

BioSoil: Demonstration Project for Monitoring European Forest Soils and Biodiversity



Estimating Soil Organic Carbon Stocks



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Introduction: Potential BioSoil Support

BioSoil*

Large-scale European study into the feasibility of providing harmonized soil and biodiversity data under a forest monitoring scheme.

Aspects related to reporting GHG from LULUCF **

- **Land Use Category**
Forest remaining Forest (FF)
- **GHG**
CO₂ (carbon), CH₄, N₂O
- **Pool**
Soil, dead organic matter, biomass***

* Forest Focus (Regulation (EC) No. 2152/2003)

** Support to "...estimate, measure, monitor, and report changes in carbon stocks and anthropogenic GHG emissions from LULUCF activities...".
Invitation to the IPCC in the Marrakesh Accords Decision 11/CP.7, paragraph 3(a)

*** From BioSoil – Biodiversity survey

BioSoil Project Participants

Soil Sampling Survey

Level 1: large-scale grid

Level 2: intensive monitoring

No. of EU countries: 22

No. of NFCs: 31

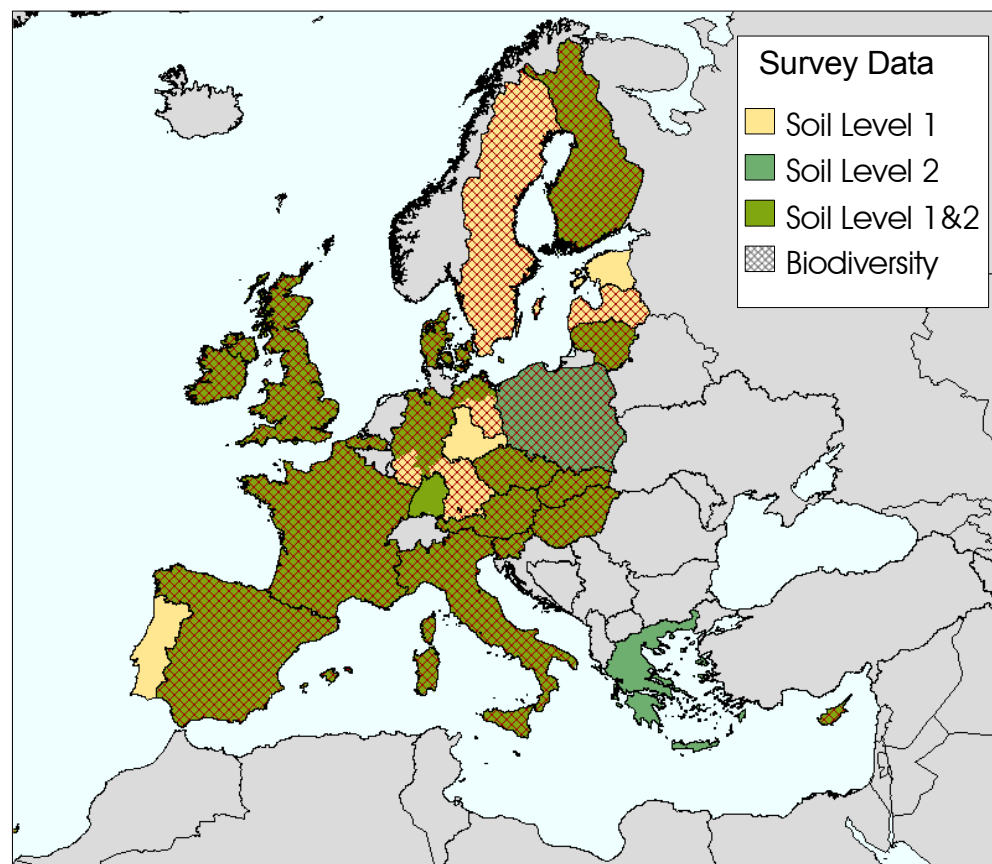
Level 1 28

Level 2 23

No. of Level 1 Plots: 4,034

with reference 4,026

No. of Level 2 Plots: 131

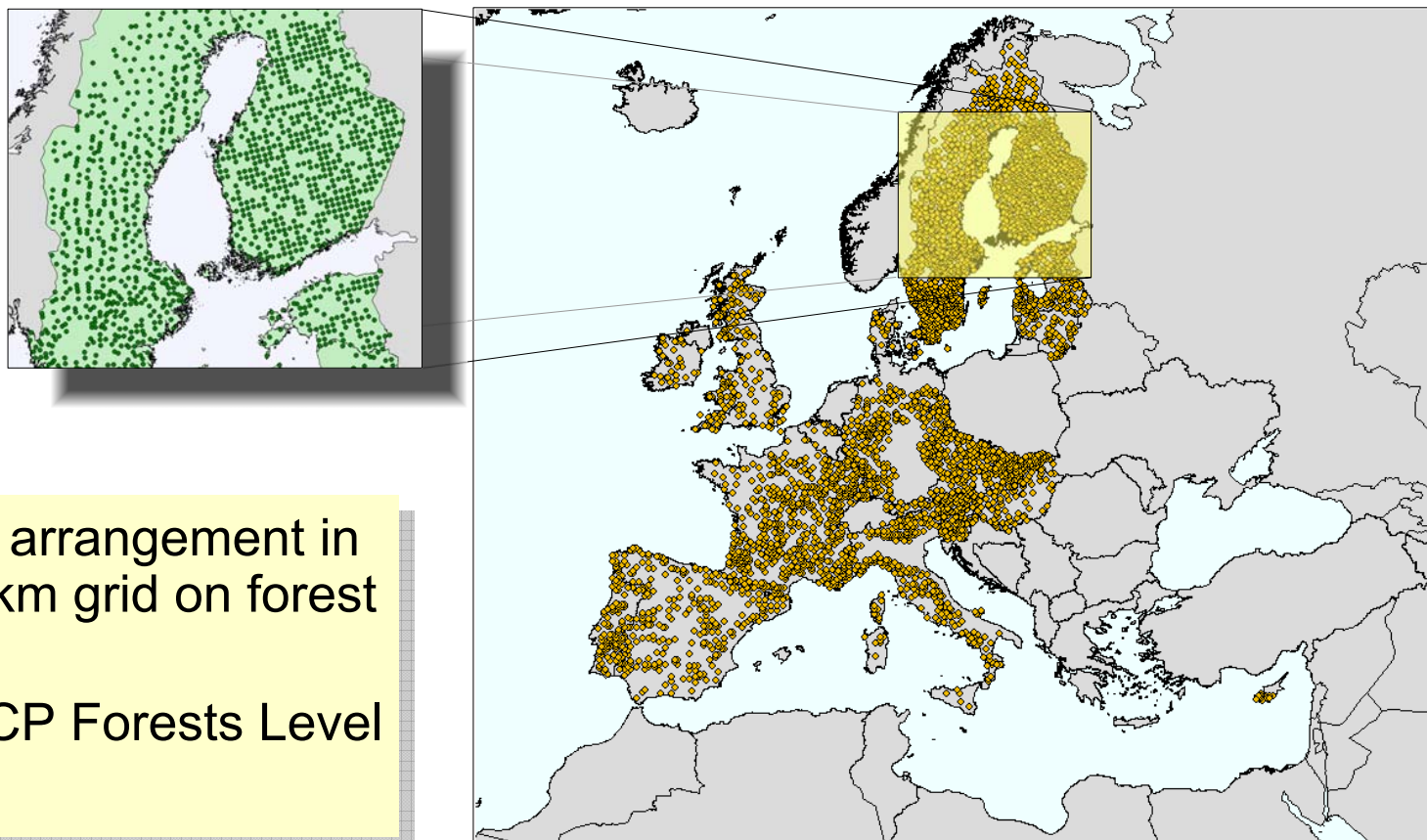


BioSoil Participating NFCs

BioSoil Project Plot Locations

Level 1 Plots: Large- Scale Survey

- Nominal arrangement in 16 x 16 km grid on forest land.
- Use of ICP Forests Level 1 plots.



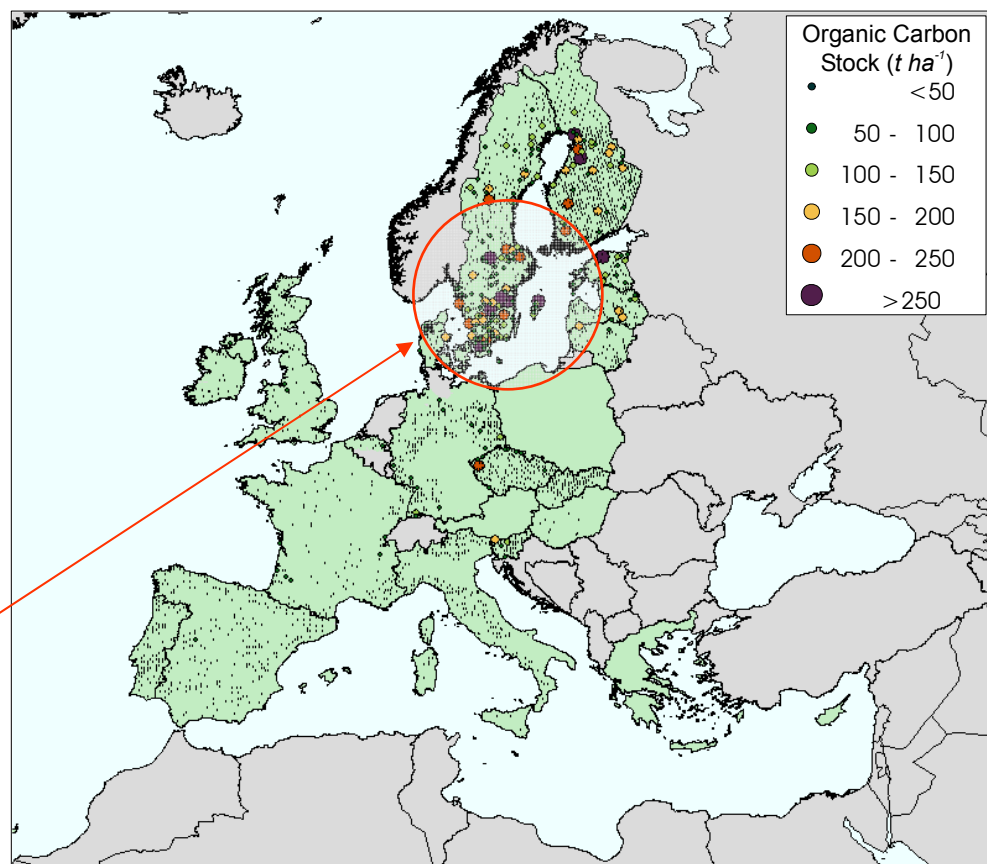
BioSoil/Soil Level 1 Sample Sites

BioSoil Soil Organic Carbon Stock

1. Organic Layer

Organic carbon stock calculated from organic layer weight.

