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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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Foreword

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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).

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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

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.

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*

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

(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.

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.

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.

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

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)].

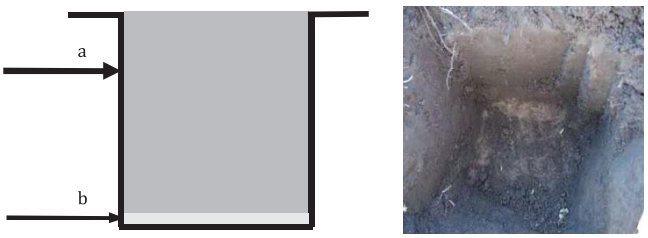
5.1.4 Level 2 — Soil structure and bulk density

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.

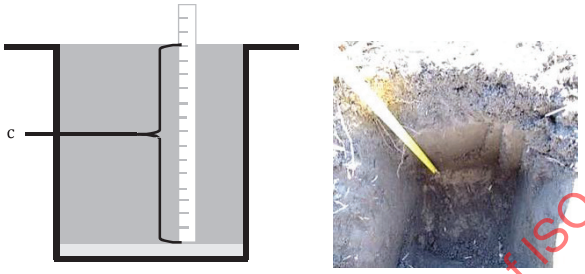
Once a soil pit has been excavated to the B horizon [see Figure 1 a)], the full depth of the A horizon is measured and recorded [see Figure 1 b), c)]. Sub-horizons are identified by changes in colour and/or by gentle prodding of a smooth vertical surface using a spade or knife to detect apparent changes 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.

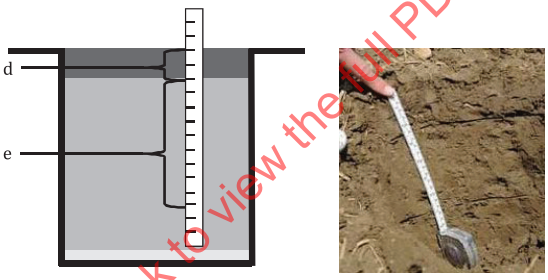
Level 2 bulk density data can be measured or estimated or both. If measured, it should be determined by laboratory analyses of intact field cores sampled adjacent to (i.e. within 1 m radius of) the soil pit following ISO 11272[19]. Bulk density should be estimated following the FAO guidelines for field 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.



a) Exposed vertical soil face of full A horizon



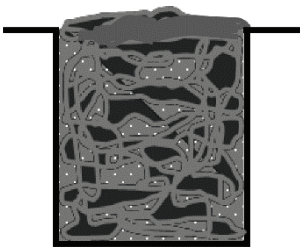
b) Measurement of full A horizon depth



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.

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.

