

Soils


A large European C reservoir


Outline

- ✓ **Soil types & stratification**
- ✓ **Mineral vs Organic soils:**
 - **SOC: Stock and Dynamic**
 - **Legacy in SOC dynamic**
 - **Symmetry in SOC dynamic**
 - **Tier 2**
- ✓ **Mass Balance & Modelling**
- ✓ **Considerations & Discussion points**

Context: SOM capacity

Within the time frame of addressing climate change [*approx. 1 century*]

- ❑ Mineral soils: limited capacity to store C [carrying capacity] 
 - SOC stock tends to reach an “equilibrium-level”
 - SOC stock changes are modeled by IPCC as changes from an equilibrium level to another

- ❑ Organic soils: unlimited & unknow capacity to store C 
 - ❑ Organic soils are modelled by IPCC as a constant, across time series, source/sink of CO₂ [and CH₄, N₂O]; the final conversion of an organic soil to a mineral soils interrupt the “organic-soil-source”

Mineral soils: SOC stock & dynamic

□ Given SOC stocks in mineral soils can be assimilated to a population in a limited environment, which dynamic in managed land is determined by:

➤ The carrying capacity, and the variables that determines it, which for IPCC default method are:

- Climate
- Soil
- Vegetation type [*i.e. natural C inputs*]

➤ The further variables that determine the equilibrium between annual C inputs and losses across a period; which for IPCC default method are:

- Land use
- Management practices/disturbance regime
- C inputs

and further variables for IPCC higher method are:

- Organic matter decomposability (*including N content*)
- Slope

furthermore, IPCC higher method further disaggregate variables in their components [*e.g. Climate, in temperature and moisture regimes*]

Legacy in SOC dynamic – mineral soils

- ❑ Changes in the variables that determine annual SOC gains and SOC losses, determine a new equilibrium level to be reached across a period. IPCC methodological approach:
 - ✓ Assumes that the new equilibrium is reached over a constant defined period, for all changes that bring to the same equilibrium level *e.g. a conversion from tillage to no tillage; whenever it occurs across the time series*
 - ✓ With Approach 2 for Land Representation, always calculates SOC changes over the entire transition period up to the new equilibrium
 - ✓ With Approach 3 for Land Representation, requires each land to be tracked across time; thus, the new equilibrium may or may not be reached before a further change in variables occurs

- ❑ Thus, the inventory system is required to:
 - ✓ Stratify the territory according to the variables
 - ✓ Identify changes in the variables [*Approach 2 for Land Representation, at minimum*]
 - ✓ *And to enhance accuracy with Approach 3 for Land Representation, geographically track across time variables and their changes*

Organic soils: SOC stock and dynamic

- ❑ In organic soils IPCC could not identify equilibrium levels of soil organic matter
[as, like mineral soils, determined by a number of natural and anthropogenic variables]
- ❑ Depending on the anoxic/oxic status of the soil *[as determined by its water content]*, the organic soil:
 - ✓ Either losing organic matter [oxic status], while emitting CO₂ [DRAINAGE]
 - ✓ Or accumulating organic matter [anoxic status], and emitting CH₄ [REWETTING]
- ❑ Organic soils may transit to mineral soils once the SOC stock decreases below the threshold applied to the definition of organic soils
[IPCC does not provide guidance on transiting organic soils to mineral soils, although identify and report such a process is in line with the general approach to good practice at any tiers]

Symmetry in SOC dynamic

☐ Mineral soils:

- ✓ Regardless to the direction of change, in mineral soils, **changes between 2 equilibrium levels bring the same absolute net change of SOC**, although the transition periods may differ
- ✓ Thus, the **inventory system** is required to **ensure that asymmetries in the calculation of the absolute net change of SOC** between equilibrium levels, **do not determine fictional SOC accumulation** across time series, *e.g. associated to rotation in the use/management practices of a land*

☐ Organic Soils:

- ✓ IPCC default methodological approach assumes that a rewetted land accumulates Carbon and emits CH_4 as a natural wetlands under similar conditions *[no transient period]*
- ✓ The accumulation rate of C of a rewetted land is not symmetric to the emission rate of a drained land in similar conditions