Plots in southern Sweden show comparatively high OC stocks in organic layer. Elsewhere OC stocks are $<50 \text{ t ha}^{-1}$.



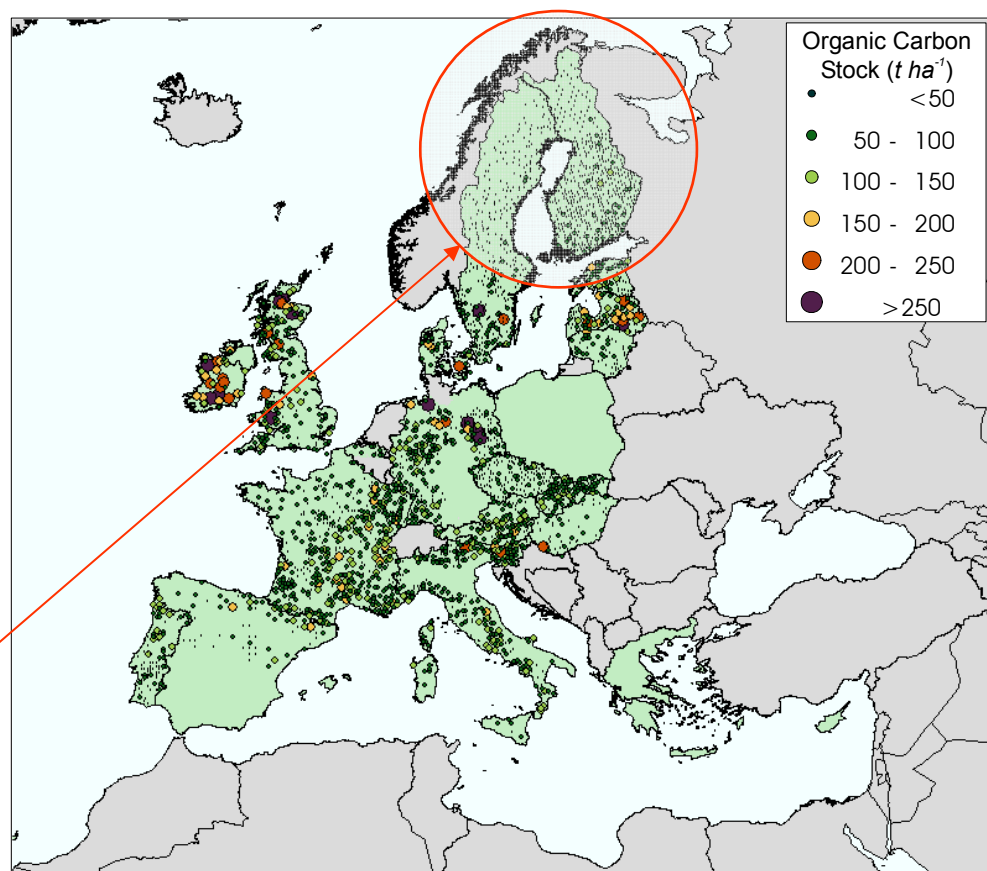
BioSoil/Soil Level 1 Organic Carbon Stock,
Organic Layer

BioSoil Soil Organic Carbon Stock

2. Soil Stratum 0–20 cm

Organic carbon stock
calculated from bulk
density

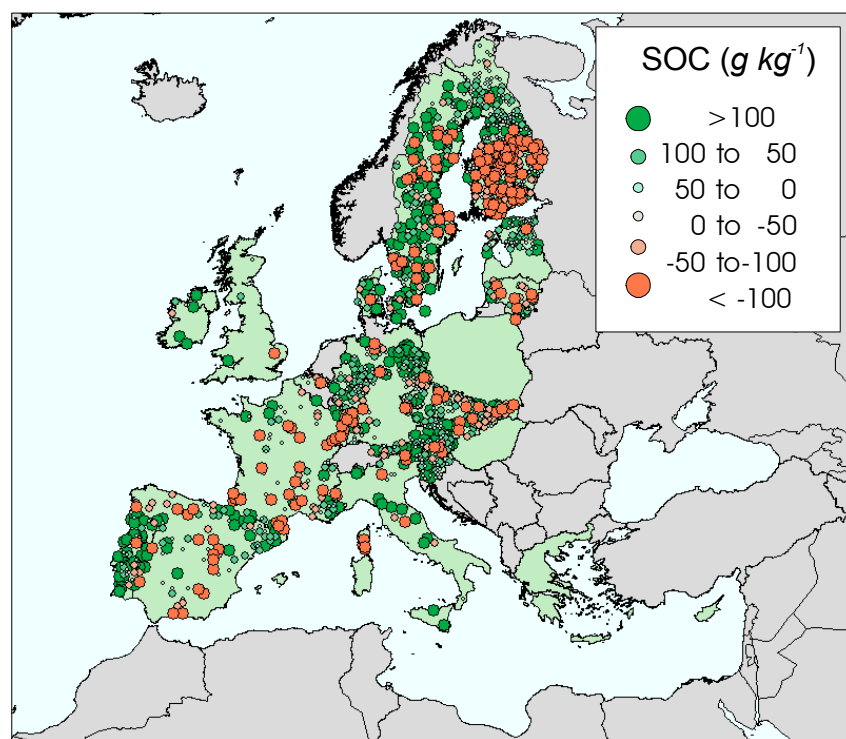
Comparatively high OC
stocks in north-west Europe
(organic soils).
Lower stocks in southern
and Nordic regions



