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The climate impact of forest and land management in the EU and the role of current reporting and accounting rules

An investigation into the incentives provided by LULUCF reporting and accounting and their implications

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Briefing for ECF and Fern

Authors

Dr. Hannes Böttcher
Oeko-Institut e.V.

Judith Reise
Oeko-Institut e.V.

Head Office Freiburg
P.O. Box 17 71
79017 Freiburg
Street address
Merzhauser Strasse 173
79100 Freiburg
Tel. +49 761 45295-0

Office Berlin
Borkumstrasse 2
13189 Berlin
Tel. +49 30 405085-0

Office Darmstadt
Rheinstrasse 95
64295 Darmstadt
Tel. +49 6151 8191-0

info@oeko.de
www.oeko.de

Table of Contents

Summary

The EU LULUCF Regulation considers, for the first time, a separate target for the land use, land use change and forestry (LULUCF) sector. The sector is also supposed to contribute to the legally binding target of net zero greenhouse gas (GHG) emissions by 2050 proposed by the European Climate Law. Hence, the importance of the LULUCF sector emissions have increased. This requires a critical review of completeness, accuracy and consistency of LULUCF reporting and accounting. But the rules for reporting and accounting as laid out in the EU LULUCF Regulation also need to better reflect this importance by setting incentives for land management improvement.

This briefing highlights challenges in GHG reporting and accounting for cropland, harvested wood products, forest management change and organic soils, e.g. related to uncertainty, lack of data and high level of aggregation, assesses the implications of these challenges on environmental integrity and incentives for improving land management.

Inaccurate accounts of **cropland** emissions and removals lead to hidden emissions but also hidden mitigation potentials which has implications for incentivising changes in management. Countries are more likely to increase their ambition level in LULUCF if there is a closer connection between concrete management practices, co-benefits of other policy targets (e.g. area of organic farming, hectares of restored ecosystems) and GHG inventories. Climate protection on cropland can only be effective with much higher granularity of reporting than currently applied by EU Member States (MS).

Also, the rather coarse representation of **harvested wood products (HWP)** in most GHG accounts of EU countries might lower incentives for mitigation measures involving HWP overall. An accurate initialisation of HWP pools is crucial but also a challenge for MS facing lack of data. There can also be inconsistencies in MS's HWP accounts because of discrepancies between harvest statistics and national forest inventories. However, as HWP is part of the reference level (FRL) that combines HWP and forest pools, the implications of inconsistencies are probably limited.

Whether impacts of changes in **forest management** on forest carbon stocks are accurately accounted for, depends also on the stratification of forests in GHG inventories and FRL. If forest stratification for reporting is too coarse, management changes might not be visible in the GHG accounts. The risk of undetected emissions and removals in forest inventories appear to be limited for reporting of forest biomass. For other forest carbon pools, the risk depends on the effect that management changes have on them. This depends again on the type of change and can result in both, higher and lower carbon stocks.

The review of accounting and reporting of **organic soils** shows that large discrepancies exist between different sources of information regarding the extent of organic soils, their status and resulting emissions. Therefore, input data to MS's GHG accounts needs to be improved. Comparisons with independent data sources can be useful for assessing the quality of GHG inventories for wetlands and organic soils.

1. Introduction

1.1. Role of land use in climate policy

In the past, the inclusion of land use, land use change and forestry (LULUCF) in climate targets was often interpreted as an attempt to reduce pressure on other sectors to bring down GHG emissions. However, this role has changed substantially over the past few years. The Paris Agreement of 2015 expects the sector to provide a large share of the sink to balance remaining GHG emissions in 2050 and enter a period of negative emissions. The EU LULUCF Regulation considers for the first time a separate target for the sector (European Commission 2018). With the European Climate Law the Commission proposes a legally binding target of net zero GHG by 2050 and thereby establishes a framework not only for the reduction of GHG but also for the enhancement of removals by natural or other sinks in the EU (European Commission 2020). The options for enhancement of natural sinks are identified to be with the natural sink of forests, soils, agricultural lands and wetlands that should be maintained and further increased. Similarly, the proposal addresses carbon removal technologies, such as carbon capture and storage and carbon capture and utilisation that should be made cost-effective and deployed.

No matter whether carbon neutrality will be achieved with larger or smaller shares of natural sinks: with the increasing focus on the long-term goal of GHG neutrality, these targets have changed the LULUCF sector's role drastically from an informal "stopgap" to a decisive "counterweight".

The EU reference scenario expects the EU LULUCF sink to decrease further from currently (2018) -294 to -267 Mt CO_2 per year in 2050, a reduction by 9 % (EU 2020; European Commission 2016). In 2010 the sector still removed 356 Mt CO_2 annually. To fulfil the expectations as regards its contribution in the future (an increased or at least maintained sink), the sector needs to undergo significant changes regarding management goals towards more effective climate services without compromising other important policy goals related to land such as food security, protection of biodiversity and other ecosystem services.

Also the rules for reporting and accounting as laid out in the EU LULUCF Regulation need to better reflect this new role (Böttcher et al. 2019). This requires not only a critical review of completeness, accuracy and consistency of LULUCF reporting and accounting. It demands much more than before that rules be designed to really set incentives for land management improvement.