Higher methods – mineral soils – Tier 2

- ❑ As per AFOLU *good practice*, higher temporal and spatial resolution and more disaggregated activity data are used in higher methods [*both promotes accuracy*]
- ❑ Thus, country-specific values will be calculated by stratifying for a higher number of variables than those applied to the IPCC default:
 - ✓ SOC_{REF}, by Climate & Soil - at least, where both variables apply a finer classification than that for the IPCC default
 - ✓ CSCFs, by temperature & precipitation regime, slope, organic matter decomposability, use, management, C inputs - at least, modelled according to SOC_{REF} stratification and at a finer disaggregation than IPCC default
- ❑ Furthermore, it is *good practice* to derive [*see Equation 5, Chapter 4, AFOLU Volume, 2019 Refinement*]:
 - ✓ SOC_{REF} to the depth at which land use/management impacts it (*e.g. a national study may report no significant impact of no tillage on the 1m depth while IPCC default values for the 30cm depth provides for a significant increase of SOC*)
 - ✓ CSCFs [optimally] by analyzing response ratios estimated from experimental/measurement data taken from plots homogeneous for all the variables of stratification of SOC_{REF} and CSCFs, including for historical values of those variables
- ❑ SOC estimates can be improved by expressing it on a soil-mass equivalent basis rather than a soil-volume equivalent (i.e. fixed depth) basis, *to avoid to count bulk density changes as SOC changes*

Higher methods – organic soils – Tier 2

- ❑ As per AFOLU *good practice*, higher temporal and spatial resolution and more disaggregated activity data are used in higher methods [*both promotes accuracy*]
- ❑ Thus, country-specific values, including for DOC, will be calculated by stratifying for a higher number of variables than those applied to the IPCC default:
 - ✓ Climate, Use/Management, Nutrient status - at least, where all variables apply a finer classification than that for the IPCC default
- ❑ Furthermore, it is *good practice* to derive by:
 - ✓ Drainage classes [water table]
 - ✓ Time since Drainage/Rewetting

Mass Balance & Modelling – Tier 3

- ❑ Differently from Tier 2, **Tier 3 approaches address:**
 - ✓ **non-linearity** in the annual SOC
 - ✓ **longer-term legacy** effects of land use/management
 - ✓ **lateral transfer:** soil erosion & deposition, DOC & POC
 - ✓ **mass balance**, i.e. SOC gains = Biomass losses + DOM losses + soil deposition (if any)
 - ✓ **Soil Inorganic Carbon**, *further than liming*

- ❑ Tier 3 can calculate SOC changes on real volume/mass rather than on the projected area [*e.g. for a 30° angle slope, 100ha (projected area) = 100/0.866(cosine of 30°) = 115.5 ha (real area)*]

- ❑ **Tier 3 can be implemented:**
 - ✓ **Either with models:**
 - **verification of models' outputs is a key requirement:** a set of benchmark sites, ideally a series of permanent sites with statistically replicated design that capture all variables and their variability
 - ✓ **Or with measurements only:**
 - **A sampling design and size capable to represent the entire variability of SOC and of SOC changes across time;** *unlikely to associate SOC changes to specific activities under specific conditions*

