HoliSoils
Working together for forest soils

D1.1 - Harmonised methodologies for assessing soil nutrient stock

Holistic management practices, modelling and monitoring for European forest soils, HoliSoils

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Deliverable D1.1 – Harmonised methodologies for assessing soil nutrient stock		
The various methods for reporting GHG stock changes in forest soils are problematic when working with transnational data sets. In this deliverable, we review four multinational forest soil monitoring networks. Based on the results, we propose a harmonized methodology for a European forest soil monitoring network. The focus was on work- and cost efficiency while gaining all necessary information for a significant data set.		
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Contents

1. Introduction

In terms of fulfilling their duties for the UNFCCC (United Nations Framework Convention on Climate Change) agreements, contributing countries are obliged to report their Greenhouse Gas (GHG) emissions. Within HoliSoils, we reviewed the National Inventory Reports (NIR) of all EU member states and found several gaps in the reporting of forest soil C stock changes (see Deliverable 3.2). One of those gaps is the use of various methods for soil sampling, resulting in differences of the sampling grid[1], the plot size[2], on-site repetitions[3], sampling depths and so on. By this, a comparison of data across EU member states is impossible and the data needs harmonisation before it can be further processed. However, not all methods used for soil sampling and analysis are harmonizable. One approach to generate comparable, Europe-wide data are international monitoring programs, whereby one sampling design is applied and a set of chosen methods is applied to all sites.

At the moment, there are different monitoring programs on forests soils. The four most important EU-wide programs have been selected for a review. We compared their methods and checked if the methods are harmonizable. As an outcome, we have designed a sampling guideline based on the results of the comparison that represents harmonised methodologies for assessing soil nutrient stock. The guideline is supposed to give a simple, cost efficient forest soil sampling design with harmonized analytical methods for their forest soil GHG reporting that is applicable across EU countries. With the growing awareness for the importance of soil microbial activities within forest ecosystems and nutrient cycling, the samples should also be analysed for biodiversity (e.g. microbial diversity and activity). A protocol for this will be published by WP 1 as a separate deliverable.

[1] The distance of evenly distributed sampling plots to each other, e.g. 16 x 16 km
[2] The plot size defines the area in which all the sampling, including repetitions is carried out, e.g. 400 m^2
[3] The number of samples pooled to represent the plot

2. Monitoring networks for forest soils

In the following part, we introduce the EU-wide monitoring programs in detail. Not all of them are forest soil-specific and they have different priorities. At the moment, the following monitoring programmes exist: LUCAS, LTER, ICOS and ICP Forests.

2.1 LUCAS Inventory

„The **Land Use/Cover Area frame statistical Survey Soil (LUCAS Soil)** is an EU-wide, regular topsoil survey aimed to determine the effect of land management on soil characteristics (Orgiazzi et al., 2018). So far, three sampling periods (2009–2012, 2015 and 2018) collected nearly 45'000 soil samples on a 16 x 16 km grid, a fourth repetition was carried out in 2022. The main focus is agricultural land use, but all land use forms are sampled. The first inventory focused on physicochemical properties, including pH, organic carbon, nutrient concentrations and cation exchange capacity within a limited number of states. The second sampling period expanded the network, now covering all EU member states. The third inventory in 2018 measured additional properties, including bulk density, soil biodiversity and specific measurements for organic-rich soil. Bulk density and soil biodiversity were sampled at the same time to explore correlations. The sampling methods are extensively described in a manual (see Ballin et al., 2022). All data are available via an open access database at the JRC.

2.2 UN ECE ICP Forests

The **International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)** was launched in 1985 under the Convention on Long-range Transboundary Air Pollution (Air Convention, formerly CLRTAP) of the United Nations Economic Commission for Europe (UNECE). At present, 42 countries in Europe and beyond participate in ICP Forests.

ICP Forests monitors forest conditions at two monitoring intensity levels:

The **Level I** annual tree crown condition monitoring is currently based on 5624 observation plots (as at 2021). The level I network is a systematic transnational grid of 16 x 16 km throughout Europe and beyond with the aim to gain insight into the geographic and temporal variations in forest condition. Hereby, in addition to the annual tree crown condition survey, soil condition (C, N, K, Ca, Mg, P, pH value, bulk density, SOC, stone content, soil profile description following WRB standards etc.) has been monitored on more than 5000 plots by two forest soil surveys across Europe and assessments of ground vegetation composition have been carried out at irregular intervals. Foliar nutrient status was determined in approximately 1400 plots in 1990s and most countries are carrying repeated foliar surveys.