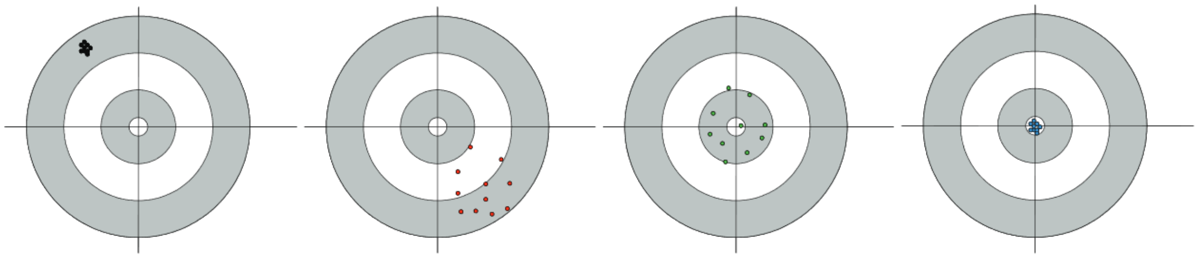
1.2. Accuracy and completeness of reporting and accounting

The EU Regulation 2018/841 (European Commission 2018) sets out the commitments of Member States for the LULUCF sector that contribute to achieving the objectives of the Paris Agreement and meeting the GHG reduction target of the Union for the period from 2021 to 2030. In order to obtain accurate accounts of emissions and removals that are comparable and consistent among countries, the IPCC Good Practice Guidance is applied (IPCC 2006a). These guidelines set the general scope for reporting by introducing basic concepts, such as the definition of anthropogenic emissions and removals, the type of gases, sectors, categories and pools to be used when compiling data for national GHG inventories. They further provide basic calculation methods combining information on the extent of an activity (i.e. activity data, often area information) with coefficients describing the emissions or removals per unit of activity (i.e. emission factors) and respective default data. Such defaults can be used by countries for estimating emissions and removals at the so-called Tier 1 level. At this level methods for all categories are designed to use readily available national or international statistics in combination with provided default emission factors that ensure that every country can estimate GHG emissions and removals at least at that level.

The guidelines also establish principles for ensuring high quality accounts by requiring that they are transparent, accurate, complete, consistent and comparable. According to the guidance, estimates of emissions and removals should be accurate and precise (Figure 1-1). Accurate means that they are neither over- nor underestimated. Estimates are precise when uncertainties are reduced as far as practicable.

Figure 1-1: Illustration of accuracy and precision

(a) inaccurate but precise; (b) inaccurate and imprecise; (c) accurate but imprecise; and (d) precise and accurate



Source: IPCC 2006b

Another requirement by the guidelines are uncertainty assessments that provide the range and likelihood of possible values for the estimate and identify categories contributing most to the overall uncertainty. Chapter 3 of the guidance suggests that uncertainties should be estimated for both the level and the trend of emissions and removals, as well as for emission factors and activity for each category. Reported uncertainties allow an assessment on how strongly the estimates may differ from emission and removals really occurring. However, also the choice of the method has implications for uncertainty. Moving to a higher tier method usually reduces uncertainties as it removes potential biases and better represents the complexity of systems. But higher tier methods may also increase uncertainty by revealing additional complexity that was not captured by the lower tier method. Thus, uncertainty estimates need to be considered carefully as they cannot be interpreted as full assessment of potential biases and knowledge gaps.

The IPCC guidelines follow the principle of conservativeness (Grassi et al. 2008). This means that when completeness or accuracy of estimates cannot be achieved, the reduction of emissions should not be overestimated, or at least the risk of overestimation should be minimised. An example is the rule under the Kyoto Protocol that foresaw that a country may choose not to account for a certain pool if transparent and verifiable information is provided that the pool is not a source.

1.3. Implications of inaccurate reporting for incentives for land management changes

The conservativeness principle described above reduces the risk of unaccounted emissions. However, it might also reduce incentives to improve land management as it makes efforts to improve land management less visible.

Grassi et al. (2008) acknowledge that conservativeness might discourage the implementation of measures because the amount of credits that can be generated through management change gets reduced. Grassi et al. further claim that it rewards quality as it assumes that more accurate or complete estimates tend to result in lower emissions and higher removals. However, increasing accuracy and completeness might also display emissions that have not been considered before, causing ambition levels to go down without additional measures. This may be dissuasive in increasing accuracy.

Table 1-1 provides an overview of types of uncertainty considered by IPCC guidelines and examples on how choices of method and data affect accuracy of GHG estimates.

Table 1-1: Types of uncertainty affecting accuracy of reporting, examples and potential effects for accuracy and incentives for land management improvement