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							

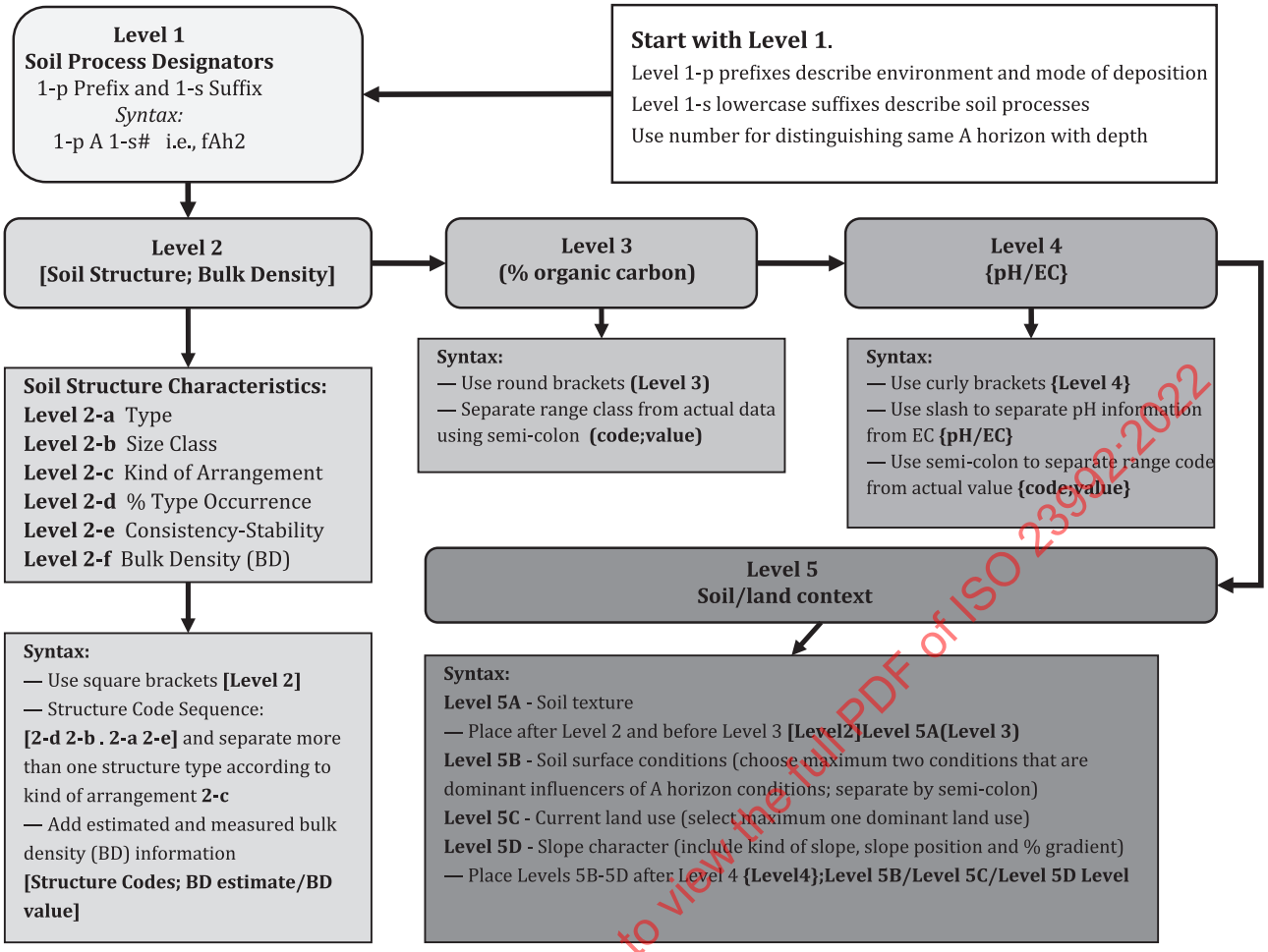
NOTE 1 Required components of the soil fingerprint code include "A" to indicate the A horizon, and the horizon number (#) in Level 1-s, all other levels are optional.

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.



NOTE Adapted from Fox et al. 2014.

Figure 2 — Flowchart showing steps to generate a soil fingerprint code with all levels of data

Level 3 describes the organic carbon content (%) of the A horizon. Information may be recorded either as a category estimate or as the percent organic carbon content of the sample measured in a laboratory, or both. If only percent organic matter is measured, percent organic carbon may be estimated using the following conversion:

% Organic Matter / 1.724 = % Organic Carbon

Level 4 describes the pH and electrical conductivity (dS/cm) of the A horizon. Information may be recorded either as a category estimate or as the pH or electrical conductivity of the sample measured in a laboratory, or both.

Level 5 provides soil and landscape contextual data. Level 5A indicates soil texture; its placement in the soil fingerprint code between Level 2 soil structure and Level 3 organic carbon provides immediate textural context for Levels 2 and 3. Level 5B indicates critical surface conditions that have a dominant influence on the A horizon that is being described. Usually one dominant surface condition is sufficient to describe the surface but up to 2 surface conditions may be chosen. Level 5C communicates the dominant land use. Level 5c describes the character of the landscape slope which has an influence on other A horizon characteristics.

The associated syntax rulesets of the five levels of information that shall be used for each soil quality framework level is provided in Table 2. All individual codes and symbols that are recommended for use for each soil quality framework level are described in Annex A. A concordance table of soil description system coding for soil structure types comparing codes in this document with the World Reference Base[26] classification system commonly used internationally is provided in Annex B.