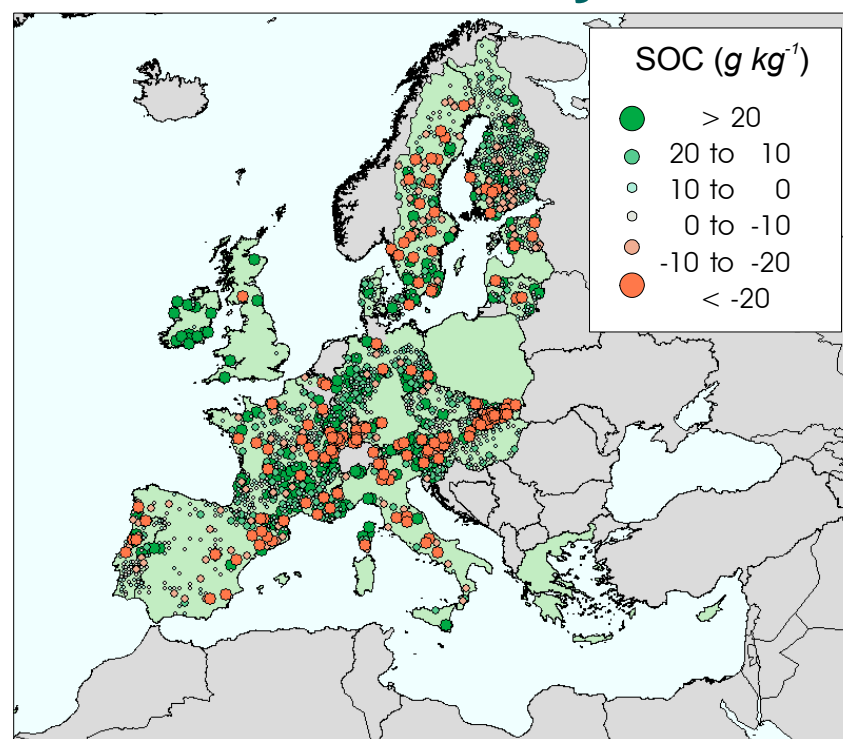
BioSoil/Soil Level 1 Organic Carbon Stock,
Soil Stratum 0-20cm

