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Soil quality — Framework for detailed recording and monitoring of changes in dynamic soil properties

Qualité du sol — Cadre pour l'enregistrement détaillé et la surveillance des modifications des propriétés dynamiques du sol

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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Contents

Page

iTeh STANDARD PREVIEW
(standards.iteh.ai)
ISO 23992:2022
https://standards.iteh.ai/catalog/standards/sist/108f147b-5ffe-40ec-859c-b17f74be7ca9/iso-23992-2022

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ISO 23992:2022

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23992-2022

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Introduction

Since it is not an absolute concept, even within a single purpose that soil can serve (e.g. natural habitat, recreational land, agriculture, ecosystem services), soil quality is difficult to define and quantify. Surface soil (also referred to as the surface A horizon or topsoil) with good quality is characterized by improved soil structure, greater water retention, nutrient cycling and aeration, and enhanced biological diversity[1]. Surface soil provides the major portion of nutrients, water and air for supporting plant and microbial growth, and is dynamic both spatially and temporally with respect to soil processes and properties. In the face of increasing global degradation of soil resources there is a growing need to describe dynamic soil properties related to soil function, along with dynamic and static conditions that influence function, in order to, for example, track effects of land management (e.g. remediation, agricultural practices) on soil quality (e.g. crop yield, drought resilience) or develop dynamic soil properties databases to enhance existing soil survey databases for estimation of carbon stocks in soils, sustainable agriculture, etc. ISO 25177 standardizes soil description for use in pedological, environmental or other studies in the field at site and plot scales. When combined with the precise system of recording needed to monitor and track changes in surface soils described in this document, data collected is optimally used, for example to identify trends due to changes in land use or land management.

This document is a framework to integratively record and monitor changes in physical, chemical and biological soil properties in surface soils as well as to systematically document landscape conditions and land use management practices. The framework records and facilitates the monitoring of soil surface horizon characteristics that represent dynamic soil properties (e.g. soil structure, organic carbon) inherent soil properties (e.g. soil texture), and landscape features (e.g. slope), land use (e.g. crop type) and land management activities (e.g. tillage practices). Collecting "contextual" data in addition to data on dynamic and static soil properties allows for comparative interpretations of soil quality change and the ability to identify trends due to changes in management practices or remediation efforts among different soils, or the same soils under different conditions or at different times.

The criteria chosen and used in the framework for soil descriptions were field-tested with the goal of maximizing information necessary for making soil quality interpretations and for designing decision models for assessing the state of soil quality. The soil quality description framework has been field-tested at sites in eastern Canada (Ontario)[2] and western Canada (British Columbia)[3] as well as in northern (Osnabrück) and eastern (Müncheberg) Germany. The framework has also been used in field studies to determine its ability to characterize surface soil in agricultural soils in Russia (Siberia).[4] In this study, differences in soil fingerprint codes were statistically compared using hierarchical cluster analyses.

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Soil quality — Framework for detailed recording and monitoring of changes in dynamic soil properties

1 Scope

This document provides a framework for the detailed assessment and monitoring of dynamic soil properties related to soil function with concomitant recording of in-situ static soil properties, landscape, land use and soil management practices that influence function at the time the data were collected. It is applicable to the assessment of soil quality in agricultural landscapes, contaminated sites and natural soil ecosystems at plot, field and landscape spatial scales. It can also be applied in the development of dynamic properties databases to enhance existing soil survey databases for estimation of carbon stocks in soils, sustainable agriculture, landscape management etc.

Although the soil quality description framework has been developed to describe surface soils, the same principles can be applied to adapt the framework to describe subsurface soil horizons.

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 11074, *Soil quality — Vocabulary*

ISO 25177, *Soil quality — Field soil description*

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ISO 23992:2022
https://standards.iteh.ai/catalog/standards/sist/108f147b-5ffe-40ec-859c-b17f74be7ca9/iso-23992-2022

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11074 and the following 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
soil fingerprint code
single line of soil and environmental information compiled using a system of formatting and syntax that is unique to an individual soil sample

Note 1 to entry: A soil fingerprint code developed in accordance with this document is considered metadata.

4 Principle

The soil quality description framework uses a system of formatting and syntax to record various soil and environmental information about a soil sample in a single line that is unique to a soil sample at the time the data were collected. This single line, or code, is analogous to the generation of a genetic code or "soil fingerprint" for a soil sample. The framework is designed with specific formatting and syntax so that each level of description is easily identifiable in the recorded soil fingerprint code. The symbols used to generate the soil fingerprint codes were developed using elements from several national and global soil description systems (including the Food Agriculture Organization of the United Nations

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(FAO), Canada, Germany, Australia, New Zealand and the United States) as well from field observations to address knowledge gaps identified during field assessments.