The **Level II** intensive monitoring is currently going on 561 plots (as at 2020) in selected forest ecosystems with the aim to clarify cause-effect relationships. The measurements cover several compartments of the forest ecosystem, including phenological and meteorological observations. Further, in addition to the annual tree crown condition monitoring, the understorey vegetation composition and tree growth are studied every 5 years, soil status every 10 years and foliar chemistry every 2 years, while soil solution chemistry, litterfall and deposition are monitored continuously. All methods of both Level I and Level II monitoring are

described in a manual (see http://icp-forests.net/page/icp-forests-manual). All data are available upon request.

2.3 ICOS

The **Integrated Carbon Observation System (ICOS)** is a pan-European research infrastructure dedicated to the observation of greenhouse gas concentrations in the atmosphere and the carbon cycle between land surfaces, atmosphere and the oceans. It aims to provide data to support research and decision-making on matters of climate change mitigation and adaptation. The research infrastructure of ICOS consists of the three main domains – atmosphere, terrestrial ecosystems and oceans – with 140 stations in 12 countries (ICOS ERIC, 2020). At the ecosystem stations, soil variables are measured according to sampling instructions mostly pertaining to ISO standards (ICOS, 2021). The focus here lies mostly on soil carbon contents.

2.4 ILTER

The **International Long-Term Ecological Research Network (ILTER)** is a global network of about 700 research sites in 44 national member networks and several regional groups. Those sites are dedicated to the fields of ecosystem, biodiversity, critical zone and socio-ecological research with a "whole-system-approach" (Mirtl et al., 2018). ILTER facilities have a rather heterogenous origin and differ widely in their methodology and instrumentation to capture both biotic and abiotic variables. Given this heterogeneity in sites (Haase et al., 2018), there are no reference procedures for reporting soil nutrients and pH values. However, some sites of LTER Europe are also associated with other monitoring networks discussed here, such as ICP Forests and ICOS (see also https://deims.org/), which have their own prescribed methodologies. More recently, scientists of the network proposed a set of recommended core biotic and abiotic variables for the sites of the ILTER network further adjusting it to already existing monitoring programmes such as ICOS and NEON (National Ecological Observatory Network) (Haase et al., 2018).

3. Comparison of the monitoring programs

In this paragraph, we list several important parameters for a forest soil monitoring system and review how the above-mentioned monitoring systems implement them. The ILTER network is not implemented, because as previously mentioned, they apply various methodologies within their network.

3.1 Site Characterization

Characterization of a site is important for setting the results in context and helps with their interpretation. In forest ecosystems, we have close relations between the vegetation and the soil. Further, climatic conditions and relief have impacts on a site. And in densely populated areas like Europe, recent and/or historic anthropogenic impacts affect a site. The various factors result in a complex system, which must be described in detail.

3.1.1 Profile description/Soil type determination

For characterizing a site, it is necessary to have a detailed description of the soil. For this, the creation of a soil profile is important, at least for the first plot description. For following inventories, samples can be drawn with an auger (see guideline in Chapter 5). A soil profile offers the possibility of a detailed look on the soil and its properties. In contrast to point samples, information is set in context. For example, the course of soil horizon borders can be followed and a correct medium thickness can be determined. Furthermore, some valuable information like stone content and rooting depth are only visible in a soil profile. Additionally, information on artefacts or morphological features might be missed by point sampling. Therefore, the creation of a soil profile for determination of soil and humus type and additional soil properties is a standard procedure in soil science.

Within the above-mentioned monitoring systems, ICP Forests has a protocol for profile description and soil classification (WRB, 2015) which includes subsoil sampling (> 30 cm depth) and the organic layers. The LUCAS inventory does not require a profile description and only takes mineral soil samples up to 30 cm depth. The most recent sampling period (2022) also includes humus samples.

Within ICOS, the description of the soil horizons and a soil classification following WRB (2015) is mandatory. The description can be done at a profile or on soil cores and a photographic documentation of the chosen method is mandatory. The description includes samples up to 100 cm depth and the organic layers.