Type of uncertainty	Examples for how a country's choice of method and data might affect accuracy	Potential effect for accuracy	Potential implications for incentivising land management change
Lack of completeness	A country omits a pool (e.g. dead wood) causing a systematic inaccuracy.	Potentially high	Mitigation measures targeting the omitted pool are not attractive, although they might create synergies, e.g. with nature conservation in the case of dead wood.
Model simplification	Applies to any model estimate but larger inaccuracies can be caused when applying models outside the range of the application they were built for and if the model was not properly validated (e.g. a soil model for boreal climate is applied for subtropical conditions).	Potentially high	If specific silvicultural practices cannot be described by the forest model used to estimate emissions and removals from managed forest land, the country has no incentives in implementing such measures.
Lack of data or representativeness of data	The most common reason for countries to apply lower tier methods and default values. For example, a country applies default values or values from a neighbouring country for emissions and removals from organic soils.	Potentially high	The use of default values or values from other countries neglect country specific circumstances that can be important for identifying more targeted mitigation measures.
Statistical random sampling error	Due to the method a country uses to compile its National Forest Inventory, statistical random sampling errors might occur.	Rather low	Measures for improving land management need to be visible in front of the sampling errors to be recorded as management change with a positive effect.
Random and systematic measurement error	The collection of empirical data is always associated with errors (e.g. the collection of soil carbon data through a survey). Systematic errors can be avoided by good quality assurance and control.	Rather low	See above
Misreporting or misclassification	This can be caused by inadequate application of definitions, e.g. regarding the differentiation between drained and undrained organic soils.	Potentially high	The use of default values or values from other countries neglect country specific circumstances that can be important for identifying more targeted mitigation measures.
Missing data	One reason for missing data can be that measurements are below a certain detection limit, e.g. regarding changes in mineral soil after management changes that are not revealed by a survey.	Depends	The lack of information on mitigation potentials due to missing data might lower incentives for countries to improve land management.

Source: IPCC 2006a and own compilation

1.4. Aim of the briefing

This briefing highlights challenges in GHG reporting and accounting e.g. related to uncertainty, lack of data and high level of aggregation, assesses the implications these challenges have on environmental integrity and incentives for improving land management and climate protection.

Hypothesis: The methods of reporting and accounting emissions do not provide the full picture of what the atmosphere sees due to inaccuracies, uncertainties and lack of information with implications for environmental integrity and incentives for management change.

The following questions guide the analysis:

- What are current challenges in emission accounting related to inaccuracies, uncertainties and lack of information? The briefing clarifies whether and how GHG reporting in the LULUCF sector is currently inaccurate, leading to missing or hidden emissions.
- How do these challenges relate to incentives for management change in the LULUCF sector? The briefing shows how current reporting within under the LULUCF regulation reduces incentives to efficiently tackle climate change.
- What are conclusions and potential solutions to the challenges that ensure that incentives are increased and how should they be implemented and by whom? The briefing looks into how better incentives for climate mitigation could coherently be supported by reporting and accounting in the LULUCF sector.

Four case studies are presented as examples of which challenges occur for different land use categories and pools:

1. Accuracy of **cropland** reporting and accounting. This case addresses the challenge of accurately reporting emissions and removals of soil organic carbon on cropland limiting the ability of MS to document positive effects of management changes.
2. Accuracy and consistency of accounting **harvested wood products** (HWP). This case addresses the challenge of reporting emissions and removals from HWP consistent with historic and recent harvest and wood use statistics.
3. Accuracy and visibility of **forest management change** reporting and accounting. This case addresses potential issues related to the ability of reporting systems detecting management changes, especially forest management intensification.
4. Completeness of **organic soils** reporting and accounting. This case addresses documented inconsistencies in the literature between independent international data on areas of organic soils und grassland and cropland compared to national inventories, potentially leading to emissions remaining unaccounted.

2. Analysis

2.1. Accuracy of cropland reporting and accounting

Soil carbon is an important carbon pool that needs to be addressed through measures aiming at mitigation of climate change. Such measures can have two purposes: increasing soil organic carbon stocks by creating a positive balance between carbon inputs into soils (e.g. through leaving biomass residues on site) and losses of carbon (e.g. through decomposition) or preventing carbon losses of soils with a high carbon stock (e.g. organic soils, see also 2.4).

In agricultural soils, the potential for increasing soil organic carbon is relatively limited compared to other options in the LULUCF sector with an estimated average potential of roughly 0.5 – 7 t CO_2 per ha per year (Poeplau & Don 2015; Roe et al. 2019; Smith 2016). However, as the area involved is very large for many MS, measures can still have a significant potential. The range of estimates at EU level for cropland carbon sequestration is 9 Mt (Frank et al. 2015) to 58 Mt CO_2 per year (Lugato, Bampa et al. 2014). While there is overall consensus that increasing soil carbon stocks is a relevant contribution to maintaining and increasing carbon sinks, there are significant uncertainties around the achievable potential (Batjes 2019; Smith et al. 2005; Smith et al. 2020). The potential for avoiding emissions from cropland through preserving stocks is theoretically as high as current emissions reported in EU MS for this category, amounting to 56.7 Mt CO_2 for the total cropland category (European Union 2020). These observed emissions are mostly related to land use change effects, not necessarily management effects (Poeplau et al. 2011). For example, the subcategory cropland remaining cropland in EU MS accounts for more than 90 % (114.5 Mha) of reported total cropland (124.6 Mha) but only for 25% of annual net emissions (14.4 Mt CO_2). Thus, only 10 Mha (8 %) in the category of land converted to cropland (mainly from forests and grassland) cause 42.4 Mt CO_2 (75 %) emissions. The emissions per year are likely to decline without management changes due to equilibrium effects (Frank et al. 2015). This shows that there is an urgency for mitigation measures to reverse the continued loss of existing stocks.

The choice of management practices that have the most significant potential for maintenance and sequestration varies according to climate and biophysical conditions (soil type and climate), as well as the production system involved. The largest potential is associated with improved crop varieties, crop rotation, use of cover crops, perennial cropping systems, reduced tillage intensity, residue retention, and improved water availability (Smith et al. 2014).