Table 2 — Description of the five levels of information and their associated syntax used in the soil quality description framework

Level	Description	Full code syntax (All levels fully populated)
Level 1 Soil formation processes and Horizon number	Indicates dominant: i) mode of deposition, environment, kind of sediment, stoniness and horizon boundary condition, and ii) impacting genetic process(es) and/or land use impact, and iii) number of A horizons (if more than one)	Surrounding A horizon symbol: i) Codes are listed as lowercase prefixes ii) Codes listed as lowercase suffixes iii) number following suffixes
Level 1 Generic Code		Level 1-p A Level1-s #
Level 2A Soil structure	Indicates: — soil structure type; — size class; — kind of structure arrangement; — percentage occurrence of structure type; — structure consistency/stability.	Follows Level 1 data, bounded by square brackets List in order (per structure type): — % occurrence; — code for size class; — code for structure type; — code for consistency; — symbol for kind of arrangement of structure types (if more than one). Repeated for up to four structure types
Level 1-2A Generic code		Level 1-p A Level 1-s # [Level 2A]
Level 2B Bulk density	Indicates: — soil bulk density by visual estimation; — laboratory-measured soil bulk density.	Follows Level 1 data, bounded by square brackets, separated from Level 2A within square brackets by semi-colon. List in order: — bulk density visual estimate code; — measured bulk density value.
Level 1-2B Generic code		Level 1-p A Level 1-s # [Level 2A; Level 2B]
Level 3 Organic carbon	Indicates: — organic carbon estimate (range class); — Laboratory-measured organic carbon content.	Follows Level 2 data, bounded by round brackets, organic carbon range class and measured value separated by semi-colon (;) List in order: — organic carbon range class; — measured organic carbon content.
Level 1-3 Generic code		Level 1-p A Level 1-s # [Level 2A; Level 2B] (Level 3)
Level 4A pH	Indicates: — soil pH estimate (range class); — laboratory-measured soil pH.	Follows Level 3 data, bounded by curly brackets, soil pH range class and measured value separated by semi-colon (;) List in order: — soil pH range class; — measured soil pH.
Level 1-4A Generic Code		Level 1-p A Level 1-s # [Level 2A; Level 2B] (Level 3) {Level 4A}

NOTE For all levels, where data is not included, maintain syntax to show missing data i.e. Ap[fm.sbk1;BD1/0.96], Ap1[;BD1/0.96], glAp[fm.sbk1; /], Ap[fm.sbk1;/0.96].

Table 2 *(continued)*

Level	Description	Full code syntax (All levels fully populated)
Level 4B Electrical conductivity	Indicates: — electrical conductivity estimate (range class); — laboratory-measured electrical conductivity.	Bounded within curly brackets, follows and is separated from Level 4A data by a right-leaning slash (/); electrical conductivity range class and measured value separated by semi-colon (;) List in order: — electrical conductivity range class; — measured electrical conductivity.
Level 1-4B Generic code		Level 1-p A Level 1-s # [Level 2A; Level 2B] (Level 3) {Level 4A/Level4B}
Level 5	Provides soil and landscape contextual data, specifically: — 5A soil texture; — 5B soil surface conditions; — 5C current land use; — 5D slope characteristics.	Level 5A data is located between Level 2 and Level 3 data Level 5B follows and is separated from Level 4 data by a semi-colon (;) 5C and 5D follow, and are separated from Level 5 B data and each other, by a right-leaning slash (/).
Level 1-5D Generic code	Level 1-p A Level 1-s # [Level 2A; Level 2B] Level 5A (Level 3) {Level 4A/Level4B}; Level 5B/Level 5C/Level 5D	
NOTE For all levels, where data is not included, maintain syntax to show missing data i.e. Ap[fm.sbk1;BD1/0.96], Ap1[;BD1/0.96], glAp[fm.sbk1; /], Ap[fm.sbk1;/0.96].		

The soil fingerprint code can be generated manually using the syntax rulesets in Tables 1 and 2 and symbology rulesets in Annex A, or it can be generated automatically from data inputted into an electronic spreadsheet using a concatenate function which joins several text strings into one text string (Figure 3;). If an electronic spreadsheet is used there is no need to memorize codes; codes can be viewed via drop down lists as data are entered (Figure 4). A concatenate function can also be used to connect individual soil sample metadata with its respective soil fingerprint code.

Field data can be entered electronically at the site using a mobile computer or tablet; however, as this might not always be practical, field templates and reference sheets can be printed out and brought to the site to record field observations (Annexes C and D).

