THÜNEN

Guideline on sampling and analysis of forest soils for GHG reporting

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Abstract

Im Zuge von internationalen Abkommen müssen Länder ihre Treibhausgase berichten. In Staatenverbünden wie der EU ist hierbei wünschenswert, dass die Daten, die zur Berichterstattung herangezogen werden, auch vergleichbar sind. Für die Datenerhebung im Waldboden gibt es bisher verschiedene Methoden zur Datenerhebung, die sich durch historisch gewachsene Gegebenheiten teilweise so stark voneinander unterscheiden, dass die gewonnenen Daten nicht harmonisierbar sind. Hinzu kommen Länder, die bisher noch keine Daten erheben, da eine systematische Erhebung, sei es im Zuge einer Inventur oder eines langfristigen Monitorings, zeit- und kostenintensiv ist. Daher schlagen wir mit dieser Guideline eine Grundlage vor, mit der in Zukunft für die Treibhausgasberichterstattung (THG) im Waldboden Daten erhoben werden können. Die Methodik basiert auf dem Manual des ICP Forests und ist auf die für die THG und ihre Interpretation relevanten Parameter beschränkt. Eine Erweiterung um einzelne Parameter ist möglich. Mit Hilfe der Guideline können Waldbodenuntersuchungen an bestehende Inventuren (z. B. Waldinventuren) angegliedert werden oder das bestehende ICP Forests Netzwerk mit weniger aufwendigen Standorten verdichtet werden.

Schlagworte: Waldboden, Inventur, Monitoring, Treibhausgasberichterstattung

As part of international agreements, countries must report their greenhouse gas emissions. In associations of states such as the EU, it is desirable that the data used for reporting is also comparable. To date, there have been various methods for collecting data on forest soil, some of which differ so greatly from one another due to historically evolved circumstances that the data obtained cannot be harmonized. In addition, there are countries that have not yet collected any data, as a systematic survey, whether as part of an inventory or long-term monitoring, is time-consuming and cost-intensive. With this guideline, we therefore propose a basis that can be used in future to collect data for greenhouse gas (GHG) reporting in forest soils. The methodology is based on the ICP Forests manual and is limited to the parameters relevant for GHG reporting and their interpretation. It is possible to add individual parameters. With the help of the guideline, forest soil investigations can be linked to existing inventories (e.g. forest inventories) or the existing ICP Forests network can be consolidated with less complex sites.

Keywords: Forest soil, inventory, monitoring, greenhouse gas reporting

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Abbreviations

Al	aluminum
approx.	approximately
As	arsenic
°C	degree Celsius
Ca	calcium
Cd	cadmium
cm	centimeter
cm^2	square centimeters
cm^3	cubic centimeters
cmol	centimol
C_{org}	organic carbon
Cr	chrome
Cu	copper
e.g.	for example
etc.	et cetera
Fe	iron
ha	hectares
Hg	mercury
H_2O	water
ICP Forests	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
ISO	International Organization for Standardization
K	potassium
Kg	kilogram
L	liter
m	meter
m^2	square meters
mg	milligram
Mg	magnesium
mm	milimeter
Mn	mangan

Na	sodium
Ni	nickel
N_{tot}	total nitrogen
Of	Of horizon
Oh	Oh horizon
Ol	Ol horizon
P	phosphorus
Pb	lead
pH	pH value
S	sulfur
t	ton
WRB	World Reference Base for Soil Resources
Zn	zinc
%	percent

1 Guideline and protocols

1.1 Site Characterisation

1.1.1 General characterisation

At first, basic geographic information is important: Coordinates (ETRS89), elevation, relief, inclination and exposition. Further, a general site characterisation including soil type, humus type and tree species composition are needed for interpreting the analytical results. If data already exists, they can be taken as they are.