In fact, many MS are aware of potentials for mitigation on cropland and have reported that they have implemented or plan to implement policies and measures. According to an analysis of MS reports, nutrient management, tillage and water management on cropland were mentioned in 24 policies and 45 measures reported by 24 MS (Paquel et al. 2017). Prominent is the 4 per 1000 initiative[1] that aims to increase the soil carbon stock by 0.4% annually through improved agricultural management and that was launched by France in 2015 at the COP 21.

2.1.1. Challenges in emission accounting

Despite the willingness of MS to undertake measures and the theoretical potential that can be derived from science and inventories, there are challenges for MS to translate the potential into action.

Wiesmeier et al. (2020) demonstrated that the implementation of the 4 per 1000 initiative has limitations. For Bavaria they simulate the effects of five combined management systems on soil carbon stocks, including cover cropping, improved crop rotation, organic farming, agroforestry and conversion of arable land to grassland. The estimated potential corresponds to only 0.1% of present carbon stocks. But even the realisation of that quarter of the 4 per 1000 target requires new incentive systems, implementation of research networks with trials demonstrating how improved soil management practices affect carbon stocks and other ecosystem services and how soil carbon can be increased permanently.

[1] https://www.4p1000.org

It can also be expected that large shares of the effect of management change will go undetected and invisible in MS national GHG accounts due to overly coarse reporting methods. There are 18 MS that report and account mineral and organic soil emissions from cropland remaining cropland at Tier 1 or Tier 2. A Tier 2 approach entails the estimation of country-specific stock change factors, Tier 1 assumes default values without country-specific reference (IPCC 2019). In theory the Tier 2 approach allows for finer categorisation that better represents management impacts on soil organic C stocks because it is based on empirical data. However, this method requires sufficient detail in the underlying data to classify the land area into a more detailed set of management systems and estimate more specific parameters. Many MS struggle with such a level of detail regarding the extent of area and type of soils where specific cropland management practices are applied (e.g. cover cropping). Moreover, cropland management systems are typically more complex and include several aspects that are difficult to disentangle. An example is organic farming, that requires certain management practices (e.g. no mineral fertiliser input, specific crop rotations) which impacts soil carbon. The large area potential and the many co-benefits expected with improved soil carbon management (e.g. improved nutrient and water storage, reduced soil erosion, protection of biodiversity etc.) make it a valuable contribution to overall improved land management and climate change adaptation (Wiesmeier et al. 2020).

But even more detailed Tier 2 approaches miss important information about spatial variability of emissions and implications of different cropland management options. Tier 3 approaches for soil carbon involve the development of advanced methods (detailed measurements and models). Such approaches better address the spatial variability and non-linearity of carbon stock changes and better capture longer-term legacy effects of land use and management (IPCC 2019). Such Tier 3 level approaches for cropland are currently applied only by Austria, Denmark, Finland and the UK.

2.1.2. Implications for incentives

Inaccurate accounts of cropland emissions and removals lead to hidden emissions but also hidden mitigation potentials. As discussed above in section 1.2, the conservativeness principle ensures that emissions are rather overestimated than underestimated. But the fuzziness of cropland or grassland emissions and removal mitigation potentials creates weaker incentives for positive changes in management from a climate perspective.

This relates to national incentive schemes under the Common Agricultural Policy and national targets for organic farming among others. **Countries would more likely to increase their ambition level in LULUCF if there was a closer connection between concrete management practices, co-benefits of other policy targets (e.g. area of organic farming) and GHG inventories.**

Moreover, the improvement of data and reporting methods, e.g. including soil surveys and modelling, is costly for MS. It might also increase relative uncertainties as more sophisticated methods introduce uncertainty, e.g. by including new processes and parameters that are ignored in default methods. Thus, MS also need to be ready for surprises regarding unexpected emissions and emission reductions in their inventories. **The improvement of inventories and the increase of accuracy is therefore not necessarily incentivised by the UNFCCC reporting system and the LULUCF Regulation.**

2.1.3. Conclusions

The IPCC has recently improved the data basis for Tier 2 reporting for cropland emissions by providing more detailed emission factors for specific practices, e.g. biochar applications (IPCC 2019). Similarly, it is important to have detailed information on initial carbon stocks for different soil categories.

A solution could be to model estimates as provided by Lugato et al. (2014) that are consistent across the EU countries and help to make soil carbon emissions but also the mitigation potentials more comparable.

Novel methods of measuring soil organic carbon change exist and are regularly reviewed in the scientific literature (Smith et al. 2020). These include establishing international benchmark sites located on representative land use types, soil types and with representative management, monitoring networks and the use of models and remote sensing data for validation.

The implementation of advanced methods for cropland reporting is not incentivised by the LULUCF Regulation that makes accounting of cropland and grassland mandatory after 2020. The accounting against a historic reference can lock MS in default methods for reporting as more advanced methods might reveal higher historic emissions as expected. **However, climate protection on cropland can only be effective with much higher granularity of reporting than currently applied by MS.**

2.2. Accuracy of HWP accounting

Harvesting wood transfers carbon stored in living biomass into different pools of harvested wood products (HWPs). The LULUCF Regulation requires the accounting of HWP using the so-called “production approach” that includes annual HWP carbon stock changes originating from wood harvested in the reporting country only and thus includes exported but excludes imported wood products. Harvested wood products in 2018 represented a net carbon storage of -44.6 Mt CO_2 in 2018 (European Union 2020). Most MS reported the stock of HWP to be increasing (Cyprus, Greece and Netherlands as an exception). The main contributors to the EU net storage in HWP are Poland, Romania, Sweden, Finland and Germany.

