arrow <<**

If your data has gaps, **>> follow this arrow <<**

DECISION TREE 3b

How to obtain SOC data when high certainty is needed

Decision tree 3b guides you through steps to take when high certainty data are required, depending on whether there are few, some, or extensive data available.

Next steps: If the tool/model for SOC assessment does not fit the scale, eco-region or SLM practice, it is recommended to gather measured data using benchmark sites of SLM interventions, to improve the tools/models for SOC assessment (go to decision tree 5). Additionally, refer to tables 8 and 9 in the corresponding SPI technical report for guidance on selecting an appropriate model to suit your purpose.

DECISION TREE 5

How to gather or improve SOC data

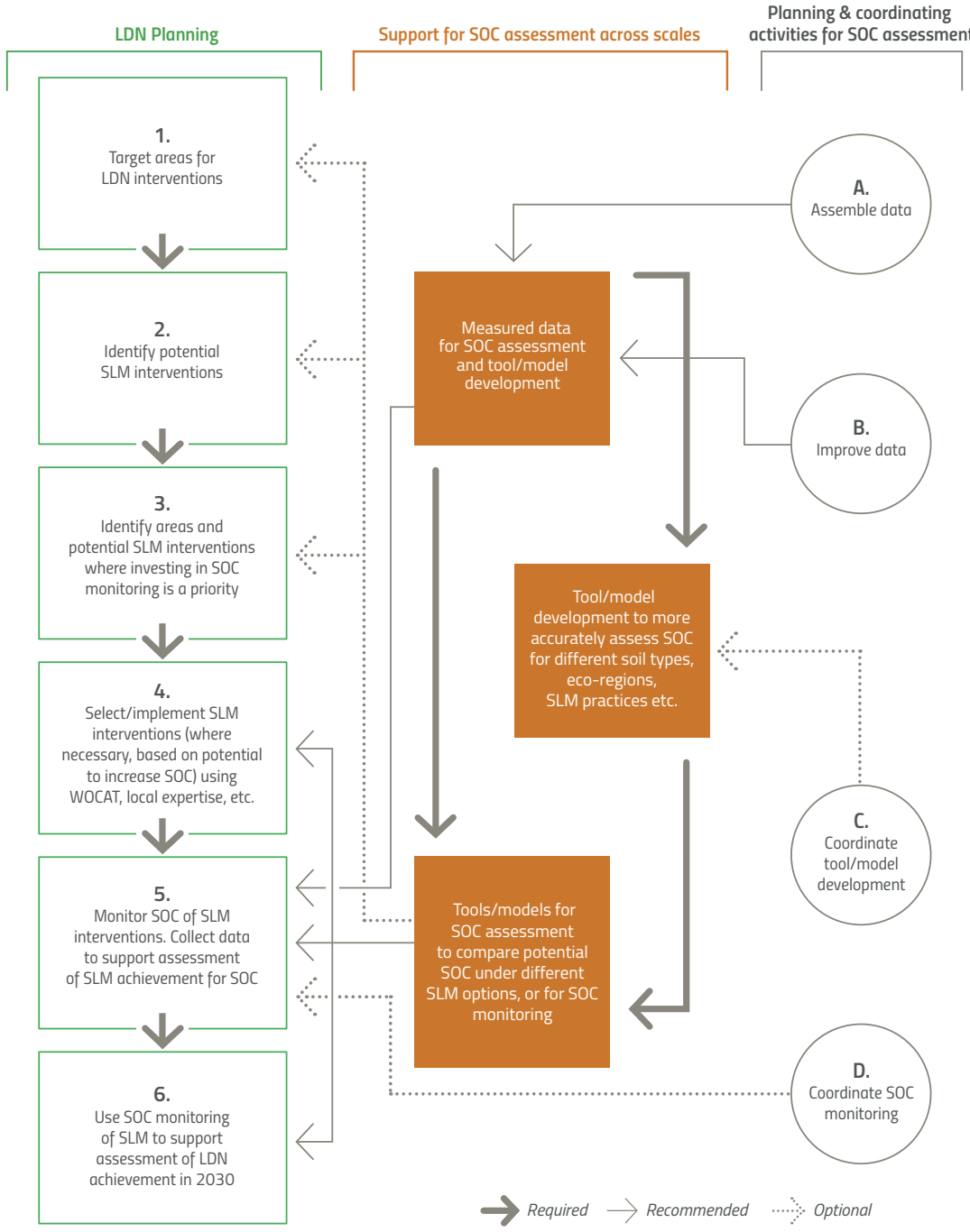
A challenge with monitoring the changes in SOC is that high measurement precision is required in order to detect SOC change due to SLM. Decision tree 5 assists in selecting a suitable approach to soil sampling fit for the challenge at hand. If financial and human resources are not a constraint, it is recommended to establish a national SOC monitoring network.

Next steps: In the case that financial and human resources are not sufficient for a national SOC monitoring program, decision tree 4 provides guidance on how to identify sites where SOC measurement is a priority. In either case, you can refer to the FAO 2019 publication "Measuring and Modelling Soil Carbon Stocks and Stock Changes in Livestock Production Systems Guidelines for Assessment" for further detailed guidance on SOC sampling.