Considerations & Discussion points

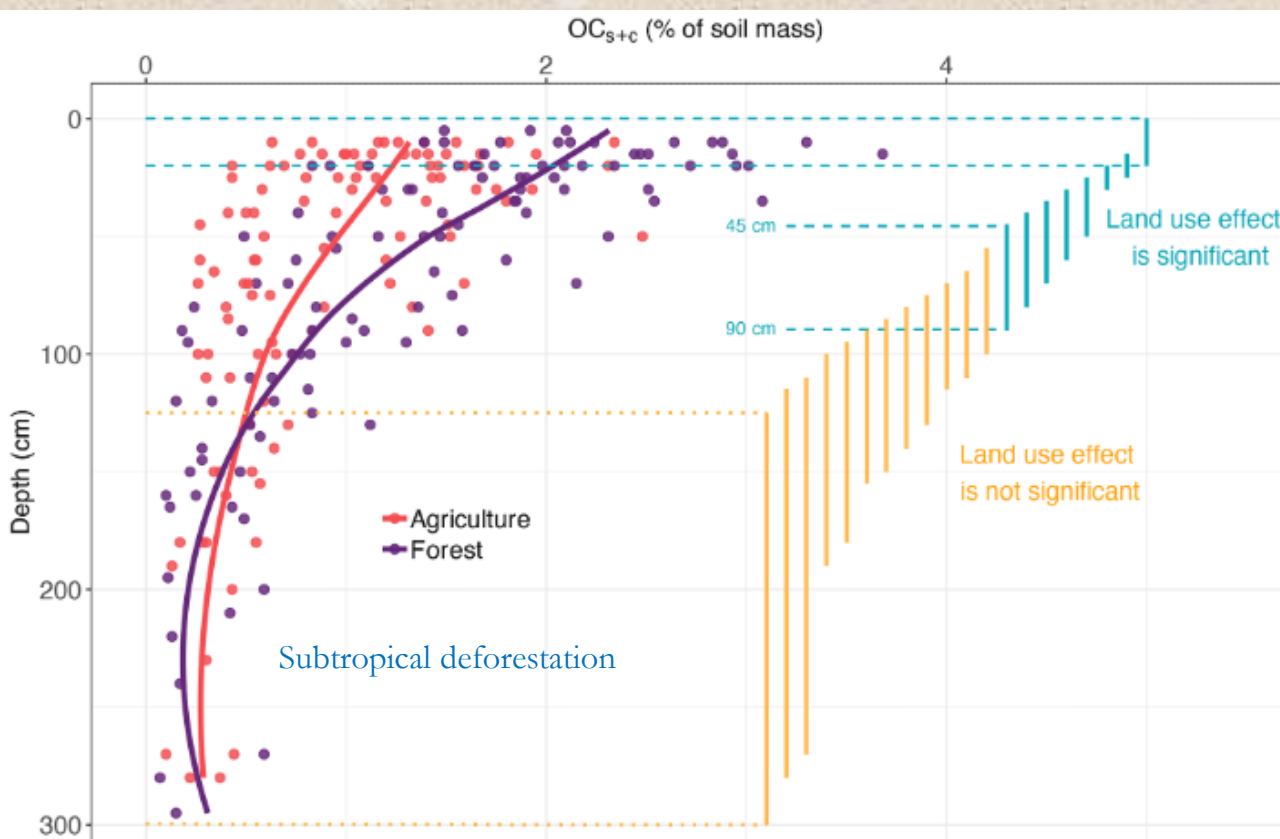
- ❑ The national **EU inventory is composed** by *sub-national* elements [*i.e. EU MS inventories*]
- ❑ *Where estimated*, **SOM is a Key Source/Sink**, across all MSs, thus Tier 2 estimates are required*
- ❑ A European climate and soil map** would promote accuracy & precision and reduce costs
 - ✓ Data from other MSs can support the calculation of Tier 2 EFs and parameters
 - ✓ Data from other MSs can verify models' outputs
 - ✓ SE of Tier 2/3 factors and parameters be used in error propagation rather than SD (*as per IPCC defaults*)
- ❑ Given that the stratification of variables promotes accuracy and precision:
 - ✓ SOC_{REF} & CSCFs calculated with country data at a level of aggregation higher than IPCC default do not promote accuracy and precisions as per IPCC Tier 2 good practice
 - ✓ Calculating SOC changes on the base of a “land-use specific aggregate of SOC_{REF} & CSCFs” do not promote accuracy and precisions as per IPCC Tier 2 good practice

* From submission in 2028 onwards, MSs shall use at least Tier 2 methodologies and from submission in 2030 onwards, apply Tier 3 methodologies in some units of land [those with high C stocks, those under protection or under climate risks]