The default method (Tier 1) to estimate carbon stock changes of HWP is the first-order decay (FOD) function (IPCC 2019). It identifies three default classes of semi-finished wood product commodities: sawnwood, wood-based panels and paper/paperboard. The carbon inflow to these classes is described by the harvested and recycled wood allocated to the classes. The outflow is described by a constant decay rate expressed as half-life in years. Tier 1 is applied by the majority (17) of EU MS. Six MS reported that they use a Tier 2 method that applies the FOD to country-specific data or a higher Tier level using country-specific methods (Estonia, Finland, France, Hungary, Sweden and UK).

Due to a certain inertia of the HWP carbon pools, a rather long record of flows into the pools needs to be reconstructed to estimate the current amount of carbon stored in products. Data on wood production from international databases, such as FAOSTAT or UNECE, have the advantage that they are relatively consistent between countries and are freely and easily available to all MS. However, the time coverage of the data can be very different. For several countries FAO statistics provide data on wood commodities from 1961 onwards. But for some countries the records start only in 1991. This limits the accuracy of estimates of HWP initial carbon stocks and thus also current and future decay rates and emissions.

The reliance on rather coarse methods for estimating carbon stock changes of HWP puts a number of challenges to countries that were partly identified by the IPCC (2019) and are presented in the following.

2.2.1. Challenges in emission accounting

The largest risk for inconsistent and inaccurate accounts of HWP potentially results from countries accounting differently for imports and exports of harvested wood. While this risk exists at international level (Sato & Nojiri 2019), the LULUCF Regulation requires all MS to use the same approach to avoid such inconsistencies.

Still, MS are free to make a number of assumptions that can be the cause of inaccuracies of HWP reported emissions and removals. For example, the tier level chosen by a MS can result in larger differences (Jasinevičius et al. 2018). Moreover, the half-life estimates very much depend on the socio-economic development in MS and its consumption pattern (IPCC 2019). But there are also other market effects that drive dynamics of HWP. For example, an increase in wood production might lead to a substitution of existing HWP and thus a shortening of the lifetime of HWP. Such dynamics are not covered by the Tier 1 method using FOD functions and applying constant default values. This causes overestimation or underestimation of annual carbon stock changes of HWP.

Another challenge for MS is the rather small number of HWP commodity classes in the default method. Tier 1 identifies three sub-pools (sawnwood, wood-based panels and paper and paper-board), represented by half-life values. Rüter (2017) presented sensitivity analyses of changes in half-lives for the HWP default commodities and found that a decrease in half-lives by 10 % would cause the sink in HWP to decrease by only 0.25 %. Such effects depend on the simulation period but also the initial stock of carbon in HWP at the start of the simulation. However, the results suggest on the one hand that there is rather limited potential for GHG mitigation through measures that aim to increase the lifetime of wood products. On the other hand, the implications of inaccurate half-lives or coarse product categories for emissions and removals from HWP also seem to be limited.

A big challenge is associated with the initialisation of HWP carbon pools. Due to the lack of long historical data series on HWP commodity classes, initial stocks are typically estimated by assuming that the stock is in an equilibrium, i.e. that inflow and decay are of the same size. This is a simplification that might overestimate emissions from long-lived HWP classes in cases where the stock was in fact growing when the simulation of carbon flows started. Such inconsistencies cause a potential disconnection between emissions and removals from managed forest land and HWP and increase overall uncertainties associated with HWP reporting and accounting.

The carbon pools for forest biomass and HWP are very closely connected and can be (in a limited way) interpreted as two “communicating vessels”, where a fraction of the carbon extracted from the forest biomass pool enters HWP and a reduction of the harvest rate increases forest biomass carbon stocks but reduces carbon stored in the HWP pool. This communicating behaviour should be reflected in accurate accounts of forest biomass and HWP. An analysis of the European Commission (EC) (Cazzaniga et al. 2019) revealed, by comparing national forest inventory and national wood harvest information, that there can be unaccounted harvests of on average 13 % in the EU, ranging from 0 % (Finland) to 70 % (Cyprus). As accounts of HWP largely build on harvest statistics, there is a risk of inaccurate accounts of HWP. However, it can be expected that relying on harvest statistics only results in an underestimation of HWP carbon inflow and can thus be considered a conservative approach. Underestimated harvest removals might also lead to an underestimation of forest emissions in rare cases where harvest statistics are the only basis for reporting forest emissions and removals. While harvest statistics are often available with a higher temporal resolution (e.g. annual), forest inventory data provides detailed information on the existing carbon stocks in forests and their changes. Forest inventories record any removal of biomass from the forest recorded as an emission. Therefore, it is essential that both information sources are combined.

Emissions can be underestimated by a country if it assumes that the unregistered wood enters the HWP pool without having evidence for this allocation. In this context, the provision of the LULUCF Regulation is relevant that requests MS to apply a constant ratio of energy to material use for the projection of the forest reference level (FRL) to account for changes in wood allocation to different uses.

