HoliSoils
Working together for forest soils

D3.5 Soil sampling design, monitoring & measurement protocols

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

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Coordinator: Natural Resources Institute Finland (Luke)

Deliverable D3.5: Soil sampling design, monitoring & measurement protocols		
D3.5 is a content-related addition to the guidelines from D1.1. A sampling design for gas flux measurements is presented and forms for soil sampling are provided.		
Due date	M31	
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Dissemination level		
PU	Public, fully open e.g. web	x
CO	Confidential, only for members of the consortium (including the Commission Services)	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	
Nature of the Deliverable		
R	Document, report	x
DEM	Demonstration, pilot, prototype, plan design	
DEC	Websites, patents filing, market studies, press & media actions, videos etc.	
OTHER	Software, technical diagram etc.	
Ethics	Ethics deliverables	

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Contents

1. Introduction

A guideline for soil monitoring has already been published as part of the work of WP3 (see Deliverable 1.1). This contains both a soil sampling design and references to current ISO standards as a methodological basis for the laboratory analysis of indicators. The present Deliverable 3.5 is intended to extend the guideline with forms for soil sampling and a proposed method for measuring forest soil greenhouse gas emissions (CO_2, N_2O, additionally CH_4 for organic soils) in the field. Our suggestion for the measurements is in accordance with the method used for the HoliSoils test sites, which has been published as Deliverable 4.1 by Lehtonen et al.

The measurement of greenhouse gas fluxes between the soil and the atmosphere provides information on the dynamics of nutrient fluxes. For drained organic soils, the specification of these fluxes is relevant for greenhouse gas reporting. However, this is usually done as a Tier 1 approach, in which emission factors (EF) specified by the IPCC are assumed. These EFs are subject to very high uncertainties and should be viewed very critically. Gas flux monitoring is necessary to generate better data.

In order to improve the data quality and at the same time obtain a cross-comparable database, we propose a standardized methodological design that can be used in the course of soil monitoring. It is based on consent from several recent review papers (e.g. Oertel et al. 2016, Pavelka et al. 2018, Jauhiainen et al. 2019) and is already being used in this or a similar form (e.g. at the HoliSoils research sites, see Lehtonen et al. 2023). More details and background information on the recommendations can be found in the references.

2. Gas flux measurements

Gas emissions from organic and mineral forest soils are measured using closed chambers that preferably are operated automatically. The measurements should be carried out with both transparent and opaque chambers. The CO_2 and N_2O fluxes are measured, CH_4 fluxes should also be measured on organic soils. Measurements should optimally be carried out every two weeks, in winter (outside the vegetation period) the measurements can also be carried out less frequently. Care should be taken to ensure that phases of snowmelt or increased precipitation, which have an impact on respiration, are nevertheless taken into account in the measurements. It is recommended to use a collar to completely seal the chambers during the measurement. To prevent the installation of the frames from influencing the measurements, they should be installed several weeks before the first measurements. However, as this is not feasible at all locations (e.g. in the case of moss cover), the use of a collar is not mandatory. The vegetation at the measuring points should be preserved and affected as little as possible by the measuring instruments. This also means that the automated chambers should hang as far away and/or as high as possible when they are not measuring, so that the measurement area can continue to be influenced by precipitation, litterfall, etc. The design of the chamber is highly dependent on the location and can therefore be determined individually. The location of all measuring points should be chosen so that they do not interfere with other data collection (soil sampling, etc.) and, conversely, so that they do not interfere with the gas measurements. Multiple measurement replicates should be set up at each location. A minimum of three replicates per site and treatment should be given. The heterogeneity of the site should be reflected; more replicates may be required. For opaque chambers, several measurements per replicate should be carried out on each measurement day in order to represent the temporal variability of the location. Care should also be taken to ensure that different times of day are covered. The length of the individual measurements is not strictly defined. However, there should be a linear regression in gas concentrations versus time before the measurement is ended. When using transparent chambers, measurements must be taken from before sunrise to after sunset (from darkness over the entire daylight cycle to darkness). In addition to the gas measurements, air temperature, soil temperature and soil moisture should also be measured. These measurements are continuous observations. At best, the soil data should be measured at several depths. The focus should be on the first 30 cm, as these are the most biologically active.

3. Forms for soil monitoring

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	

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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/dm^2]		[Vol-%]	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

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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 [cm^3]	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 [cm^2]	Horizon thickness (per satellite) [cm]				Sample number (combined sample)
		1	2	3	4	

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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)

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)

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)

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 [number]	Fine 0,5-2 mm [number]	Medium 2-5 mm [number]	Coarse >5 mm [number]
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

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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/dm^2]		[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												

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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 [cm^3]	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 [cm^2]	Horizon thickness (per satellite) [cm]				Sample number (combined sample)
		1	2	3	4	
OL	400					
OF	400					
OH	400					

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5. References

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Lehtonen et al. (2023): Protocol of site, soil property & GHG measurements at management test sites.

Oertel, C. et al. (2016): Greenhouse gas emissions from soils—A review. *Geochemistry 76*. 327-352. DOI: 10.1016/j.chemer.2016.04.002

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