Figure 3 and the electronic field sheet are also available at the following URN: https://standards.iso.org/iso/23992/ed-1/en

Level 0: metadata							Level 1 : horizon designators									[Level 2] soil structure characterization (up to maximum of 4 types) and bulk density																					Level 5-A	(Level 3)		{Level 4}				Level 5-B		Level 5-C	Level 5-D slope character		
Sample collection date	GPS coordinates/ latitude longitude	Sample identifiers			Horizon depth (m)		Environment prefixes			A	Process suffixes				A hor.	Structure 1				Mod.	Stucture 2				Mod.	Structure 3				Mod.	Structure 4				Bulk density		Soil	% org. carbon		pH		EC salinity		Surface cond.		Land	Kind of	Slope	Gradient
		Site	Plot	Repl.	Upper	Lower	1st	2nd	3rd	Hor	1st	2nd	3rd	4th	No.	%	Class	Type	Cons.	Symb.	%	Class	Type	Cons.	Symb.	%	Class	Type	Cons.	Symb.	%	Class	Type	Cons.	Est.	Lab an.	texture	Est.	Lab an.	Est.	Lab an.	Est.	Lab an.	1	2	use	slope	position	%
2019-04-24	4902051221315	WLT	FOR	2	0	12	gl			A	p				1	10	m.	py	1	+	60	f.	gr	1	+	30	vf.	pc	1						BD1	0,91	CL	h	4,35	sa	5,0	N		TH		aG	s	L	1
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GPS coordinates/ latitude longitude	Field site	Plot	Repl.	Depth (cm)		Date collected	Soil fingerprint code
				Upper	Lower		
4902051221315	WLT	FOR	2	0	12	2019-04-24	glAp1 [10m.py1 +60f.gr1+30vf.pc1;BD1/0,91] CL (h;4,35) {sa;5/N;};TH;/aG/sL1
							A [;/] (;) {;/;};;//
							A [;/] (;) {;/;};;//
							A [;/] (;) {;/;};;//

Legend:

A hor	A horizon
A hor. No.	A horizon number
No.	Number
Cons.	Consistency
Mod. symb.	Modifier symbol
Org carbon	Organic carbon
Est.	Field estimate
Lab an.	Laboratory analytical result
EC	Electrical conductivity
Surface cond.	Surface condition

Figure 3 — Schematic of an electronic spreadsheet that illustrates a soil fingerprint code automatically generated from digitally inputted data

[Level 2] Soil structure characterization (up to maximum of 4 types) and bulk density

Structure 1				Mod.	Stucture 2				Mod.	Structure 3				Mod.	Structure 4				Bulk density	
%	Class	Type	Cons.	Symb.	%	Class	Type	Cons.	Symb.	%	Class	Type	Cons.	Symb.	%	Class	Type	Cons.	Est.	Lab An.
	c.	sbk	1	+		m.	pt	1											BD2	1,22
	mc.	sbk	2	+		mc.	gr	2											BD2	1,36
	mc.	sbk	2	+		m.	gr	2											BD3	1,4
	mc.	sbk	2	+		m.	gr	2											BD2	1,2

Structure type	Code
Structureless	
1. massive/amorphous	m
2. single grain	sg
3. layered (sediments)	sd
Platy	pt
Lenticular	nt
Wedge	w
Prismatic	pr
Columnar	cpr
Blocky	

Figure 4 — Schematic of an example drop down list of coding in the electronic spreadsheet for the soil quality description framework

6 Reporting

Soil fingerprint codes and the data used to generate them may be reported as printed text or as a digital data set in project reports depending on project requirements. If extensive databases of soil fingerprint codes are created, the use of digital spreadsheets or other digital software is recommended. Soil fingerprint codes may be reported as fully detailed codes (i.e. all levels are fully populated as per Table 2) or as abbreviated codes where any soil information in Levels 1-5 is excluded if it is not deemed important for study objectives or interpretation.

Additional levels may also be developed and added to soil fingerprint codes so that data recorded by the soil fingerprint codes complies with the requirements of international or national data recording standards. Additional levels may also be developed to customize the use of the soil fingerprint codes for specific project objectives. For example, an additional level can be added that includes soil contaminant concentrations, ecotoxicity and soil ecological data for investigations of contaminated sites. For projects monitoring, the effects of agronomic management levels that include soil fertility, soil aggregate stability or soil pore characterization can be added.