2.2.2. Implications for incentives

Substitution of GHG intensive materials with harvested wood products is among the most popular mitigation measures reported by EU MS to the European Commission, as 11 out of 27 Member States have implemented policies and measures aimed at increasing HWP (Paquel et al. 2017). Most of these countries apply default values for half-lives of HWP pools. This means that the planned measures need to reflect the reporting structure of these countries in order to become visible in their GHG inventories. **If measures are implemented that result in longer lifetimes of HWP, e.g. in the pool of wood-based panels, through increased recycling rates and the use of recovered wood, such changes would not affect GHG accounts of the country.** Thus, the impact of the mitigation measures concerning HWP cannot be accurately monitored through the GHG inventory. **The identified issues of accuracy with reporting and accounting of HWP therefore lower the incentives for implementing measures and might also lead to wrong conclusions regarding priorities for mitigation strategies.**

2.2.3. Conclusions

Rüter (2017) showed that the sensitivity of half-lives on total GHG emissions and removals from HWP is probably small. At the same time an accurate initialisation of HWP pools is important. However, since the accounting of HWP is done against a reference level that is constructed with the same assumptions on initial stocks and initial half-lives, it can be assumed that implications of discrepancies between default values and actual rates balance each other out. Therefore, the overall size of emissions and removals being missed through accounting is probably small.

The fluxes between the "communicating vessels" of forest biomass carbon and HWP are not trivial due to delay effects. This causes potential inconsistencies between the pools. As both are accounted for against a forest reference level (FRL) that combines both pools, the implications of inconsistencies are probably limited. Moreover, for FRL, calculation inconsistencies are a trigger for technical correction (IPCC 2013). This means that MS must ensure consistency between the FRL and the GHG inventory used for accounting. This reduces the risk of unbalanced accounting further.

The LULUCF Regulation requires MS to apply a constant ratio between energy and material use to for the calculation of the FRL. This can be an additional incentive for countries to implement measures that increase the share for material use of harvested wood.

Nevertheless, the rather coarse representation of HWP in most GHG accounts of EU countries might lower incentives for mitigation measures involving HWP overall. This leaves scope for improving estimates for HWP by involving detailed country statistics. For example, the Eora global supply chain database[2] consists of a time series of multiregional input–output (MRIO) tables that have been used with the aim to improve HWP accounts (Zhang et al. 2020). However, the approach is limited by the data base that only provides historic data from 1992 onwards, thus ignoring the input of carbon to HWP before that year. Still, such independent databases can be used for consistency checks of national HWP accounts.

[2] www.worldmrio.com

2.3. Accuracy and visibility of forest management change reporting and accounting

Under the second commitment period of the Kyoto Protocol, a reference level accounting approach was adopted for forest management, and the LULUCF Regulation continued with such an approach by establishing the forest reference level (FRL) for accounting of managed forest land. It constitutes a counterfactual value of emissions and removals that would occur in managed forest land in the absence of any future change in management practices compared to the reference period of 2000-2009. The aim is to only account for the anthropogenic impact of changes induced by management practice and level out indirectly human-induced fluctuations of emissions and removals in forests (i.e. effects due to age class transition (Böttcher et al. 2008)).

The FRL includes all reported forest carbon pools (biomass, litter and soil) and the pool of harvested wood products. Accounting against such an FRL would give a country debits if an intensification of management decreases the sink compared to the reference level even though the forest is still a net sink of CO_2. Similarly, a country that reduces management intensity can claim net credits for a sink increase relative to the reference that might show a sink reduction compared to the past or even a switch to a net source. Accounting against the FRL aims at making management changes compared to the reference visible and therefore set incentives to relatively increase carbon stocks in forests and harvested wood products (Böttcher et al. 2008).

The LULUCF Regulation specifies in its Annex IV criteria and guidance for determining FRLs as well as elements for the National Forestry Accounting Plans (NFAPs) that document the FRL estimation (European Commission 2018). There are also guidelines that have been developed by contractors for the EC that provide data sets, methods and good practices to be followed voluntarily (Forsell et al. 2018). Nevertheless, MS have freedom in choosing methods for establishing their FRL. An assessment of the FRL submitted to the EC by MS in 2019 showed a large variety of approaches with different levels of complexity (ICF, Aether, IIASA 2019).

2.3.1. Challenges in emission accounting

The diversity of approaches for calculating FRLs causes potential inconsistencies between the FRL estimates. Moreover, a profound review is difficult and very much depends on how transparently MS present their approaches in their NFAPs (ICF, Aether, IIASA 2019). This diversity also applies to the way management systems were defined by MS and how the forest area has been stratified. While some countries apply detailed strata using geographic region, forest ownership, main function of forest and forest type (characterised by tree species, e.g. Sweden), others use rather broad categories for describing their forests by volume and age-classes, ignoring tree species groups and other possible criteria influencing management types (e.g. Germany). The forest strata form the basis for characterising forest management practices and types and their allocation to the forest area in the reference period 2000-2009 but also for the projection. Thus, they also determine what kind of management changes can be monitored.

In theory, the LULUCF Regulation requires FRLs to be methodologically consistent with the MS's GHG inventory (European Commission 2018). In practice, it turns out to be a challenge for MS to document this consistency, especially in cases where methods, such as stratification differ between GHG inventory and FRL estimation (ICF, Aether, IIASA 2019). But what are potential implication of inconsistencies for the accounting of emissions and removals from managed forests?