Soil type description follows WRB, 2015, humus types follow the European Humus Forms Reference Base (Jabiol et al. 2013). Above mineral soils, we find

- Mull
- Moder
- Mor
- Amphi
- Tangel

For peat soils, we differentiate

- Histomull
- Histomoder
- Histomor
- Histoamphi
- Anmoor

Additionally, a description of the stand at the sampled plot shall be made:

Table 1: Tree stand classification

Tree stand (main)
Spruce (pure) stock (≥ 70 % spruce)
Pine (pure) stock (≥ 70 % pine)
Other coniferous species (≥ 70 % other conifers)
Beech (pure) stock (≥ 70 % beech)
Oak (pure) stand (≥ 70 % oak)
Hardwood-rich mixed coniferous stands (> 30 % hardwood)
Mixed hardwood stands rich in conifers (> 30 % conifers)
Other hardwood species (≥ 70 % other hardwood)

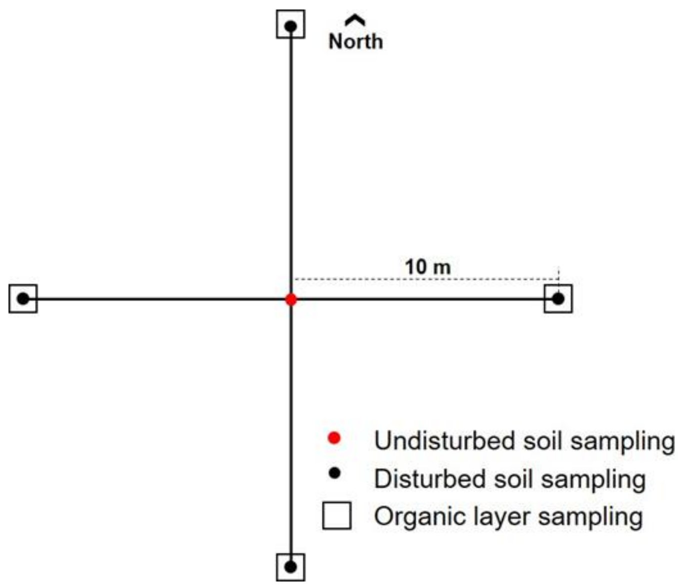
1.1.2 Plot design

Sampling should be done according to the sampling scheme that ensures that a sufficiently large forest stand of approx. 700 m^2 is represented (**Fehler! Verweisquelle konnte nicht gefunden werden.**). In the centre (red point), a pit for a soil profile description with at least 1 m depth should be created. This enables the soil classification, determination of the coarse fraction and the sampling of undisturbed soil samples. At the four satellites, the sampling of the organic layer (see Chapter 1.1.3) and the disturbed soil sampling (see Chapter 1.1.4) are executed. If no profile is established, undisturbed soil samples can be taken at the satellites (four samples per plot) und up to 30 cm depth.

All soil samples should be taken when the soil moisture is close to field capacity, which is often towards the end of the winter or in late spring in cold winter climate after thawing of the frozen subsoil. Sampling should be avoided when it is freezing. The organic and mineral soil should be sampled at exactly the same place, which means that sampling the mineral soil is performed there where the organic layer has already been removed for sampling. At least 500 g sampling material should remain for the laboratory analyses after removing excess sampling material.

Between sampling and pre-treatment, the samples must be stored cool or chilled and dry. Evaporation and mould growth are possible problems which influence analysis results and therefore must be avoided. The time between sampling and pre-treatment must be kept as short as possible to avoid said problems. If analysis of soil microbial properties are intended from the same sample, required fraction of sampling material should be frozen as soon as possible and stored at -18°C or lower temperature.

Figure 1:Sampling design



1.1.3 Sampling of the organic layer

The organic layer at the soil surface is carefully sampled separately from the underlying mineral soil. Separation will be done in the field. At each satellite, the organic layer has to be sampled using metal frames with a dimension sufficient to collect enough sampling material for the analysis. It is recommended to sample the organic layer with a frame of a minimum total surface area of 500 cm^2. The complete material of the organic layer within the frame has to be collected.

The frame is pushed carefully into the forest floor. Then the organic horizons are cut out along the frame using a sharp knife. Living material (such as moss, roots, etc.) and objects > 2 cm in diameter are removed from the sample, whereby smaller twigs, fruits remain to determine the mass of the sample. It is important to note the height of the organic layer sample. The Ol, Of and Oh horizons are sampled together. The four satellite samples are combined to one plot sample.

After removal of living material (such as moss, roots, etc.) and objects > 2 cm, collected samples (preferably not less than 500 g fresh material) should be transported to the laboratory as soon as possible.

When samples are bulked in the field and only a subsample is taken to the laboratory, the fresh mass (kg m^{-2}) of each organic sublayer should be measured in the field. Furthermore, it is strongly recommended to measure the thickness of each organic sublayer in each subsample in the field. Firstly, because the horizon thickness (in cm in terms of the upper and lower limit) is mandatory to report in the profile description file. Secondly, it is useful as a crosscheck.