Examples of how the soil quality monitoring framework integrates quantitative and qualitative static and dynamic soil data as well as concomitant environmental, soil formation and land use and land management data systematically into a single line of code are provided in Annex E.

Additional reporting, documentation and presentation of site, soil or metadata data collected using this document shall and should be reported following ISO 25177 and ISO 18400-107[10], respectively.

Raw field data, field reports and project reports shall be stored according to ISO 25177.

Annex A
(informative)

List of recommended codes with descriptions

Table A.1 — List of recommended codes with descriptions

Code	Code description	References
Level 1-p: Environmental prefixes and mode of deposition		[2],[23],[24]
c	colluvial	
e	eolian	
f	fluvial	
fe	fluviaeolian	
fl	fluviolacustrine	
fm	fluviomarine	
gf	glaciofluvial	
gl	glaciolacustrine	
gm	glaciomarine	
L	lacustrine	
Lt	lacustrine-till	
m	moraine	
mt	morainal, till	
j	anthropogenic deposition of natual materials	
y	anthropogenic deposition of artificial materials	
tb	tidal, brackish	
tm	tidal, marine	
tp	tidal, fluvial	
X1	stony/fragments <25 % internal content	
X2	stony/fragments 25- 50 % internal content	
X3	stony/fragments 50-75 % internal content	
X4	stony/fragments >75 % internal content	
Pf	Permafrost	
Ps	Part of palesol formation	
ar	Original A horizon removed	
wb	Wavy boundary indentations wider than deep	
ib	Irregular boundary indentations deeper than wide	
bb	Broken boundary, portions of horizon unconnected	
Level 1 1-s: Genetic process and land use impact designators		[3],[22],[23],[25],[26],[27] [28]
Level 1 Genetic process designators		
	Chemical	
h	enriched organic carbon (≥ 2 to ≤ 17 % Organic C)	
e	eluviation of clay, Fe, Al or organic matter; bleached appearance	
g	gleying; grey colours and/or distinct to prominent mottles	
k	presence of carbonate, visible effervescence with dilute HCl	
ca	secondary carbonate enrichment, pedogenic calcium carbonate accumulations	

Table A.1 *(continued)*

Code	Code description	References
s	distinct to prominent occurrences of visible salts	
sa	secondary enrichment of soluble salts	
n	associated with prismatic or columnar structure in B horizon, high sodium salts	
	Biological	
q	Distinct to prominent fungal hyphae and/or fungal mats (> 25 % of A horizon)	
fn	Distinct to prominent evidence of soil biota activity within A horizon (occurs > 25 %) .	
rt	Dominated by root material; forms > 40% of A horizon	
	Physical	
b	buried; has distinct evidence of processes prior to burial	
o	formed from deposited sediments by environmental events (wind and/or water erosion)	
v	distinct and prominent features resulting from shrinkage, cracking, and swelling	
w	formed as outcome of natural blow down of trees	
y	impacted by cryogenic processes (i.e. cryoturbation, sorting, ice lens)	
z	frozen layer, continuous, long time period; permafrost soils.	
	Level 1 Land Use Impact Designators	
p	Affected by agricultural activities.	
pa	Plaggen horizon; human transported natural soil materials from different location in past for agricultural activities, crop and livestock production	
pr	Included organic residues (>30 %) from tillage-management operations; various stages of decomposition; may appear brown, reddish or black in colour.	
pi	Formed as direct result of activities undertaken for intensive irrigation operations	
d	Distinct soil material from B and/or C horizons as result of tillage operations.	
fr	Impacted by forest activities related to logging operations.	
u	Includes human transported materials from urban, industrial uses or mining operations.	
Level 2 Soil structure class size		[2]
vf.	Very fine	
vff.	Very fine to fine	
vfm.	Very fine to medium	
vfc.	Very fine to coarse	
vfvc.	Very fine to very coarse	
f.	Fine	
fvf.	Fine to very fine	
fm.	Fine to medium	
fc.	Fine to coarse	
fvc.	Fine to very coarse	
m.	Medium	
mvf.	Medium to very fine	
mf.	Medium to fine	
mc.	Medium to Coarse	