Assuming an extreme case where a country cuts a natural forest with high proportion of old trees and deadwood and reforests the area with fast growing tree species (e.g. pine, eucalyptus): The loss of carbon will show up in reported pools of living biomass, deadwood, soil (mineral, organic) and litter. However, if only coarse stratification of the forest is applied that does not discriminate between forest types or species, certain effects of changes in management, e.g. naturally generated forest with native species changed to planted forest with non-native species, might not be adequately represented.

Another challenge is that the carbon pools deadwood, litter and soil, which are also potentially sensitive towards forest management change are less frequently reported than living biomass. The omission of such pools might thus lead to emissions and removals caused by management changes not being accounted for.

2.3.2. Implications for incentives

Changes in carbon stocks in different pools at the stand level might be measurable but not visible at the national level due to coarse reporting methods. The effect depends on the type and magnitude of management changes and the area affected. **In general, it can be stated that a lower granularity of reporting on forest leads to lower incentives for MS regarding changes in forest management towards more carbon storage because effects might not become visible in their GHG inventories.** Moreover, management changes towards reducing carbon stocks in forests are not penalised if their effects fall below the level of detectability of the reporting system, which is higher for coarse reporting methods and application of default values.

The current reporting rules under the LULUCF Regulation are probably capable of detecting drastic changes in forest management compared to the reference period that are not driven by age-class transitions, e.g. changes in harvest age and intensification of forest thinning. Thus, the risk of undetected emissions and removals appears to be limited for reporting of forest biomass. For other forest carbon pools, the risk depends on the effect that management changes have on them. This depends again on the type of change and can result in both, higher and lower carbon stocks. For example, higher management intensity might lead to increased carbon stocks in dead biomass (harvest residues) and soil carbon. On the other hand, standing deadwood might be reduced with higher intensity, so that net effects might be small.

It has to be noted that reported carbon stock changes do not necessarily relate to other important environmental impacts like loss in biodiversity and changes in the landscape water balance that management changes might cause. However, this is a general shortcoming of the accounting rules focusing on carbon only.

2.3.3. Conclusions

The accuracy issues related to reporting and accounting of forest management changes discussed above can lead to weaker incentives for changing forest management practices. **If forest stratification for reporting is too coarse, certain management changes might not be visible in the GHG accounts.** Coarse representation of managed forests might thus allow for intensification of management below the level of detection by the GHG reporting system.

The current rules for accounting of managed forests leave room for MS to apply individual approaches. This is an important feature to reflect the different characteristics of the forestry sector but also data availability in MS. However, this causes potential issues of transparency, especially in cases where forest stratification is rather coarse.

2.4. Completeness of organic soils reporting and accounting

Organic soils develop on wetlands where the production of organic matter primarily from plant biomass in water saturated areas, exceeds decomposition. Typically, organic soils consist of about 12-

18 % of organic carbon depending on the clay content of the mineral fraction (Mokma 2005). Peat is a special type of organic soil, which has no standardised international definition of layer thickness or carbon content. Organic soils are the most efficient carbon sink in the world and store half of Europe's total soil organic carbon and about five times more carbon compared to forests in Europe (Swindles et al. 2019). If these soils are drained, oxygen enters, and microbes decompose the organic matter leading to substantial emissions of CO_2 and N_2O. The EU is the second largest emitter of GHG from drained peatlands in the world with about 220 Mt CO_2eq/year (Joosten 2009), which accounts for about 5 % of the EU reported GHG emissions (4,483 Mt CO_2eq/year[3]). Also, drained organic soils are responsible for about 55 % of emissions from agriculture in the EU (UBA 2019).

Reducing emissions from drained organic soils under different land uses has thus a significant potential with high emission reductions per hectare possible after rewetting (e.g. 28 CO_2eq per ha per year on cropland, Wilson et al. 2016), despite the fact that the potential area is relatively small. Compared to other options on mineral soils, these measures can have much higher costs. Therefore, incentives for implementation of mitigation measures need to be relatively high. An important game changer for such measures can be the fact that the LULUCF Regulation requires mandatory accounting of wetlands from 2026 onwards and MS will then be obliged to improve their estimates. However, countries still struggle with accuracy and completeness of reporting and accounting of organic soils that can be found in all land use categories. Also, the level of detail in which countries report on this category varies widely.

2.4.1. Challenges in emission accounting

One of the main obstacles is the correct estimation of the organic soil area under the different land use categories (activity data). According to a study by Barthelmes (2018) the differences in the areas reported by the MS compared to the areas estimated by the Global Peatland Database (GPD) are considerable and show that many countries underestimate their area of drained organic soils. The differences are especially high for Romania, the UK, Ireland, Estonia, Hungary and Austria. Barthelmes (2018) identified several problems in the accounting of the organic soil activity data:

It is challenging from a methodological point of view because so far organic soils cannot be identified directly by remote sensing methodologies. Also, automatic mapping approaches often extrapolate over large areas that may include different soil, vegetation and land use types and underestimate organic soil area. Some countries might have a different understanding of the "managed land use proxy" according to the IPCC, which assumes that all emissions and removals are anthropogenic on managed land. However, if a drained organic soil area is now under nature protection and no longer used for agricultural purposes, it still emits GHG which are not reported because it is not considered to be "managed" any longer. Also, MS might use land use data that exclude fallows and areas with ceased land use but still with active drainage. Additionally, geo-referenced profiles in organic soils are very scarce in several national and European databases creating a data bias, which can result in low modelled coverages of organic soils.