1.1.4 Sampling of the mineral soil

For sampling of the mineral soil for chemical analysis, it is recommended to use augers appropriate for the different soil texture types and moisture conditions. The auger should reach at least the lowest depth intervals to avoid using multiple sampling approaches for the same satellite and depth intervals. At each satellite, one or two samples (if the auger is does not give enough sampling material) have to be taken for the fixed depth intervals 0-10, 10-20, 20-40, 40-80 cm (in line with ICP Forest requirements, only until the bedrock is reached). The samples at the satellites of one plot have to be mixed to receive one sample for each individual depth interval. At least 300 g sampling material of each depth segment should remain for the lab analysis after removing stones (> 2 mm) and drying (40°C) for chemical analysis. If biochemist analyses are planned, a subsample should be frozen instead of dried.

The determination of the bulk density should be done exclusively at the centre of each plot. Here, three undisturbed cores per depth interval (0-10, 10-20 and 20-40 cm) have to be taken at each plot. The minimal core volume is 100 cm^3. Provide the exact depth range of the core cylinder in cm by reporting the depth of the upper and lower end of the cylinder (e.g. 2-7 cm for a cylinder of 5 cm in height). It is important to collect the complete soil material from the metal rings without leaving anything at the plot. The bottom of the sample ring should have a cutting edge to facilitate the sampling.

An estimation of the stone fraction in the soil, is needed to calculate the fine earth content. Depending on the size and relative abundance of stones in the soil profile, two different approaches can be used. If there are < 5 % stones, the mass and volume of the stones in the bulk density samples can be used. If there is > 5 % stone content, then a visual assessment at the soil profile will need to be made.

1.2 Laboratory work

1.2.1 Pre-treatment (following ICP Forests manual)

For both the organic layer and mineral soil horizons, samples need to be collected and processed according to standardized guidelines for the specific chemical analysis to be conducted.

Samples collected to measure bulk density, fine earth content, texture, cation exchange capacity, water content, pH (H_2O), (organic) carbon content and total nitrogen should be sieved (2 mm), air dried or oven dried at a temperature of 40°C (105°C for bulk density and water content). The sample is subsequently crushed or milled to size < 2 mm. Thereafter they can be stored until analysis.

1.2.2 Analysis

Table 2 (see below) gives an overview of measured variables and their references. The references give detailed information on the respective analysis methods and must be followed to get harmonized data.

1.2.3 Inventory repetition

We suggest a repetition of the inventory every 10-15 years. Hereby, only the chemical variables have to be remeasured, as physical variables do not change that quickly. In the table below, we marked the variables suggested for repeated measurement with an asterisk. In the field, for repeated measurements, no soil profile needs to be dug and no undisturbed soil samples need to be taken.

Table 2: List of variables, references of their analysis methods and additional information on sampling depths and accuracy of data. M = mandatory, O = optional, - = not applicable.

Variable	Reference	Units	Decimal places	Depth [cm] / horizon					
				L, Of, Oh	0-10	10-20	20-40	40-80	80-100
Bulk density	ISO 11272	g cm^{-3}	1	-	M	M	M	M	O
Fine earth content	ISO 11464	t ha^{-1}	0	-	M	M	M	M	O
Texture	ISO 11277	%	1	-	M	M	M	M	O
Organic layer density	ISO 11272	t ha^{-1}	1	M	-	-	-	-	-
Water content	ISO 11465	%	2	M	-	-	-	-	-
pH (H_2O)	ISO 10390	-	1	M	M	M	M	M	O
C_{org}	ISO 10694*	g kg^{-1}	2	M	M	M	M	M	O
N_{tot}	ISO 13878	g kg^{-1}	2	M	M	M	M	M	O
Carbonate content	ISO 10693*	g kg^{-1}	0	M	M	M	M	M	O
Nitrate, Sulfur	ISO 10304-1	mg l^{-1}	1	O	O	O	O	O	O
plant-available P	Olsen-P or citric extract P	mg kg^{-1}	2	O	O	O	O	O	O
Cation exchange capacity	ISO 11260	cmol kg^{-1}	0	O	O	O	O	O	O
Aqua regia digestation (Al, Ca, Fe, K, Mg, Mn, Na, P, S, Cd, Cu, Pb, Zn, As, Cr, Ni, Hg)	ISO 54321	mg kg^{-1}	1	M	M	M	M	M	O

* The carbonate content of the soils should be considered and is decisive for the implementation of the method.