3.1.2 Stand description

The interactions between tree stand and soil are complex. Tree stand and vegetation influence the soil, in reverse, the soil type determines the (potential/natural) vegetation (non-exclusively, but as an important factor). That is why a classification and description of the stand is needed.

ICP Forests and ICOS both have a manual for describing the aboveground biomass in a circular plot (2000 m² area, 25,24 m radius). Trees in particular are all measured and their height and diameter (at breast height) are noted. Both inventories repeat the stand description regularly (ICP F every 5 years, ICOS every 10 years). The LUCAS inventory has no stand description intended.

3.1.3 Sampling design

The sampling design determines the representativeness of the results. Forest soils are particularly heterogenous in space, compared to agriculturally managed soils. The sampling design for forest soil research must therefore be well-planned and include enough subsamples to accurately represent the study site. At the same time, more subsamples need more sampling time per plot, resulting in higher costs per plot. A balanced cost-benefit analysis has to be considered.

The collected samples for LUCAS and ICP Forests at each location comprises at minimum five subsamples that are mixed to form a single composite sample. ICOS requires 5 subsamples for core sampling and 3 subsamples for pit sampling.

3.2 Laboratory analysis

In this chapter, we compare several important variables for forest soil monitoring in regard of the different monitoring systems. A summary of all recommended variables can be found in Table 1, where we included all necessary variables for an extensive forest soil monitoring, especially in regards of forest ecosystems and their role within GHG reporting. Below, we only discuss selected variables where our recommendations might be less understandable and non-comparative methods were used.

3.2.1 Texture

Determining the soil texture is one of the most basic soil analyses. The soil texture gives information on the shares of sand, silt and clay in the fine soil (soil particles < 2 mm diameter) of a soil sample. These shares determine further physical soil properties like pore volume and water permeability. Further, the soils ability to store nutrients can be estimated based on their texture. For the texture determination, the Pipette method (ISO 11277) is widely used in soil science. This method is very accurate, but time-consuming. Therefore, laser diffraction was developed (ISO 13320), both methods being comparable (Müller et al., 2009). There are other methods for analysing the soil texture, but they are not used by the reviewed inventories, therefore, we do not discuss them here. Attention should be paid in international context: the present size limits for the texture classes may differ between countries.

Three of four inventories apply the pipette method for assessing the soil texture. The only exception is the LUCAS inventory, where laser diffraction is applied (see Table 1). As the classification of the texture classes is based on the Pipette method, we recommend it for analysis. Both methods are comparable, but

3.2.2 Total nitrogen

Nitrogen (N) is a limiting nutrient for plants. While a shortage has negative effects on plant growth, a long-term high supply results in acidification and eutrophication of the soil. Analysing the total N content of a soil gives information on the current nutritional status and helps forest management to counteract if necessary (e.g. with liming to increase pH values).

There are two popular laboratory methods for analysing total N content: The Kjeldahl method (ISO 13878) and the Dumas method (also known as dry combustion, ISO 13878). The advantage of the Dumas method is that no hazardous substances are used, while the Kjeldahl method requires cooking of H_2SO_4 and therefore is less safe for the users. Additionally, the Dumas method simultaneously measures the C content of the sample, saving time and money for the analyses. For more information on C measurements, see Chapter 3.2.3.

The Kjeldahl method is applied by the ICOS network, while LUCAS applies a modified version of it for N determination. ICP Forests uses the Dumas method. Although the Kjeldahl method is used more often, we recommend using the Dumas method: It is safer for lab technicians and the C content of the sample can be measured simultaneously, without further sample preparation. However, the two methods are comparable after application of a conversion formula.

3.2.3 Carbon

Soil is one of the most important carbon storages. Here, it has two main forms: organic and inorganic. In its organic form, it is relevant for soil fertility. The inorganic form depends on the

soil's bedrock. While almost no inorganic carbon is found in acidic soils, which tend to be found in forests of the northern half of Europe, it is found in soils on carbonate rock. These are mainly (but not exclusively) found in the Mediterranean region.

