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Guidelines for the determination of organic carbon and nitrogen stocks and their variations in mineral soils at field scale

Lignes directrices pour la détermination des stocks de carbone organique et d'azote et de leurs variations dans les sols minéraux à l'échelle d'une parcelle

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 190, *Soil quality*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Soils comprise an important pool in the biogeochemical cycles of carbon (C) and nitrogen (N), and thus are critical for climate regulation either by emitting greenhouse gases (GHGs) or by sequestering C.[1]. Soils are the largest terrestrial reservoir of organic carbon, accounting for more carbon than contained in the atmosphere or biota. Consequently, relatively small changes in soil carbon stocks can equate to considerable exchanges with other actively cycling carbon pools, such as the atmosphere. Estimation of soil organic carbon stock changes is one of the main methods applied to determine long-term carbon fluxes and to design carbon sequestration strategies. Soil organic carbon (soil OC) is the balance between inputs (e.g. plant residues, manure, etc.) and biologically mediated losses. Information on soil total N stocks is valuable, because adequate N is critical for plant production while excessive N can be an environmental hazard. Leakage of nitrous oxide (N_2O) from terrestrial systems to the atmosphere (where it enhances radiative forcing and may catalyse stratospheric ozone (O_3) destruction) is one hazard associated with excessive soil N inputs. The ratio of organic C to total N stock can also provide insight into soil OC stability and potential for element retention in the soil. Climate policies promote actions regarding the protection and increase of soil OC stocks. Such measures require standardized methods to assess the current soil OC stocks at the relevant scale (e.g. plot, farm, region) and to verify the efficiency of soil carbon sequestration actions. This document provides guidance on the measurement of carbon and nitrogen stocks in soils and to the detection of their temporal variations.

Guidelines for the determination of organic carbon and nitrogen stocks and their variations in mineral soils at field scale

1 Scope

This document presents a method to quantify the soil organic carbon and nitrogen stocks in mineral soils at plot scale. It also provides guidance on how to detect and quantify simultaneously the variations of carbon and nitrogen stocks over time in mineral soils at field scale. It is based on several documents already published[2],[3],[4],[5],[6],[7],[8].

This document does not apply to organic soils, soils with permafrost, wetland soils, or to soil layers prone to submergence below the groundwater table.

NOTE 1 The possibility of increasing soil C storage is viewed as a means to sequester atmospheric carbon dioxide (CO_2) and mitigate greenhouse gas (GHG) emissions. Information on soil nitrogen (N) stocks is crucial because it interacts with carbon cycling through plant nutrition and organic matter decomposition, and leakage of N is of environmental concern (e.g. N_2O emissions, NO_3- leaching). Therefore, it is becoming increasingly important to measure accurately the impact of changes of land uses and practices on organic carbon and nitrogen stocks.

NOTE 2 While understanding changes in soil inorganic carbon it is important also to understand the land-atmosphere exchange of CO_2, measuring stocks of soil inorganic carbon is outside the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16133, *Soil quality — Guidance on the establishment and maintenance of monitoring programmes*

ISO 18400-101, *Soil quality — Sampling — Part 101: Framework for the preparation and application of a sampling plan*

ISO 18400-105, *Soil quality — Sampling — Part 105: Packaging, transport, storage and preservation of samples*

ISO 18400-206, *Soil quality — Sampling — Part 206: Collection, handling and storage of soil under aerobic conditions for the assessment of microbiological processes, biomass and diversity in the laboratory*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
spatial composite sample
two or more individual soil samples (e.g. cores) separated laterally in space having the same volume, and coming from the same soil layer or depth increment

Note 1 to entry: Also called average sample or aggregated sample.

Note 2 to entry: Composite samples sometimes are collected to encompass more lateral variability and better represent the mean of the measurement (e.g. water content, or C concentration) than provided by a single soil core.

3.2
land cover
observed (bio)physical cover of the Earth's surface

3.3
land use
socio-economic purpose of the land

3.4
land management practices
approach taken to achieve a land use outcome - the 'how' of land use (e.g. cultivation practices, such as minimum tillage and direct drilling)

3.5
mineral soil
soil composed largely or entirely of mineral (inorganic) constituents

[SOURCE: ISO 14688-1:2017]

3.6
organic soil
soil in which the organic component is dominant with respect to the mineral component

Note 1 to entry: For the purpose of this standard, organic soils are taken to contain more than 50 % organic matter by volume or more than 30 % organic matter by weight, i.e. 17 % of organic carbon. The definition of 'organic soil" varies between different soil classification systems.