Estimating Changes in SOC Content

BioSoil 2006 vs. FSCC / ICP Forests 1996 Survey Plots



Organic Layers

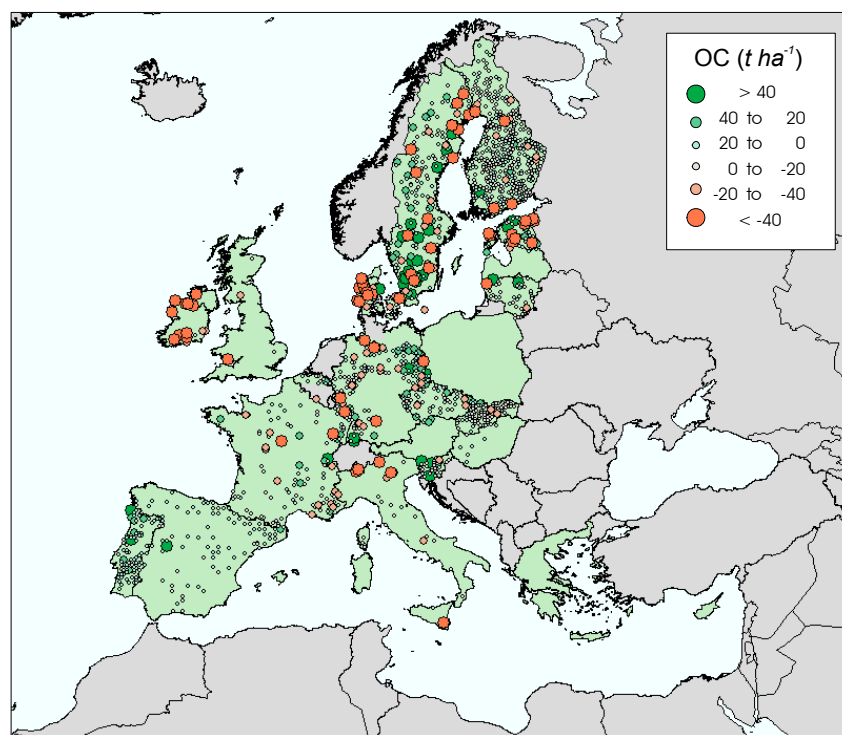


Soil Stratum 0-20cm

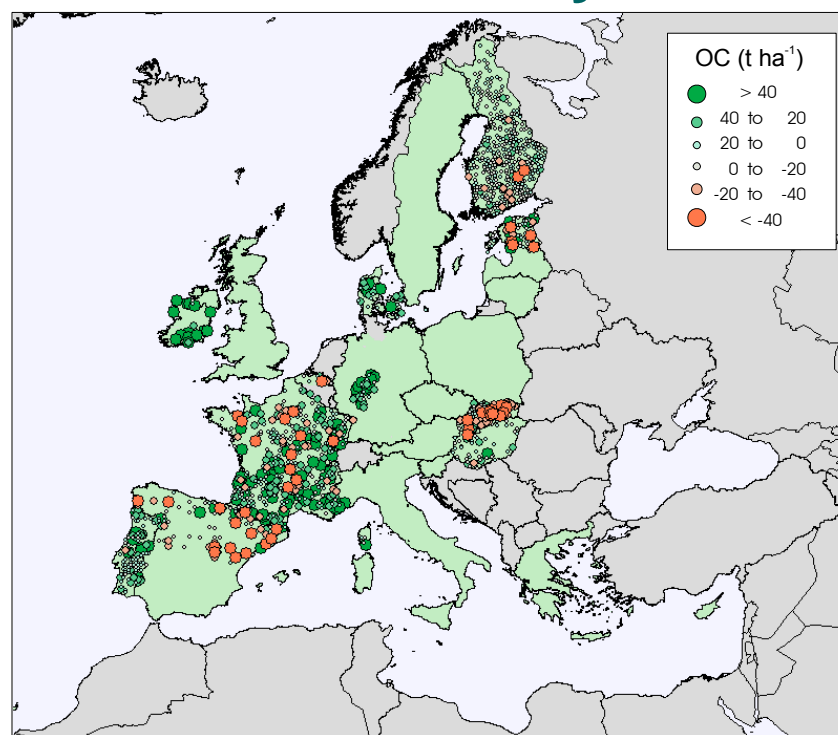
Change in Organic Carbon Content (g kg^{-1})

Estimating Changes in SOC Stocks

BioSoil 2006 vs. FSCC / ICP Forests 1996 Survey Plots



Organic Layers



Soil Stratum 0-20cm

Change in Organic Carbon Stock ($t\ ha^{-1}$)

Forest Soil Profile Sections

Typified Profile (Mineral Soil)

1. Organic Layer

Accumulation of organic material overlaying soil layer, unless buried.

2. Mineral Soil Layer

Non-organic soil material with particle sizes (sand, silt, clay) and variable amount of soil organic matter.

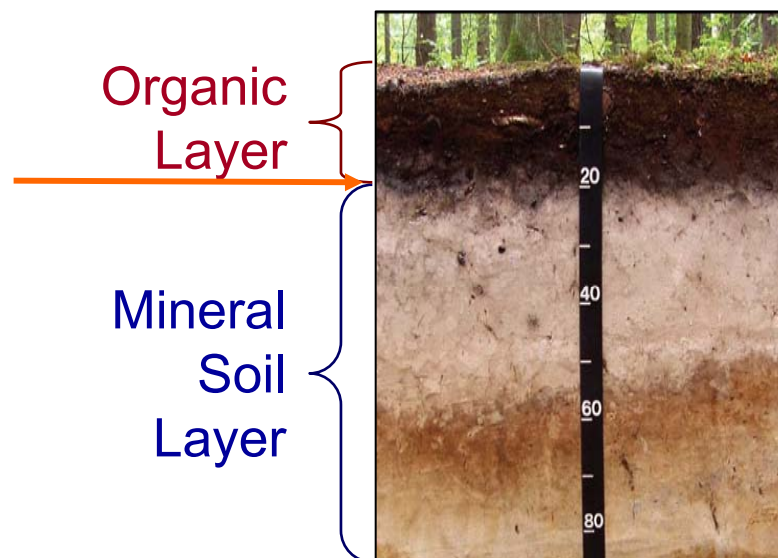


Image from E. Micheli in: Jones, A., V. Stolbovoy, C. Tarnocai, G. Broll, O. Spaargaren and L. Montanarella (2010) Soil Atlas of the Northern Circumpolar Region. Publication Office of the European Union, Luxembourg, 144 pp.

Show definition
organic material

Definitions of Soil Sections

Pool		GPG LULUCF ¹	FAO / BioSoil ²
Dead Organic Matter³	Dead wood	all non-living woody biomass not contained in the litter	OL horizon (litter layer) mainly leaves/needles, twigs and woody materials ⁴
	Litter	all non-living biomass ... in various states of decomposition above the mineral or organic soil. This includes the litter, fomic, and humic layers.	OF horizon (fragmented) partly decomposed organic matter
			OH horizon (humification) well-decomposed, amorphous organic matter
Soils	Soil organic matter	organic carbon in mineral and organic soils (including peat) to a specified depth	Mineral soil not organic soil
			Organic soil 40 cm or more organic soil material within upper 80 cm...



¹ IPCC Good Practice Guidance for LULUCF, 3.15, TABLE 3.1.2

² BioSoil Manual; FAO. 1990. Guidelines for soil description, 3rd (revised) edition.

³ Not presented: separation of O (aerated) from H (saturated) organic layers.

⁴ Under BioSoil the OL horizon must be sampled separately. OH has to be sampled separately only if >1cm thick.