Table A.1 *(continued)*

Code	Code description	References
mvc.	Medium to Very Coarse	
c.	Coarse	
cvf.	Coarse to very fine	
cf.	Coarse to fine	
cm.	Coarse to medium	
cvc.	Coarse to very coarse	
vc.	Very coarse	
vcvf.	Very coarse to very fine	
vcf.	Very coarse to fine	
vcm.	Very coarse to medium	
vcc.	Very coarse to coarse	
Level 2 Soil structure type		[22],[29],[30],[33],[34]
	Structureless	
m	Massive/amorphous	
sg	Single grain	
sd	Layered (sediments)	
pt	Platy	
nt	Lenticular	
w	Wedge	
pr	Prismatic	
cpr	Columnar	
	Blocky	
bk	Blocky	
abk	Angular blocky	
sbk	Subangular blocky	
py	Polyhedral	
gr	Granular	
pc	Very porous peds	
ct	Cast (i.e. biota)	
	Mechanically Formed	
cd	Cloddy	
lu	Lumpy	
cr	Crumbly	

Table A.1 *(continued)*

Code	Code description	References
Level 2 Soil structure consistency-stability		[2]
1	Loose, soft, very friable, friable	
2	Firm, hard	
3	Very firm, extremely hard	
Level 2 Soil structure arrangement		[2]
+	All structure types are present; random	
--	Parting to series of smaller soil peds	
/	One structure merges or grades to another	
Level 2 Bulk density		
	Range class for bulk density (g/cm^3)	[22]
BD1	< 1,2	
BD2	1,2 – 1,4	
BD3	1,4 – 1,6	
BD4	1,6 – 1,8	
BD5	>1,8	
Level 3 % Organic Carbon		[2]
	Estimate for organic carbon	
xl	Extremely low (< 0,5 %)	
lw	Low (0,5 to < 1,5 %)	
m	Medium (1,5 to < 3 %)	
h	High (3 to < 5 %)	
vh	Very high (5 to < 10 %)	
xh	Extremely high (10 to ≤ 17 %)	
Level 4 pH		
	Range class (in 0,01 M $CaCl_2$)	[23],[29]
xa	Extremely acid: pH ≤ 4,5	
sa	Strongly acid: 4,6 to 5,5	
ma	Moderately acid: 5,6 to 6,0	
wa	Weakly acid: 6,1 to 6,5	
n	Neutral: 6,6 to 7,3	
wk	Slightly alkaline: 7,4 to 7,8	
mk	Moderately alkaline: 7,9 to 8,4	
sk	Strongly alkaline: pH ≥ 8,5	
Level 4 Electrical conductivity		[18]
	Range class (dS/m) as saturated paste extract	
N	Non-saline (≤ 2)	
VS	Very alight (2 to < 4)	
S	Slight (4 to < 8)	
M	Moderate (8 to < 16)	
X	Extreme (≥ 16)	
Level 5 Soil and landscape contextual information		
Level 5A Soil texture		[22],[29],[30]
S	Sand (unspecified)	
sS	Sand (sorted)	
VFS	Very fine sand	

Table A.1 *(continued)*

Code	Code description	References
FS	Fine sand	
MS	Medium sand	
CoS	Coarse sand	
LS	Loamy sand	
LVFS	Loamy very fine sand	
LFS	Loamy fine sand	
LCoS	Loamy coarse sand	
SL	Sandy loam	
FSL	Fine sandy loam	
CoSL	Coarse sandy loam	
L	Loam	
SiL	Silt loam	
Si	Silt	
SCL	Sandy clay loam	
CL	Clay loam	
SiCL	Silty clay loam	
SC	Sandy clay	
SiC	Silty clay	
C	Clay loam	
HC	Heavy clay	
Level 5 B Soil surface condition		[2]
B	Biota casts (cover > 25 % soil surface)	
CR	Plant or crop residues; covers >30 % of surface	
OL	Organic Layers (i.e. L, F and H layers)	
TH	Thatch layers (grassland); continuous occurrence	
ER	Eroded soil surface	
DS	Deposited sediments from natural erosion processes	
RS	Redistributed sediments on surface by tillage erosion	
CFg	Coarse fragments (gravelly, ≤ 8 cm in diameter)	
CFc	Coarse fragments (cobbly, 8-25 cm in diameter)	
CFs	Coarse fragments (stony, > 25 cm in diameter)	
CFsl	Coarse fragments (shaly, slaty, ≤ 15 cm in length)	
CF	Coarse fragments (> 50 % surface covered)	
WT	Wheel traffic; tire threads or marked depression visible	
ABi	Amendment - Biosolids	
MNsd	Amendment - Manure-solid	
MNLq	Amendment - Manure-liquid	
CPa	Amendment - Compost-animal	
CPf	Amendment - Compost-Food waste	
CPy	Amendment - Compost- Yard waste	
MUw	Amendment - Mulch, i.e. wood chips	
MUpw	Amendment- Mulch, i.e. paper waste	