2 List of references

DIN ISO 11272, Normenausschuss Wasserwesen (NAW) in the Dt. Inst. für Normung e.V. [Eds.] (2001): Bodenbeschaffenheit - Bestimmung der Trockenrohdichte (Soil composition, Determination of bulk density).

FAO 1990: Guidelines for soil description, 3rd (revised) edition. ISO 11465. 1993: Soil Quality – Determination of dry matter and water content on a mass basis – Gravimetric method. International Organization for Standardization. Geneva, Switzerland. 3 p. [available at www.iso.ch]

Fäth, J., Mellert, K., Blum, U., Göttlein, A. (2019): Assessing phosphorus nutrition of the main European tree species by simple soil extraction methods. Forest Ecology and Management. https://doi.org/10.1016/j.foreco.2018.10.007.

Haase, P., Tonkin, J.D., Stoll, S., Burkhard, B., Frenzel, M., Geijzendorffer, I.R., Häuser, C., Klotz, S., Kühn, I., McDowell, W.H., Mirtl, M., Müller, F., Musche, M., Penner, J., Zacharias, S., Schmeller, D.S. (2018): The next generation of site-based long-term ecological monitoring: Linking essential biodiversity variables and ecosystem integrity. Science of The Total Environment 613–614, 1376–1384. https://doi.org/10.1016/j.scitotenv.2017.08.111.

ICOS ERIC (2020): ICOS Handbook 2020. ISBN 978-952-69501-1-2.

ICOS (2021): Instructions for Soil Sampling and Preparation for monitoring the soil organic carbon and nitrogen - Version 20211109. ICOS Ecosystem Instructions. [available at http://www.icos-etc.eu/icos/documents/instructions]

ISO 10304-1:2007 Water quality – Determination of dissolved anions by liquid chromatography of ions. Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate. International Organization for Standardization. Geneva, Switzerland.

ISO 10390:1994 Soil Quality Determination of pH. International Organization for Standardization. Geneva, Switzerland.

ISO 10693: Soil quality – Determination of carbonate content. Volumetric method. International Organization for Standardization. Geneva, Switzerland.

ISO 10694:1995 Soil quality – Determination of organic and total carbon after dry combustion (elementary analysis). International Organization for Standardization. Geneva, Switzerland.

ISO 11277. 1998: Soil Quality – Determination of particle size distribution in mineral soil material – Method by sieving and sedimentation. International Organization for Standardization. Geneva, Switzerland.

ISO 11260:1994 Soil Quality Determination of Effective Cation Exchange Capacity and Base Saturation Level Using Barium Chloride Solution. International Organization for Standardization. Geneva, Switzerland.

ISO 11261:1995 Soil Quality Determination of Total Nitrogen Modified Kjeldahl Method. International Organization for Standardization. Geneva, Switzerland.

ISO 11263:1994 Soil Quality Determination of Phosphorus. Spectro-metric Determination of Phosphorus Soluble in Sodium Hydrogen Carbonate Solution. International Organization for Standardization. Geneva, Switzerland.

ISO 11265:1994 Soil Quality Determination of the Specific Electrical Conductivity. International Organization for Standardization. Geneva, Switzerland.

ISO 11272:1993 Soil Quality – Determination of dry bulk density. International Organization for Standardization. Geneva, Switzerland.

ISO 11277:1998 Soil Quality – Determination of particle size distribution in mineral soil material – Method by sieving and sedimentation. International Organization for Standardization. Geneva, Switzerland.

ISO 11464:2006 Soil Quality – Pretreatment of samples for physico-chemical analysis. International Organization for Standardization. Geneva, Switzerland.

ISO 11465:1993/Cor 1:1994 Soil Quality – Determination of dry matter and water content on a mass basis. Gravimetric method. International Organization for Standardization. Geneva, Switzerland.

ISO 13320:2009. Particle Size Analysis Laser Diffraction Methods. International Organization for Standardization. Geneva, Switzerland.

ISO 13878:1998 Soil Quality – Determination of total nitrogen content by dry combustion (“elemental analysis”). International Organization for Standardization. Geneva, Switzerland.