To establish tools/models to access SOC stocks, **>> follow this arrow <<**

A framework to manage SOC for LDN

To optimize the use of limited resources to manage SOC using SLM to pursue LDN, the framework below matches areas of land to suitable SLM approaches which are supported by information from SOC measurements and tools/models for SOC assessment. The framework guides the development, testing and refinement of SOC assessment methods for application in SOC monitoring, to support the assessment of LDN achievement.



This framework shows how the combined use of measured data and tools/models for SOC assessment (orange boxes), supported by planning and coordination activities (grey circles) underpin LDN planning activities leading to LDN achievement (green boxes). Planning activities to (A) assemble data, (B) improve data and coordinate activities (C and D) can occur with scientific, industry, and other activities outside of LDN efforts.

What can policy-makers do right now?

- **Focus SOC measurement on sites where SOC is the key indicator** (e.g. in croplands and grazing lands where NPP and LCC are less reliable indicators of land degradation and improvement – such as between different cropland management practices; or where specific land degradation processes are not readily reflected in trends in land cover and land productivity);
- **Use national/local data and local expertise** to apply SOC tools/models for SOC assessment for estimation and monitoring. There are several free global datasets that offer soil SOC information that may be suitable, depending on the level of certainty required.
- **Combining measurement and tools/models for SOC assessment** can be an efficient and robust approach to minimize cost: use measurement to establish the baseline, apply tools/models to estimate SOC change. Quantify and report measurement and model uncertainties.
- **Use SOC estimation tools to choose appropriate SLM practices**, suited to the local context.
- **Encourage gender-responsive actions** to promote gender equality by including gender equality in the preliminary LDN assessment as well as developing criteria to evaluate gender balance.
- **Target application of SLM practices** (policies,strategies,approaches, and technologies) to maintain or increase SOC, to achieve LDN and multiple benefits at landscape and national level.
- **Assess co-benefits** and trade-offs between ecosystem services provided by land, to contribute to the evidence base of quantified examples of the multiple benefits of SLM.

Further practical guidance on estimation of SOC is provided in the UNCCD-SPI technical report "Realising the Carbon Benefits of Sustainable Land Management Practices: Guidelines for Estimation of Soil organic Carbon in the Context of Land Degradation Neutrality Planning and Monitoring".

UNCCD-SPI related publications

- J. L. Chotte, E. Aynekulu, A. Cowie, E. Campbell, P. Vlek, R. Lal, M. Kapović-Solomun, G. von Maltitz, G. Kust, N. Barger, R. Vargas and S. Gastrow. 2019. Realising the Carbon Benefits of Sustainable Land Management Practices: Guidelines for Estimation of Soil Organic Carbon in the Context of Land Degradation Neutrality Planning and Monitoring. A report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn Germany.
- P. H. Verburg, G. Metternicht, C. Allen, N. Debonne, M. Akhtar-Schuster, M. Inácio da Cunha, Z. Karim, A. Pilon, O. Raja, M. Sánchez Santivañez and A. Senyaz. 2019. Creating an Enabling Environment for Land Degradation Neutrality and its Potential Contribution to Enhancing Well-being, Livelihoods and the Environment. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.
- A. Reichhuber, N. Gerber, A. Mirzabaev, M. Svoboda, A. López Santos, V. Graw, R. Stefanski, J. Davies, A. Vuković, M. A. Fernández García, C. Fiati and X.Jia. 2019. The Land-Drought Nexus: Enhancing the Role of Land-Based Interventions in Drought Mitigation and Risk Management. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.
- B. J. Orr, A. L. Cowie, V. M. Castillo Sanchez, P. Chasek, N. D. Crossman, A. Erlewein, G. Louwagie, M. Maron, G. I. Metternicht, S. Minelli, A. E. Tengberg, S. Walter and S. Welton. 2017. Scientific Conceptual Framework for Land Degradation Neutrality. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.
- M. J. Sanz, J. de Vente, J.-L. Chotte, M. Bernoux, G. Kust, I. Ruiz, M. Almagro, J.-A. Alloza, R. Vallejo, V. Castillo, A. Hebel and M. Akhtar-Schuster. 2017. Sustainable Land Management contribution to successful land-based climate change adaptation and mitigation. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany
- UNCCD 2018. Gender Action Plan https://www.unccd.int/sites/default/files/documents/2018-01/GAP%20ENG%20%20low%20res_0.pdf

Further reading:

- FAO. 2019. Measuring and modeling soil carbon stocks and stock changes in livestock production systems: Guidelines for assessment (Version 1). Livestock Environmental Assessment and Performance (LEAP) Partnership. Rome, FAO.
- FAO. 2017. Soil Organic Carbon: the hidden potential. Food and Agriculture Organization of the United Nations. Rome, Italy.

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Download the corresponding SPI Technical Report and supplementary materials here:

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UNCCD SPI Science - Policy Interface

The mission of the UNCCD Science-Policy Interface (SPI) is to facilitate a two-way dialogue between scientists and policy makers in order to ensure the delivery of science-based, policy-relevant information, knowledge and advice.