NOTE The framework does not attempt to recreate any particular international or national soil description, or try to use only one system or standard for its terminology. The framework stands outside traditional soil description terminology, which is primarily used for enabling the classification of soils. The framework has borrowed from many systems in order to maximize the ability to record what is observed in the field/landscape and measured in the laboratory, and then uses the complete set of information in the format of a soil fingerprint code. This soil fingerprint code is then used to determine changes in soil quality and obtain an understanding of where the change is happening. Because the framework is designed to be flexible (i.e. levels and codes can be changed depending on the application of the framework) it can be used with any international or national soil classification system (e.g. see Annex A for an example concordance table of soil description coding for soil structure types).

The framework generates five levels of information in a soil fingerprint code:

— Level 1 – soil process, parent materials and mode of deposition;

— Level 2 – soil structure attributes and bulk density;

— Level 3 – percentage organic carbon;

— Level 4 – pH/electrical conductivity;

— Level 5 – soil and landscape context.

Once all of the data have been obtained the soil fingerprint code is generated using symbology and syntax rulesets. In brief, each level has a defined location in the soil fingerprint code, and the order and specific syntax (brackets, semi-colons, etc.) within each level indicates the type of information that augments the symbol “A” which indicates that the soil is an A, or surface soil, horizon. A description of the five levels of information and their associated syntax is provided in Tables 1 and 2 with detailed descriptions of individual codes and symbols for each level provided in Annex B.

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ISO 23992:2022

The soil quality description framework includes organic carbon, soil pH, electrical conductivity, bulk density and especially soil structure as these are considered key dynamic properties to record when monitoring the effect of land use and land management on soil quality in agricultural, contaminated, forest and other natural soil ecosystems[14]. It is recommended to refer to related International Standards for each of the chemical and bulk density measurements (e.g. ISO 10390[15], ISO 10694[16], ISO 14235[17], ISO 11265[18], ISO 11272[19], ISO 11508[20]).

A key design feature of the soil quality description framework is that the amount and type of data in the code is flexible; any soil information in Levels 1 to 5 may be excluded if it is not deemed important for study objectives or data interpretation. Conversely, new levels and associated syntax and symbols may be developed for inclusion into the framework depending on study objectives (e.g. microbial structure and function endpoints, ecotoxicity, soil fertility, soil pore characteristics, water infiltration rate, etc.). Many International Standards that measure dynamic soil properties or indicators of soil function (e.g. soil aggregate stability, effect of pollution on earthworms and collembolans, soil microbial respiration, sampling of soil invertebrates) can be incorporated into the soil framework. Additional information such as sampling date, soil horizon depth and sample location identifying coordinates (e.g. GPS or latitude/longitude coordinates) can also be integrated into a soil fingerprint code.

If extensive databases of soil codes are created, interpretative frameworks for individual codes specific to soil type, land use and climate (and broad study objectives) can be created.

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5 Methodology

5.1 Obtaining data

5.1.1 General

The quality of field-observed data depends on the knowledge and experience of the observer. To ensure consistent soil observations field soil descriptions should be conducted by trained and experienced personnel, ideally those familiar with similar landscapes, soil types and project objectives (see ISO 25177).

All quantitative data measured for all soil quality framework levels shall be recorded and reported in International Units. ISO 18400-101 [5], ISO 18400-102[6], ISO 18400-103[7], ISO 18400-104 [8], ISO 18400-203[11] and ISO 18400-205[12] can be applied for soil sampling preparation and sampling implementation. Regarding QA/QC procedures, where aspects of soil description are mentioned or given in ISO 18400-106, ISO 18400-106 can be applied. Alternatively or in addition, other guidance on QA/QC can be applicable.

To facilitate digital exchange of soil related data, ISO 28258 can be applied[13].

The data to be collected and the method(s) used to collect data for each soil quality framework level shall be decided in advance and documented in a sampling plan. If a decision is made to not collect data for one or more levels the decision and the reason for it shall also be recorded in a sampling plan. Deviations from the plan and the reasons for these deviations shall be recorded. If a specific soil taxonomic classification is used instead of the symbology in the framework (see Annex B), the classification system (including reference) used shall be recorded in the sampling plan.

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Subclauses 5.1.2 to 5.1.7 describe the collection of data required to populate each soil quality framework level.

ISO 23992:2022
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5.1.2 Level 0 — Metadata

Metadata associated with the collection of each soil fingerprint code shall be collected and/or recorded and include:

— date (and where applicable and/or possible, time) of soil sample collection;

— geospecific location of soil sample collection (e.g. latitude and longitude or global positioning system coordinates with associated projections, etc.);

— identification references of soil sample locations (e.g. project number, project name, field site, field plot, sampling position, sample number, etc., as appropriate); field site, field plot, field replicate names, as appropriate);

— upper and lower extents of soil horizon depth (m) from soil surface of sample collected.