ISO 54321:2020 Soil, treated biowaste, sludge and waste – Digestion of aqua regia soluble fractions of elements. International Organization for Standardization. Geneva, Switzerland.

Jabiol, B.; Zanella, A.; Ponge, J-F.; Sartori, G.; Englisch, M.; van Delft, B.; de Waal, R.; Le Bayon, R-C. (2013): A proposal for including humus forms in the World Reference Base for Soil Resources (WRB-FAO), Geoderma, Volume 192, Pages 286-294, ISSN 0016-7061, https://doi.org/10.1016/j.geoderma.2012.08.002.

Manghabati, H., Weis, W., Göttlein, A. (2018): Importance of soil extractable phosphorus distribution for mature Norway spruce nutrition and productivity. Eur. J. Forest Res.137, 631–642. DOI: 10.1007/s10342-018-1130-3.

Mirtl, M., T. Borer, E., Djukic, I., Forsius, M., Haubold, H., Hugo, W., Jourdan, J., Lindenmayer, D., McDowell, W.H., Muraoka, H., Orenstein, D.E., Pauw, J.C., Peterseil, J., Shibata, H., Wohner, C., Yu, X., Haase, P. (2018): Genesis, goals and achievements of Long-Term Ecological Research at the global scale: A critical review of ILTER and future directions. Science of The Total Environment 626, 1439–1462. https://doi.org/10.1016/j.scitotenv. 2017.12.001.

Müller, H.W., Dohrmann, R., Klosa, D., Rehder, S., Eckelmann, W. 2009. Comparison of two Procedures for Particle Size Analysis: KÖHN-pipette and X-ray Granulometry. Journal of Plant Nutrition and Soil Science, 172, 172-179.

Orgiazzi A., C. Ballabio, P. Panagos, A. Jones & O. Fernández-Ugalde (2018) LUCAS Soil, the largest expandable soil dataset forEurope: a review. European Journal of Soil Science, January 2018, 69, 140–153 doi: 10.1111/ejss.12499.

Riek, W., Wolff, B., 2006: Evaluierung von Verfahren zur Erfassung des Grobbodenanteils von Waldböden – Erarbeitung von Empfehlungen für die Anwendung dieser Verfahren im Rahmen der Bodenzustandserhebung im Wald (BZE II)“. Eberswalde (Evaluation of methods to determine the coarse fragment portion of forest soils – Drawing up recommendations for the use of these methods in forest soil surveys).

Annexes – worksheets

Forms for the field work are attached below. Code tables are also listed to ensure that these are filled out uniformly. These correspond to the code tables from the ICP Forests Manual (Parts 2[1] and 10[2]). The numerical codes do not have to be used for general sampling, but they facilitate recording and correspond to the codes of the ICP Forest and its database. A direct comparison of the data is thus guaranteed.

This guideline is limited to the most important parameters that are relevant for a site survey with a focus on greenhouse gas reporting. If a more detailed recording of individual parameters or the recording of additional parameters is desired, the ICP Forests Manual should be used as a guide. This ensures a coherent assessment that is internationally comparable.

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[1] Ferretti M, Fischer R, Mues V, Granke O, Lorenz M, Seidling W, Nicolas M, 2020: Part II: Basic design principles for the ICP Forests Monitoring Networks. Version 2020-2. In: UNECE ICP Forests Programme Co-ordinating Centre (ed.): Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Thünen Institute of Forest Ecosystems, Eberswalde, Germany, 33 p + Annex. [http://icp-forests.net/page/icp-forests-manual]

[2] Cools N, De Vos B, 2020: Part X: Sampling and Analysis of Soil. Version 2020-1. In: UNECE ICP Forests Programme Co-ordinating Centre (ed.): Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Thünen Institute of Forest Ecosystems, Eberswalde, Germany, 29 p + Annex [http://www.icp-forests.org/manual.htm]

Site description

Team		Plot number	
Date	DD.MM.YYYY	Photos	

Geographic information

Coordinates [WGS84]	North	
	East	
Elevation [m]		
Slope position		
Slope form		
Slope gradient [%]		
Slope orientation [degree]		Azimuth

Land use	
Human influence	
Forest type classification	Broadleaved deciduous forests/Broadleaved evergreen forests/Coniferous forests/Mixed forests
Tree species composition	