3.7
organic soil layer
horizon dominated by organic material, consisting of undecomposed or partially decomposed litter, such as leaves, needles, twigs, moss, and lichens, which has accumulated on the surface; they may be on top of either mineral or organic soils

3.8
permafrost
ground consisting of mineral soil and sediment, rock, ice, peat and other organic materials that remain below 0 °C for at least two consecutive years

3.9
sampling point
precise position within a sampling site or within each soil constituting horizon from which samples are collected

Note 1 to entry: The coordinates must include x and y dimensions to indicate lateral locations and may also indicate the elevation of the soil surface in m relative to sea level.

3.10
undisturbed sample
sample obtained from the soil using a method designed to preserve the soil structure

3.11
soil layer
layer of soil defined by its upper and deeper dimension (e.g. 0-30; 30-50 cm etc.) and/or by the sampling procedure and it may comprise, or intersect, one or more soil horizons

Note 1 to entry: An horizon is a layer in soil that is roughly parallel to the ground surface and which is distinguished from layers above or below it on the basis of physical, chemical or biological differences ([9],[10]).

Note 2 to entry: Horizon related sample: sample collected from and representing a defined soil horizon.

4 Principle

Organic carbon and nitrogen stocks in mineral soils reflect the balance between inputs and outputs of C and N to the soil over decadal spans of time. Soil is heterogeneous due to variations in climate, parent material, topography, organisms (including human activity) and time. Consequently, soil C stocks vary with depth, location in space and sampling time. A proper sampling strategy should be implemented to take this into account in order to get a representative estimate of C and N stocks. This generally entails collecting several soil samples at different depths and locations.

To estimate soil organic carbon (soil OC) and total nitrogen (TN) stocks, samples of a known volume shall be collected, and the following determinations made:

— dry mass of the entire sample;

— dry mass of coarse (> 2 mm) mineral fragments or stones;

— fine soil (≤ 2mm) mass per volume sampled ("bulk density");

— carbon and nitrogen concentrations in the fine soil fraction.

In general, significant field variations in organic carbon and nitrogen stocks occur very slowly, often over a period of 5 to 10 years as a minimum, depending on climate and soil management practices. Careful consideration of the complex factors governing the distribution of carbon and nitrogen stocks is important for the sampling design over space and time to be able to differentiate spatial and temporal variations.

Each step of the procedure (e.g. sampling, analysis) is associated with uncertainties, which can be quantified in order to calculate the total uncertainties regarding stocks and stock variation values. However, it could suffice to collect replicate cores, recognizing that they will encompass variability in space as well as errors associated with all the steps. Separately quantifying analytical uncertainties can verify that properly implemented methods using modern elemental analysers have small errors.

5 Procedure

5.1 Site investigation strategy

Site and soil description are necessary to interpret soil carbon stocks measurements and provide a basis for extrapolation.

A site investigation strategy shall be prepared for the overall investigation. In addition to the sampling strategy prepared in accordance with 5.2. This might include:

— description of the area of interest;

— current and past uses (e.g. crops, livestock, natural vegetation, restoration works) and management (e.g. soil tillage, organic fertilization and amendment, cover crops, crop yields, crop residue removal);

— characterization of soils and profiles as deemed necessary, including for example soil type, layer thicknesses, and basic physical and chemical characteristics;

— using methods to record sampling locations that will permit precise positioning of subsequent (5 to 10 years in the future) sampling, including GPS coordinates with sub-metre resolution, distances to other permanent features, installation of an electromagnetic marker, etc.

Particular care shall be taken when developing the overall strategy and the sampling strategy so that samples can be collected from the same sampling locations in future years to monitor changes in soil organic carbon stock (in accordance with ISO 16133 relating to monitoring sites). Sufficient and appropriate information on the site/area and soils should be collected to enable comparisons with the results for other areas, when this is required.