These metadata shall be recorded in the sampling plan and collated with soil fingerprint codes (see Figure 3 and Annex A).

Existing or antecedent field conditions that can influence soil sample data (e.g., dry or wet soil conditions) should be recorded. ISO 25177 description shall be applied for description of other metadata.

5.1.3 Level 1 — Soil formation processes and horizon number

Level 1 soil formation process data can be obtained from soil survey records. To determine horizon number, the soil profile of the entire surface soil horizon shall be exposed. This can be done by excavating a small soil pit using a spade or shovel to the entire depth of the A horizon [see Figure 1 a)]. When excavating the pit, the integrity of the soil profile shall be maintained so the depth of each surface soil sub-horizon can be determined and recorded [see Figure 1 b), c)].

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5.1.4 Level 2 — Soil structure and bulk density

To collect Level 2 data on soil structure attributes, the soil profile of the entire A (surface) soil horizon shall be exposed as described in 5.1.3. When excavating the pit, the integrity of the soil profile shall be maintained (e.g. expose a smooth vertical surface) to observe details in soil structure, textural change and soil biotic influences. Digital photograph recording of the exposed soil pit for later reference is recommended.

Once a soil pit has been excavated to the B horizon [see Figure 1 a)], the full depth of the A horizon is measured and recorded [see Figure 1 b), c)]. Sub-horizons are identified by changes in colour and/or by gentle prodding of a smooth vertical surface using a spade or knife to detect apparent changes in compaction. If sub-horizons are present recording their upper and lower depths from the surface is recommended [see Figure 1 c)]. The identification and description of separate A sub-horizons is recommended but not required. Whether or not sub-horizons are described depends on the objective(s) of the project.

If soil structure attributes are being included in the soil fingerprint code, soil structure type, size class, percentage of type and size class, consistency and extent of organization of different structural types shall be visually assessed [Figure 1 d), e)] by experienced field personnel. If one or more sub-horizons are present soil structural information can be collected for each sub-horizon. There are many visual soil assessment protocols available, but the use of guidance provided in ISO 25177 and/or United Nations Food and Agriculture Organization (FAO) Guidelines for soil description[21] is recommended. Recording of soil structure type, size class, percentage of type and size class, consistency and extent of organization of different structural types using the framework symbology and syntax (see Table 2, Annexes A, B and C) is recommended.

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Level 2 bulk density data can be measured or estimated or both. If measured, it should be determined by laboratory analyses of intact field cores sampled adjacent to (i.e. within 1 m radius of) the soil pit following ISO 11272[19]. Bulk density should be estimated following the FAO guidelines for field estimation of bulk density for mineral soils if applicable[21]. Bulk density samples may also be taken from the vertical soil pit surface if doing so is consistent with the project objectives specified in the sampling plan. Bulk density shall be coded either as actual measured values or be coded as a range class, and the range class as defined in the framework (from <1,2 to >1,8 g/m^3) should be used.

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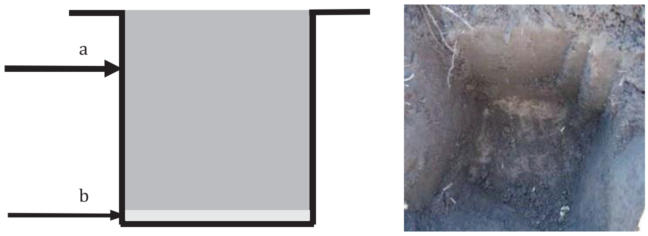
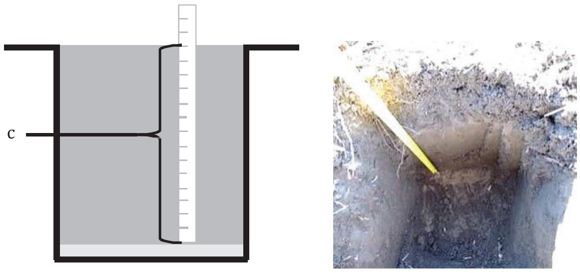


a) Exposed vertical soil face of full A horizon



b) Measurement of full A horizon depth

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ISO 23992:2022
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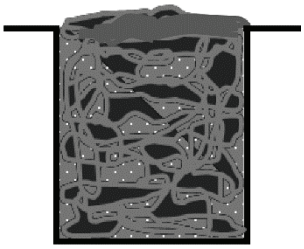
c) Measurement of upper and lower depths of A sub-horizons