Soil characterisation

Soil type [WRB]	
Humus type [Jabiol et al. 2013]	
Parent material	
Groundwater table	

Soil profile description

Team	
Date	

Number	**Horizon limits**		**Color**	**Carbonate**	**Mottling**		**Texture of the fine-earth fraction**	**other pedogenic features**	**Roots**		**Rocks**	
	upper	**lower**			**Abundance**	**Color**	**Textural class**		**Abundance**	**Distribution**	**Abundance**	**Size**
Unit	[cm]	[cm]	[Munsell]		[%]	[Munsell]	[finger testing or pipette]		[roots/dm²]		[Vol-%]	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

Soil sampling

Team		**Plot number**	
Date		**Photos**	

Mineral soil sampling – Profile, undisturbed samples

Depth interval	**Bulk density measurement**				**Coarse soil content [%]**
	sampling depth [cm]		Core volume [cm³]	Sample number	
	upper	lower			

Mineral soil sampling – Satellites, disturbed samples

Depth interval	**Satellite**				**Sample number (combined sample)**
	1	**2**	**3**	**4**	

Organic layers sampling - Satellites

Sampled horizon	**Frame size [cm²]**	**Horizon thickness (per satellite) [cm]**				**Sample number (combined sample)**
		1	**2**	**3**	**4**	

Code tables – Site description

Slope position

Position in flat or almost flat terrain	
Code	Description
1	Higher part (rise)
2	Intermediate part
3	Lower part (and dip)
4	Bottom (drainage line)

Position in undulating to mountainous terrain	
Code	Description
5	Crest (summit)
6	Upper slope (shoulder)
7	Middle slope
8	Lower slope (foot slope)
9	Toe slope
10	Bottom (flat)

Slope form

Code		Description
1	SS	Straight, straight
2	SV	Straight, convex
3	SC	Straight, concave
4	VS	Convex, straight
5	VV	Convex, convex
6	VC	Convex, concave
7	CS	Concave, straight
8	CV	Concave, convex
9	CC	Concave, concave
10		Terraced
11		Complex (irregular)

Land Use

Code	Description
50	Natural forest and woodland (mostly natural regeneration)
51	Natural forest and woodland without felling
52	Natural forest and woodland with selective felling
53	Natural forest and woodland with clear felling
60	Plantation forestry (mostly planted)
61	Plantation forestry without felling
62	Plantation forestry with selective felling
63	Plantation forestry with clear felling
70	Agro-forestry
80	Nature protection
90	Other (explain)

Human influence

Code	Description
1	No influence
2	Vegetation disturbed (not specified)
3	Vegetation slightly disturbed
4	Vegetation moderately disturbed
5	Vegetation strongly disturbed
6	Mineral additions (not specified)
7	Sand additions
8	Organic additions (not specified)
9	Ploughing (not specified)
10	Shallow ploughing (< 20 cm)
11	Ploughing (20-40 cm)
12	Deep ploughing (> 40 cm)
13	Spitting (traces of spade marks)
14	Plaggen

Code	Description
15	Raised beds
16	Terracing
17	Land fill
18	Levelling
19	Artificial drainage
20	Irrigation (not specified)
21	Clearing
22	Burning
23	Surface compaction
24	Traffic traces
25	Application of fertilizers
26	Pollution
30	Others

Tree species composition

Code	Description
1	Monoculture
2	Single tree-wise mixture
3	Group-wise mixture

Code	Description
4	Mixture by layers
9	Irregular, none of the above
99	Unknown

Code tables – Site description (2)

Parent Material

Code	Description
0000	No information
1000	Consolidated-clastic-sedimentary rocks
2000	Other sedimentary rocks (chemically precipitated, evaporated, or organogenic or biogenic in origin)
3000	Igneous rocks
4000	Metamorphic rocks

Code	Description
5000	Unconsolidated deposits (alluvium, weathering residuum and slope deposits)
6000	Unconsolidated glacial deposits/glacial drift
7000	Aeolian deposits
8000	Organic materials
9000	Anthropogenic deposits

Groundwater table

Code	Description	Class limits
9	No water table observed or unknown	
1	Very shallow to shallow	0 - 50 cm
2	Moderately deep	50 - 100 cm

Code	Description	Class limits
3	Deep	100 - 150 cm
4	Very deep	150 - 200 cm
5	Extremely deep	>200 cm