Show definition
organic soil

Soil Profile Sampling Methods

A. Horizons (WRB)

1. Organic Layer

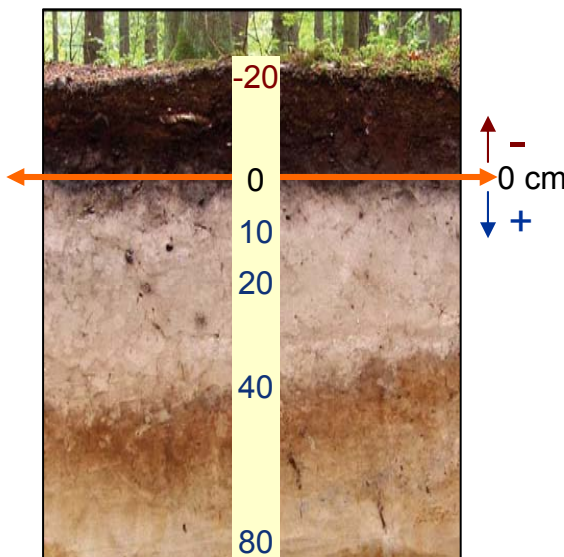
- a) Saturation period*.
- b) Decomposition status**.

2. Mineral Soil Layer

Classified according to the World Reference Base for Soil Resources (WRB).

- * Distinction between
- saturated (H) and
 - non-saturated (O).

- ** Separation by
- dead;
 - partly decomposed;
 - well-decomposed.



Reported:
organic carbon content
bulk density
volume of stones
layer thickness
organic layer weight

B. Fixed Depth

1. Organic Layer

- a) Saturation period*.
- b) Decomposition status**.

2. Mineral Soil Layer

Fixed thickness

Mandatory	Optional ¹
0 – 10	0 – 5
	5 – 10
10 – 20	
	20 – 40 ²
	40 – 80 ²

¹ For Level 1 plots.

² Optional, but recommended (mandatory for 1st assessment on Level 2 plots)

Show calculation
SOC stock

CO₂ Emissions from Mineral and Organic Soils

IPCC Changes in SOC Stocks

Change in Soil C = Sum of changes in soil C by soil type:

$$\Delta CFF_{Soil} = \Delta CFF_{Mineral} + \Delta CFF_{Organic}$$

Emission =
change in
SOC stock

Annual C
emission
from soil

Estimating CO₂ Emission

Estimate of C-Stock Change

$$\Delta CFF_{Soil} = \Delta CFF_{Mineral} + \Delta CFF_{Organic}$$

where

$$\Delta CFF_{Mineral} = \frac{\sum_{ij} [(SOC_j - SOC_i) * A_{ij}]}{T_{ij}}$$

and

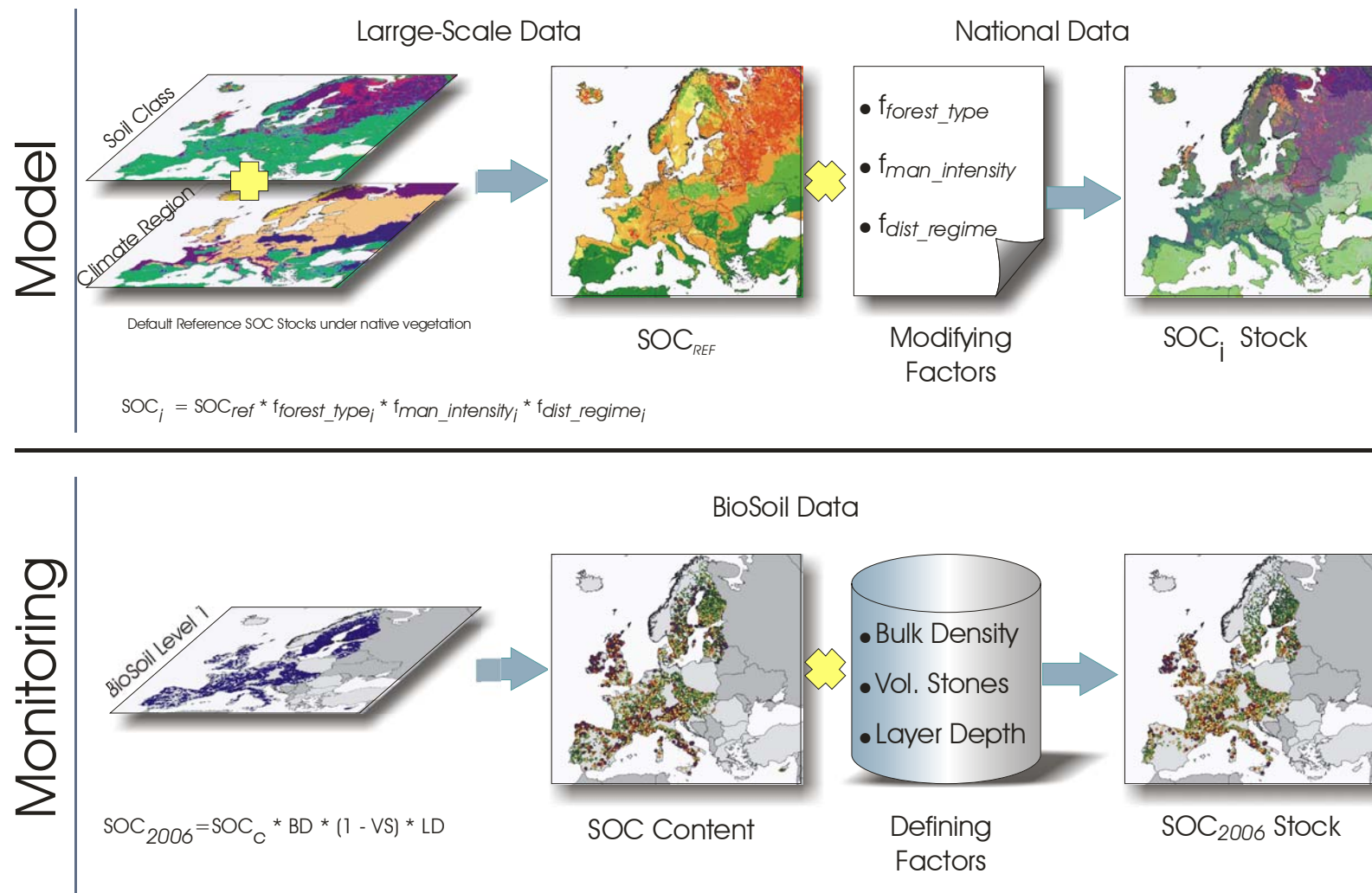
$$SOC_i = SOC_{ref} * f_{forest_type_i} * f_{man_intensity_i} * f_{dist_regime_i}$$