NOTE 1 ISO 18400-202 gives detailed guidance on desk studies and site inspections (preliminary investigations) and ISO 18400-205 gives further guidance relating to natural, near natural and cultivated sites. ISO 18400-205 gives specific guidance on sampling in orchards etc. and wooded areas.

NOTE 2 ISO 25177 provides guidance on site and soil descriptions.

5.2 Sampling

5.2.1 Sampling objectives

The goal of soil sampling is to collect volumetric samples that represent the area of interest, and that estimate mean soil OC and TN stocks (element masses per unit area to a specified soil depth and mass), including estimates of variability (i.e. scatter or dispersion of the data) about the means.

Determination of the soil organic carbon and total nitrogen stocks for a defined area (e.g., plot, field) thus requires the boundaries of the area of interest to be delineated and the depth (range) of interest to be decided.

The mass of soil also shall be stated. Assuming negligible geomorphological processes, comparisons among soil OC or TN stocks should preferably be based on an equivalent soil mass, rather than on a fixed volume.

It is also necessary to know the moisture content so that the results can be expressed on a dry weight basis. The analytical measurements for C and N are made on the less than 2 mm fraction. It is therefore necessary to know the mass of material (e.g. rocks, organic fragments) in the soil that is > 2 mm.

All organic matter in representative soil samples must be quantified, including the coarse (> 2mm) organic fraction. Such materials can be ground or chopped to < 2 mm and included for analysis with the entire < 2 mm mineral soil sample, or they can be isolated (e.g. as particulate or light fraction OM) and analysed independently, but they must not be discarded.

NOTE 1 Scale is discussed in ISO 18400-104, 5.6 and Annex E.

NOTE 2 Since sample processing and chemical analyses account for relatively small cost increments on sample collection, it usually is preferable to perform independent analyses on separate sampling points and soil layers. This provides important information on variability in three dimensions. In addition, when samples are taken on at least two different collection dates, it makes it possible to distinguish temporal variability from spatial variability.

NOTE 3 Depending on the specific program objectives, the coarse organic fraction could be determined (and its C-N content measured) separately from the mineral soil to assess the time dynamics for specific purposes (short term change of stocks, effect of a specific practice of OM management etc.). Particulate or light fraction OM is often sensitive to management changes, and measuring > 2 mm fractions could provide early and valuable indications of forthcoming changes in soil OC stocks.

5.2.2 Sampling plan

A sampling plan shall be prepared in accordance with ISO 18400-101.

This should describe what is to be done to obtain the required samples and the practical requirements for carrying out the work (i.e. how to implement the sampling strategy, see 5.2.3).

Whatever the methods used to collect or form samples, their form and how they are to be taken should be prescribed in the sampling plan.

5.2.3 Sampling strategy

5.2.3.1 General

A sampling strategy should be prepared in accordance with the guidance in ISO 18400-104 having regard also to the guidance in ISO 18400-205. Usually based on the site investigation (5.1), the site may be stratified in different zones using as a minimum the following variables[11]:

— land location (nearest settlement or roadway), legal land description, GPS coordinates;

— typical soil texture, parent material, solum thickness, soil classification;

— topography and landscape morphology (e.g. slope position, surface shape (concavity/convexity), erosion forms, drainage and water regime);

— biome, ecodistrict (if known), remote sensing images, vegetative cover, land use and management.

The sampling strategy should also:

— include all sampling activities that are to be undertaken;

— determine how to collect volumetric samples that represent the area of interest and that estimate mean soil OC and TN stocks including estimates of variability about the means;

— provide information on spatial variation at the desired scale if required.

Mean elemental stocks of the area can be determined using composite sampling (see 5.2.3.2 – Figure 1) or by averaging the stocks from independent sampling points (see 5.2.3.3 – Figure 1). The latter is preferred because it will yield information on variability at the scale of the sampling pattern and it allows pairing of sampling points from different sampling times to improve assessment of temporal changes (see Clause 7). However, depending on the budget, compositing can be required. Figure 1 gives an overview of the different steps needed from sampling to calculating to obtain a mean elemental value of the stock of an area.

Bulk density measurements and carbon and nitrogen concentrations should all derive from the same core sample to determine the soil OC and TN stocks for that sample.