d) Soil sample removed comprising the entire A horizon

e) Visual assessment of soil structure for full A horizon



f) Soil pit re-filled with extracted soil

Key

a A horizon
b B horizon
c full a horizon
d A1 horizon depth
e A2 horizon depth

Figure 1 — Steps to obtaining soil structural data

5.1.5 Level 3 — Organic carbon

Level 3 percent organic carbon is determined by laboratory analyses of soil cores sampled adjacent to the soil pit and can be coded either as actual measured values or as range classes defined in the framework (from extremely low to extremely high) or both. If organic carbon is measured it should be determined following ISO 14235[17] or ISO 10694[16] as applicable.

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5.1.6 Level 4 — pH and electrical conductivity

Level 4 pH and electrical conductivity are determined by laboratory analyses of soil cores sampled adjacent to the soil pit and can be coded either as actual measured values or as range classes (extremely acid to strongly alkaline and non-saline to extreme for pH and electrical conductivity, respectively) or both. If pH or EC are measured, they should be determined following respectively, ISO 10390[15] and ISO 11265[18], if applicable.

5.1.7 Level 5 — Soil and landscape contextual data

Level 5 soil and landscape contextual data include soil texture, surface conditions, land use and slope character (kind of slope, slope position and % gradient). Soil texture (the relative content of sand, silt and clay for particle sizes <2 mm) is determined from laboratory analyses of soil cores sampled adjacent (i.e., within 1 m radius) of the soil pit. Texture should be determined following ISO 11508[20].

Surface conditions and land use shall be observed in the field at time of sampling. Slope position and kind of slope may be recorded at a different time from when the sample was collected, however it is recommended that they are also observed at the time of sampling. Slope % gradient can be either estimated in the field or obtained from soil survey data.

Soil samples collected for pH, electrical conductivity and particle size distribution analyses should be sampled adjacent to (i.e. within a 1 m radius of) the soil sampling pit rather than from within the pit itself in order to collect soil samples to soil depths and/or sub-horizons consistent with project objectives specified in the sampling plan. Multiple cores may need to be collected and composited from within the area adjacent to the soil pit in order to obtain sufficient soil volume for laboratory analyses.

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5.2 Generating a soil fingerprint code

5.2.1 General

Once all of the data have been obtained, the soil fingerprint code is generated using symbology and syntax rulesets. Each level of data has a defined location in the soil fingerprint code, and the order and specific syntax (brackets, semi-colons, etc.) within each level indicates the type of information that augments the symbol “A” which indicates that the soil is an A, or surface soil, horizon (see Table 1). Figure 2 describes the steps to generate a soil fingerprint code.

Table 1 — Generic soil fingerprint code

Environment prefixes		Soil process	Soil structure: Bulk dcnsity	Organic Carbon	pH/Electrical conductivity	Soil/Land contextual information	Additional new level(s)
Level 1-p	A	Level 1-s	[Level 2]	(Level 3)	{Level 4}	Level 5: A/B/C/D	New syntax
Level 1-p A Level 1-s # [Level2] Level 5A (Level 3) {Level4}; Level 5B/Level 5C/Level 5D							

NOTE 1 Required components of the soil fingerprint code include “A” to indicate the A horizon, and the horizon number (#) in Level 1-s, all other levels are optional.

NOTE 2 New syntax and symbology rulesets are required when new levels are developed.

5.2.2 Populating soil fingerprint code levels

Level 1 1-p is a prefix designator to provide information on mode of deposition, or environment, sediments, stoniness, and up to 3 designators may be chosen. Level 1 1-s is a suffix designator to provide information on soil genetic processes and land use impact designators and up to a maximum of 4 genetic process and land use designators may be chosen. If more than one A horizon is identified having the same process designation, a number (#) is used to distinguish the same A horizon with depth (i.e. Ap1, Ap2).

Level 2 describes soil structure characteristics and bulk density. From the visual assessment of soil structure, the percent (%) occurrence (2-d) of primary structure type in the A horizon is recorded. The dominant soil structure class size is then recorded, and where a range of two structure sizes is present codes that indicate a range of structure sizes may be chosen (e.g. vff for very fine to fine). The structure type is then recorded (2-a). If more than one structure type exists choose the symbol separator according to kind of arrangement (e.g. granular and very porous peds would be indicated as gr + pc). Up to 4 structure types may be recorded. The consistency/stability of the described soil structure is reported (2-e); it is assumed that it is described under moist to dry conditions (i.e., the soil is not saturated). Bulk density (g/cm^3) information may be recorded either as a category estimate or as the bulk density of the sample measured in a laboratory, or both.

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