$$BioSoil - SOC_{2006} = SOC_c * BD * (1 - VS) * LD$$

$$! \quad \Delta CFF_{Mineral} \neq \frac{\sum_{i,2006} [(SOC_j - SOC_{2006}) * A_{i,2006}]}{T_{i,2006}}$$

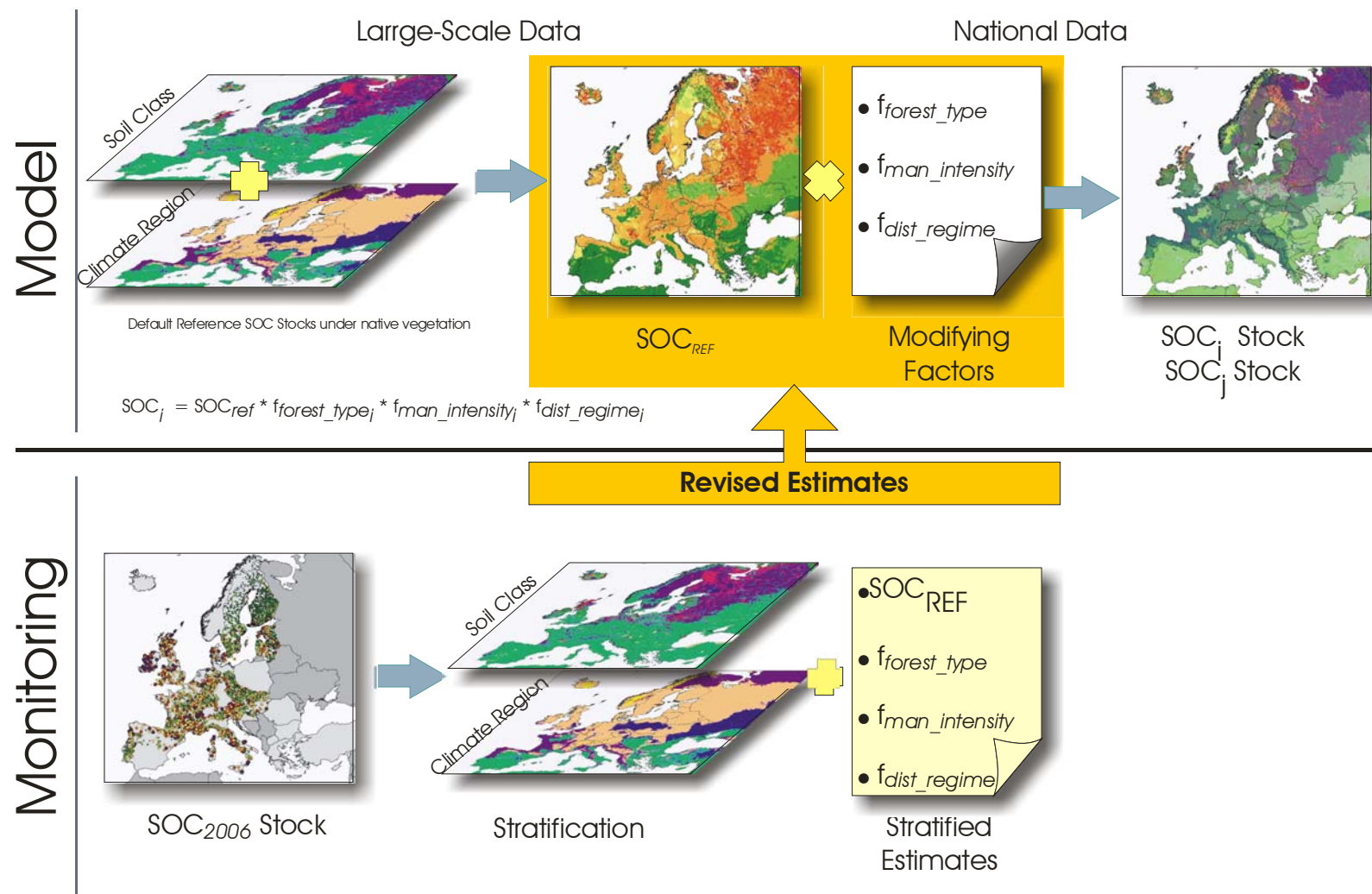
Modelled SOC_i and measured $SOC_{BioSoil}$ **not** directly comparable.