When determining soil carbon, the carbonate content of the source rock must be considered. A widely used method for the determination of soil carbon is dry combustion (ISO 10694, also called Dumas method, see chapter above). For acidic soils, it can be assumed that this determines the proportion of organic carbon and that this also corresponds to the total carbon. For samples of carbonate soils, the carbonate content must first be determined (following ISO 10693) and this subtracted from the measured total carbon to determine the proportion of organic carbon in the sample. Soils with a carbonate content greater than 70 % must be additionally decarbonated before analysis.

3.2.4 Fine earth content

The fine earth content of a soil describes the volumetric share of soil with grain sizes < 2 mm in relation to the whole soil in a specific volume (mostly standardized soil cores with 100 cm^3 or 250 cm^3 volume). This is especially important for soils with a high share of coarse (> 2 mm) fragments; the fine earth content gives information on their water regime and is needed to calculate soil nutrient stocks.

The share of the fine earth content is mainly calculated from the volumetric share (%) of the coarse fraction, often also called rock fraction. The coarse fraction has to be determined in a soil profile, therefore, only ICP Forests requires this information. For ICOS and LUCAS, the share of the coarse fraction in the mineral soil samples is determined by weight. For very coarse soils or soils where the coarse fragments are larger than the core diameter, this method is inaccurate. However, the WRB classification applied by ICOS includes shares of coarse fragments in their classification of diagnostic horizons, so the share of coarse fragments is partly covered by that.

3.2.5 Phosphorus

As N, phosphorus (P) is a limiting nutrient for plants. While N can enter forest ecosystems over deposition, the main P source is the bedrock. In the soil, organic and inorganic P fractions arise. P forms strong bindings with soil particles and is slowly released in plant-available forms by acidification (e.g. by roots releasing acids). Due to this dependency and the small-scale heterogeneity of forest soils, even on a profile basis, there are various pools of different P fractions in forest soils. Their detection is not uniform, there are several widely-used approaches. Soil P analyses base on this release by acid, one of the most common methods is the Hedley fractionation, whereby different soil P forms are dissolved by various extractants and subsequently analysed spectrophotometrically for their orthophosphate content. Hereby, stable and labile soil P pools can be differentiated. Other methods are used for the determination of total P, which gives no information about plant availabilities or the determination of individual P forms by only one step extraction. Hereby, it is necessary to fit the chosen extractant to the research question.

Within the inventories, only LUCAS analyses the so-called plant-available P fraction by extraction with sodium hydrogen carbonate ($NaHCO_3$, also called Olsen-P). As this is a common procedure for soil P analysis, we think it is suitable. However, we would like to draw

additional attention to another method. Citric acid (1 %) extraction is a relatively recently developed method for phosphorus analysis (Fäth et al, 2019). According to initial results, it is more suitable for determining plant-available phosphorus than $NaHCO_3$ on acidic soils (Manghabati et al., 2018). For carbonate soils, the Olsen-P method should be retained.

Table 1: Variables and determination methods for soil samples of different monitoring programs. The ILTER inventory does not have uniform methods and is therefore not listed here.

Variable	Method	ICP Forests	LUCAS	ICOS	Suggestion and comments
Electrical Conductivity (EC)	Determination of EC, ISO 11265 (Soil)	ISO 7888*	ISO 11265	n.a.	ISO 11265
Cation exchange capacity	Determination of CEC with barium chloride solution (ISO 11260)	ISO 11260	ISO 11260	n.a.	ISO 11260
Bulk density	Determination by calculation from mass and volume (ISO 11272) Drying for organic layers at 60°C!	ISO 11272	ISO 11272	ISO 11272	ISO 11272
Organic layer bulk density		core samples or frame samples	core samples	frame samples	frame or core, comparable, ISO 11272 is for mineral soils only but the principle is the same as for organic layers
Fine earth content	Determination by mass and volume calculations (ISO 11464)	ISO 11464	ISO 11464	ICOS Soil Sampling & Preparation Manual	ISO 11464
Texture	Pipette method (ISO 11277), Laser diffraction (ISO 13320)	ISO 11277	ISO 13320	ISO 11277	ISO 11277, comparable
Water content	Gravimetric determination of water content (ISO 11465)	ISO 11465	soil core sample weighted before and after air drying	not specified	ISO 11465
pH (H_2O)	Determination of pH (ISO 10390)	ISO 10390	ISO 10390	n.a.	ISO 10390
C_{tot}	dry combustion (ISO 10694, EN 15936)	ISO 10694	ISO 10694	ISO 10694	ISO 10694 is officially withdrawn and EN 15936 suggested as replacement
C_{org}					
Carbonate	dry combustion (EN 15936), volumetric determination (ISO 10693)	ISO 10693, EN 15936	ISO 10693	ISO 10693	ISO 10693 and EN 15936; comparable
Ntot	dry combustion (ISO 13878), modified Kjehldahl (ISO 11261)	ISO 13878, ISO 11261	ISO 11261	ISO 13878	ISO 13878, methods are convertible
Nitrate	Liquid chromatography, ISO 10304-1 (1:2-Extract)	n.a.	n.a.	n.a.	ISO 10304-1
Sulfate					