Table A.1 *(continued)*

Code	Code description	References
Additional codes for surface conditions		[33]
M	Self mulching, strongly pedal loose surface mulch forms on wetting and drying; peds less than 5 mm in least dimension.	
G	Surface cracking; cracks at least 5 mm wide extending upwards to surface	
C	Surface crust, offten laminated, few mm to tens of mm, hard and brittle when dry; cannot be easily separated or lifted off underlying material.	
X	Surface flaking	
Y	Cryptogram surface, crust of biologically stable material, algae, mosses, liverworts	
T	Trampled dry, by hoofed animals	
P	Trampled wet	
R	Recently cultivated	
Z	Saline	
Level 5C Current land use		[2],[31]
	Agriculture	
aH	Horticulture (vegetables, processing crops)	
aO	Orchards	
aV	Vineyards	
aC	Cropland (cereals, corn, oilseeds)	
aG	Improved pasture/grassland for forage, hay	
aF	Agroforestry	
	Rough grazing, rangeland, grassland	
gE	Natural rangeland/grassland grazing (extensive use)	
gN	Intensive use grazing (i.e. livestock in small areas)	
gW	Woodland grazing	
gF	Abandoned farmland	
	Woodland	
wC	Coniferous, natural	
wD	Deciduous, natural	
wM	Mixed, natural	
wPc	Planted, coniferous	
wPd	Planted, deciduous	
wH	Hedgerows, Windbreak	
wF	Forestry Operations - recent	
wG	Grass undergrowth, or mowed	

Table A.1 *(continued)*

Code	Code description	References
	Other natural areas	
nA	Alpine	
nT	Tundra	
nW	Wetland	
	Urban	
uL	Landfill	
uR	Recreational area, park	
uA	Built up areas (houses, residential)	
	Industrial	
iM	Mining deposition (i.e. tailings)	
iF	Industrial affected area, i.e. brownfields	
	Special sampling locations	
sFr	Fence row (adjacent to fields, woodlot)	
sRc	Road cut (adjacent to road, soil profile above road level)	
sDb	Ditch bank	
Level 5D Kind of slope		[29]
s	Simple slope: Slope is > 50 m in length, regular surface	
c	Complex slope: Slope is < 50 m in length, irregular surface	
Level 5D Slope position		[22],[29],[30],[32]
CR	Crest	
UP	Upper slope, shoulder slope	
MS	Middle slope, back slope	
FS	Lower slope, foot slope	
TS	Lower slope, toe slope	
D	Depression	
L	Level	

Annex B
(informative)

Concordance table of soil description system coding for soil structure types

Table B.1 — Concordance table of soil description system coding for soil structure types.

Soil structure type	ISO framework codes	Soil description for World Reference Base [28 p. 46]
Massive/amorphous	m	MA and PM porous massive
Single grain	sg	SG
Layered (sediments)	sd	SS
Platy	pt	PL
Lenticular	nt	Perhaps AP angular blocky (parallelepiped)
Wedge	w	Perhaps AW angular blocky (wedge-shaped)
Prismatic	pr	PR
Columnar	cpr	CO
Blocky (mixture)	bk	SA subangular and angular blocky or AS subangular and angular blocky
Angular blocky	abk	AB
Subangular blocky	sbk	SB
Polyhedral	py	SN similar to nutty subangular blocky
Granular	gr	GR
Very porous peds (bread-crumb-like)	pc	no equivalent
Cast (i.e. biota)	ct	WC worm casts
Mechanically Formed		
Cloddy, clods	cd	CL
Lumpy	lu	LU
Crumbly	cr	CR

Annex C
(informative)

Printable field observation templates for recording field observations at the study site

Printable field sheet templates are also available at the following URN: https://standards.iso.org/iso/23992/ed-1/en

Example field observation templates provided in this annex are limited to levels that might require input of field data on-site (e.g. Levels 2, 3, 4, 5B, C, D) since it is assumed that other data will be entered into the full fingerprint framework electronic field form once back in an office.