Monitoring vs. Modelling C-Stock in Mineral Soils



- 1 Commission Decision of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC (2010/335/EU), OJ L151 17.06.2010 pp. 19-41.
- 2 Spatial layer generated after IPCC Guidelines for national GHG Inventories, Table 2.3

Monitoring Support to Modelling C-Stock



Estimating Changes in SOC Stocks

Compliance with Data Robustness Criteria

Criterion	Compliance
Sample representative for country.	<ul style="list-style-type: none">• Depending on local variability. Probably where $n > 30$.
Relationships statistically significant.	<ul style="list-style-type: none">• Yes Parameter measured, not modelled.
Verification of results.	<ul style="list-style-type: none">• Yes 10% re-analysis by central laboratory.
Methods well documented.	<ul style="list-style-type: none">• Yes Fully documented in manual.
Uncertainty analysis available.	<ul style="list-style-type: none">• Yes/No For samples, not by country.

Estimating Changes in SOC Stocks

Specific Aspects for Considerations

Aspect	Condition
Soil organic carbon stock in mineral and organic soils.	<ul style="list-style-type: none">• Sufficient number of samples within country.
Dominant soil type (Tier 3).	<ul style="list-style-type: none">• Also from soil databases, such as European Soil Database.
Estimating CO ₂ emissions by SOC-stock change in mineral layer.	<ul style="list-style-type: none">• Comparable data from another survey available.
Estimating CO ₂ emissions from of organic layer.	<ul style="list-style-type: none">• Coherent definition of organic layer.• C-stock change not a suitable parameter.

BioSoil Data for SOC-Stock Estimates

Summary

- BioSoil provides most comprehensive and recent (2006) measured data of forest soil conditions with detailed manual for sampling procedures and analysis methods.
- Profile data sampled by fixed layer and pedological horizon.
- Useful as validated data for calibrating soil C-stock modelling approaches for mineral soils.
- Differences in definition of organic layer between GPG LULUCF and FAO classification.
- Estimating changes in soil organic carbon stocks over previous survey data only feasible with particular care.
- Specific national conditions need to be accounted for.

Organic Soil Material (diagnostic criteria)

Organic soil material must have one of the two following:

1. if saturated with water for long periods (unless artificially drained), and excluding live roots,
EITHER
 - a) 18 % organic carbon (30 % organic matter) or more if the mineral fraction comprises 60 % or more clay; or
 - b) 12 % organic carbon (20 % organic matter) or more if the mineral fraction has no clay; or
 - c) a proportional lower limit of organic carbon content between 12 and 18 percent if the clay content of the mineral fraction is between 0 and 60 percent;**OR**
2. if never saturated with water for more than a few days, 20 percent or more organic carbon.

Note: The Glossary entry “ORGANIC SOILS” of the IPCC Good Practice Guidance for LULUCF defines organic material according to FAO, 1998, not organic soils.

[Back](#)

Organic Soil Classification

WRB: Histosols (HS)¹

Soils having **40 cm or more organic soil material** (60 cm or more if the organic materials consist mainly of sphagnum or moss or have a bulk density of less than 0.1 Mg/m³) either extending down from the surface or taken cumulatively within the upper 80 cm of the soil.

The thickness of the organic surface horizon may be less if it rests on rock or on fragmental material in which the interstices are filled with organic matter.

¹ FAO (1998) World reference base for soil resources, World Soil Resources Report 84, Food and Agriculture Organization of the United Nations, Rome.

Computing Soil Organic Carbon Stock

a) for Soil Substrate

$$SOC_{Soil} = SOC_C \times BD \times \left(1 - \frac{VS}{100}\right) \times LD \times 10^2$$

b) for Organic Layer

$$OC_{Org} = SOC_C \times OLW \times \left(1 - \frac{VS}{100}\right) \times 10^{-1}$$

SOC_{Soil} : Organic carbon stock in soil ($t\ ha^{-1}$)
 OC_{Org} : Organic carbon stock in organic layer ($t\ ha^{-1}$)

SOC_C : Soil organic carbon content (%)
 BD : Dry bulk density ($g\ cm^{-3}$)
 LD : Depth of soil layer (m)
 OLW : Organic Layer Weight (kg)
 VS : Volume of stones (%)

[Back](#)

Tier Level Support – $\Delta CFF_{Mineral}$

Tier 1

- Assumes that carbon stock in mineral soils does not change.

Tier 2

- Function of reference soil carbon stock, forest type, management intensity, disturbance regime.
- National values for transition period with non-linear dynamic.

Tier 3

- Domestic monitoring scheme and/or modelling tool.
- Stratification by climatic zone, forest type, management regime.
- Soil carbon pool, processes and conditions for SOC I/O.
- Suitable methods to estimate C emissions/removals.

Tier Level Support – $\Delta CFF_{Organic}$

Tier 1

- National data on area of drained organic soils and **default** emission factors.

Tier 2

- National data on area of drained organic soils and **representative** emission factors.

Tier 3

- Entire area of organic soils.
- All anthropogenic activities likely to alter hydrologic regime, surface temperature and vegetation composition.
- Full carbon balance, including fluxes of CO₂ and CH₄, consistent with the estimation procedures for non-CO₂ GHG.