Code tables – Soil profile description

Carbonates

Code	Description
9	No presence of carbonates
1	Matrix is non-calcareous, presence of secondary carbonate
2	Matrix is calcareous, no evidences of secondary carbonate
3	Matrix is calcareous, presence of secondary carbonates

Mottling – Abundance

Code	Description	Class limits
1	None	0 %
2	Very few	0 - 2 %
3	Few	2 - 5 %
4	Common	5 - 15 %
5	Many	15 - 40 %
6	Abundant	>40 %

Roots – Abundance

Code	Size Class	Very fine < 0,5 mm	Fine 0,5-2 mm	Medium 2-5 mm	Coarse >5 mm
9	None	0	0	0	0
1	Very few	1-20	1-20	1-2	1-2
2	Few	20-50	20-50	2-5	2-5
3	Common	50-200	50-200	5-20	5-20
4	Many	>200	>200	>20	>20

Roots – Distribution

Code	Description
1	Continuous
2	in the space of cracks
3	in the space of vughs and channels
4	concentrated in nests

Rock fragments - Abundance

Code	Description (FAO, 2006)	Class limits (volume%)	Description SGDBE (Lambert et al. 2003)
9	None	0 %	No stones or gravel
1	Very few to few	0 – 5 %	Very few
2	Common	5 – 15 %	Few
3	Many	15 – 40 %	Frequent or many
4	Abundant	40 – 80 %	Very frequent, very many
5	Dominant	> 80 %	Dominant or skeletal

Rock fragments – Size

Code	Description	Class limits
1	Fine gravel	0.2 – 0.6 cm
2	Medium gravel	0.6 – 2 cm
3	Coarse gravel	2 – 6 cm
4	Stones	6 – 20 cm
5	Boulders	20 – 60 cm
6	Large boulders	60 – 200 cm

Site description – EXAMPLE FORM

Team	Doe, John & Doe, Jane	**Plot number**	AB1234
Date	31.02.2023	**Photos**	99950-99955

Geographic information

Coordinates [WGS84]	**North**	+512331
	East	+115240
Elevation [m]		123
Slope position		2
Slope form		3
Slope gradient [%]		2
Slope orientation [degree]		151

Land use	62
Human influence	11, 24
Forest type classification	Coniferous forests
Tree species composition	1

Soil characterisation

Soil type [WRB]	Dystric Gleysol
Humus type [Jabiol et al. 2013]	Mor
Parent material	6000
Groundwater table	2

Soil profile description – EXAMPLE FORM

Team	Doe, John & Doe, Jane
Date	31.02.2023

Number	Horizon limits		Color	Carbonate	Mottling		Texture of the fine-earth fraction	other pedogenic features	Roots		Rocks	
	upper	lower			Abundance	Color	Textural class		Abundance	Distribution	Abundance	Size
Unit	[cm]	[cm]	[Munsell]			[Munsell]	[finger testing or pipette]		[roots/dm²]		[Vol-%]	
1	0	3	10YR 2/1	9	1		LS		1	1	9	
2	3	10	7.5YR 4/3	9	1		LS		2	1	9	
3	10	49	10YR 4/4	9	1		FSL		1	1	1	1
4	49	77	10YR 5/6	9	3	10R 4/6	SDL		1	1	1	1,2
5	77	100	10YR 6/6	9	4	10R 4/6	LS		9		9	
6	100	200	10YR 6/6	9	1		LS		9		1	1,2
7												
8												
9												
10												
11												
12												

Soil sampling – EXAMPLE FORM

Team	Doe, John & Doe, Jane	**Plot number**	AB1234
Date	31.02.2023	**Photos**	99955-99960

Mineral soil sampling – Profile, undisturbed samples

Depth interval	**Bulk density measurement**				**Coarse soil content [%]**
	sampling depth [cm]		Core volume [cm³]	Sample number	
	upper	lower			
1	3	10	250		
2	15	22	250		
3			250		
4			250		
5			250		
6			250		
			250		

Mineral soil sampling – Satellites, disturbed samples

Depth interval	**Satellite**				**Sample number (combined sample)**
	1	**2**	**3**	**4**	

Organic layers sampling - Satellites

Sampled horizon	**Frame size [cm²]**	**Horizon thickness (per satellite) [cm]**				**Sample number (combined sample)**
		1	**2**	**3**	**4**	
OL	400					
OF	400					
OH	400					

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