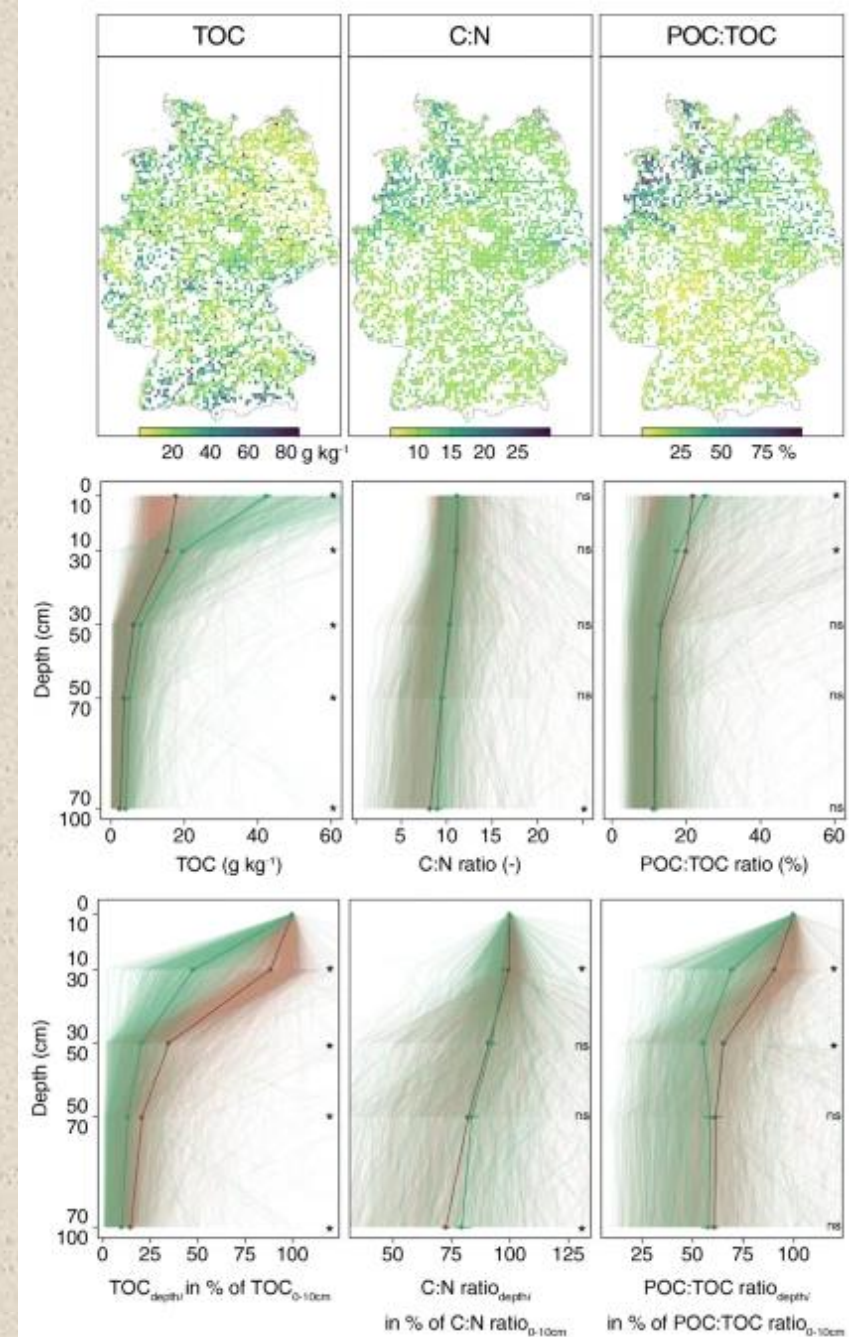
** including soil depth

Considerations & Discussion points

- Transparency of Tier 2 SOC_{REF} & CSCFs, as well as of Tier 3 models/methods is achieved by providing methods (*including assumptions and inferences*) and background data, or by referencing an accessible publication of those
- The mass of SOM actually affected by use/management changes is deeper than 30 cm



from: Müller et al. 2024 - <https://doi.org/10.5194/soil-10-349-2024>



Agricultural land: TOC = Total Organic Carbon; POC = Particulate Organic Carbon

from: Schneider et al. 2021 - <https://doi.org/10.1007/s11104-020-04769-w>