plant-available P	$NaHCO_3$-extraction (ISO 11263), citric acid extraction (Fäth et al. 2019)		ISO 11263		citric acid for acidic soils, $NaHCO_3$ extraction for carbonate soils
other Elements (Al, Ca, Fe, K, Mg, Mn, Na, P, S, Cd, Cu, Pb, Zn, As, Cr, Ni, Hg)	Digestion of aqua regia soluble fractions of elements (ISO 54321)	ISO 54321	ISO 11466 (withdrawn)		recommended following ISO 54321
*not measured at soil samples, but on soil solution					

4. Guideline and protocols

4.1 Site Characterisation

4.1.1 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:

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)

4.1.2 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 (Figure 1). 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 1.2) and the disturbed soil sampling (see Chapter 1.3) 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.

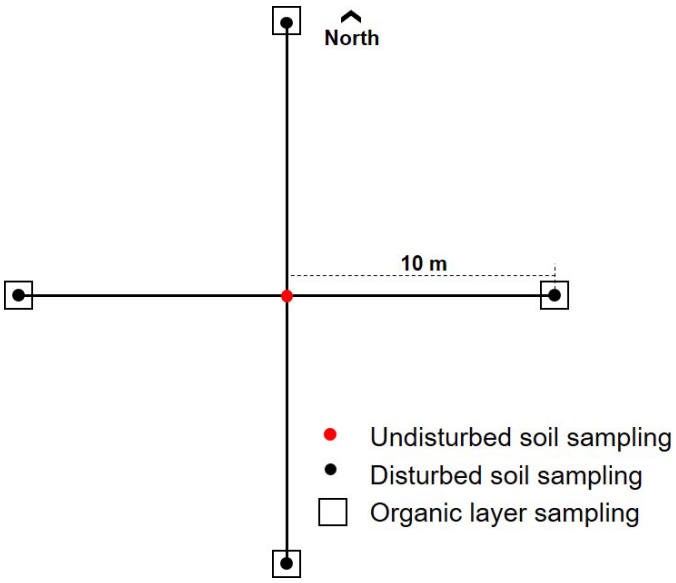

Figure 1: Sampling design

4.1.3 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.

4.1.4 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.

4.2 Laboratory work

4.2.1 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.

4.2.2 Analysis

The following table 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.

4.2.3 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	0	-	M	M	M	M	O
Texture	ISO 11277	%	1	-	M	M	M	M	O
Organic layer density	ISO 11272	t/ha	1	M	-	-	-	-	-
Water content	ISO 11465	%	2	M	-	-	-	-	-
pH (H_2O)	ISO 10390	-	1	M	M	M	M	M	O
Corg	ISO 10694*	g/kg	2	M	M	M	M	M	O
Ntot	ISO 13878	g/kg	2	M	M	M	M	M	O
Carbonate content	ISO 10693*	g/kg	0	M	M	M	M	M	O
Nitrate, Sulfur	SO 10304-1	mg/l	1	O	O	O	O	O	O
plant-available P	Olsen-P or citric extract P	mg/kg	2	O	O	O	O	O	O
Cation exchange capacity	ISO 11260	cmolc/kg	0	O	O	O	O	O	O
Aqua regia digestion (Al, Ca, Fe, K, Mg, Mn, Na, P, S, Cd, Cu, Pb, Zn, As, Cr, Ni, Hg)	ISO 54321	mg/kg	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									

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