The colours in the templates indicate the corresponding soil quality description framework level and can be summarized as follows: green represents Level 1 information, yellow represents Level 2 information, pink represents Level 3 information, blue represents Level 4 information, and brown represents Level 5 information.

Page _____ of _____

Date(s): Sampler Name: Site Location ID:

Sample ID	GPS ID	Sampling Date	A Hrz #	Depth (cm)		[Level 2] Soil Structure Characterization (up to maximum of 4 types)																				Photograph(s) ID #
						Structure 1				Mod.	**Structure 2**				Mod.	**Structure 3**				Mod.	**Structure 4**				
				Upper	Lower	%	Class	Type	Cons.	Symb.	%	Class	Type	Cons.	Symb.	%	Class	Type	Cons.	Symb.	%	Class	Type	Cons.	

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Date(s): Sampler Name: Site Location ID:

Sample ID	GPS ID	Sampling Date	A Hrz #	Depth (cm)		{Level 3}	{Level 4}		Level 5-B		5-C	5-D Slope Character			Sampling Conditions/Comments
				Upper	Lower	OC	pH	EC Salinity	Surface Cond.		Land Use	Kind of slope	Slope Position	Gradient %	
						Est.	Est.	Est.	1	2					

Annex D
(informative)

Printable field reference sheets for use at the study site

Printable field reference sheets are also available at the following URN: https://standards.iso.org/iso/23992/ed-1/en

Example reference sheets provided in this annex are designed to be printed out and taken into the field for easy reference. Each reference sheet can be double-side printed and laminated for practicality and durability.

Example reference sheets provided in this annex are limited to levels that might require input of field data on-site (e.g. Levels 2, 3, 4, 5B, C, D) since it is assumed that other data will be entered into the full fingerprint framework electronic field form once back in an office.

The colours of the reference sheets indicate the corresponding soil quality description framework level and can be summarized as follows: green represents Level 1 information, yellow represents Level 2 information, pink represents Level 3 information, blue represents Level 4 information, and brown represents Level 5 information.

Figure D.1 — Level 2: Soil structure and bulk density designators

(Level 3) Organic Carbon (with optional OM conversion)			
% Organic Carbon (OC)		**% Organic Matter (OM)**	
Est. OC	Calc. OC	Est. OM	Calc. OM

Estimated Range Class for % Organic Carbon and % Organic Matter

Code	Estimated Range	Organic Carbon	Organic Matter (OC x 1,728)
xl	Extremely Low	(< 0,5%)	(< 0,86 %)
lw	Low	(0,5 to < 1,5 %)	(0,86 to < 2,59 %)
m	Medium	(1,5 to < 3 %)	(2,59 to < 5,18 %)
h	High	(3 to < 5 %)	(5,18 to < 8,64 %)
vh	Very high	(5 to < 10 %)	(8,64 to < 17,28 %)
xh	Extremely high	(10 to ≤ 17 %)	(17,28 to < 29,38 %)

Figure D.2 — Level 3: Organic carbon/organic matter

{Level 4}				
pH *in* $CaCl_2$		**Electrical cond. (salinity)**		**Calcareous class**
Estimated	Analysis	Estimated	Analysis	

pH (*in 0,01 M* $CaCl_2$)
Choose appropriate range class code from drop down list.

Code	pH range class
xa	Extremely acid: pH ≤ 4,5
sa	Strongly acid: 4,6 to 5,5
ma	Moderately acid: 5,6 to 6,0
wa	Weakly acid: 6,1 to 6,5
n	Neutral: 6,6 to 7,3
wk	Slightly alkaline: 7,4 to 7,8
mk	Moderately alkaline: 7,9 to 8,4
sk	Strongly alkaline: pH ≥ 8,5

Electrical conductivity (EC)
(Saturated paste extract)
Choose appropriate salinity class from drop down list for estimate.

Salinity Class		EC dS/m
N	Non-saline	≤ 2
VS	Very slight	2 to <4
S	Slight	4 to <8
M	Moderate	8 to <16

Calcareousness class

0	Non-calcareous
1	Weakly calcareous
2	Strongly calcareous

Figure D.3 — Level 4: pH, electrical conductivity (EC) and calcareous class