The IPCC 2013 Wetlands Supplement (IPCC 2014) provides guidelines for accounting the emissions from CO_2, CH_4 and N_2O for drained and rewetted organic soils but these emissions are often not reported for all land use categories in many GHG inventories (Barthelmes 2018). Only Denmark, Germany, Latvia and Sweden cover all relevant GHGs under forest land, grassland and cropland. Especially emission reports of CH_4 from drained land and ditches are often missing although the IPCC provides methodology and emission factors.

[3] Eurostat Greenhouse gas emission statistics https://ec.europa.eu/eurostat/statistics-explained/pdfscache/1180.pdf

When compared to different data sources such as the GPD, the emissions reported by the MS for drained peatlands can deviate quite considerably. For example, according to the GPD the total EU GHG emissions from drained peatlands in 2008 were about 220 Mt CO_2eq/year (Joosten 2009), which is more than twice as high compared to the emissions (105 Mt CO_2eq/year) reported in the EU inventory report 2020 for 2008.

Figure 2-1 shows original data from the GPD in 2008 (Joosten 2009) compared to the National Inventory Submissions to UNFCCC (NIS) of 2020 for the year 2008 of nine countries with high CO_2 emissions from drained peatlands. The main differences are that the MS report up to ten times lower total emissions in 2008, like Poland with 2.2 Mt/CO_2/year compared to Joosten (2009) with 23.5 Mt/CO_2/year.

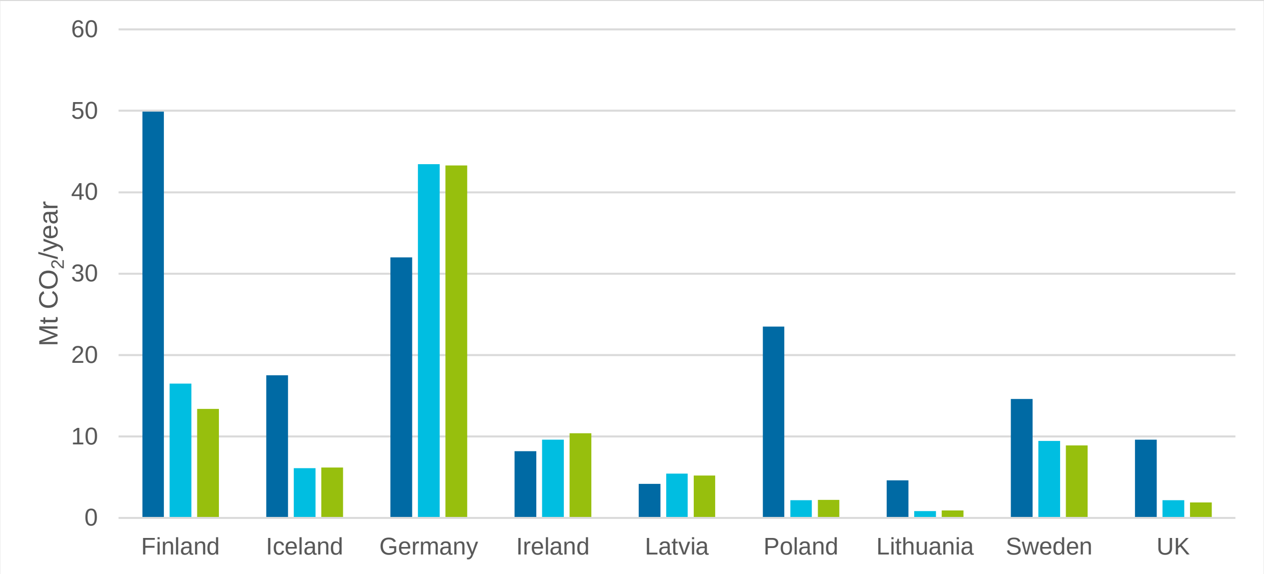


Figure 2-1: Comparison of emissions from degraded peatlands in 2008 provided by Joosten (2009) with emissions data of organic soils from the National Inventory Submission (NIS) 2020 for the years 2008 and 2018.

Table 2-1: Implied emissions factors calculated from area and emissions data from degraded peatlands from the GPD in 2008 compared to the implied emission factors calculated from the area and emissions data on organic soils from the National Inventory Submission (NIS) 2020 for the year 2008 and 2018.

Member State	**Implied Emission Factor 2008 degraded peatland** (t CO_2/ha/year, Joosten 2009)	**NIS 2020 Implied Emission Factor 2008** (t CO_2/ha/year)	**NIS 2020 Implied Emission Factor 2018** (t CO_2/ha/year)
Finland	7.9	1.3	1.1
Iceland	24.9	5.9	6.0
Germany	24.6	23.9	23.8
Ireland	21.9	4.8	5.1
Latvia	21.2	5.6	5.4
Poland	23.0	1.4	1.4
Lithuania	16.8	1.1	1.1
Sweden	11.2	0.8	0.8
UK	22.3	1.2	1.1

Source: Own calculation with original data from the sources indicated in the first row of table.

The implied emission factors calculated from the data available by Joosten (2009) are up to 20 times higher compared to NIS 2020 submissions for the year 2008 (Table 2-1). The implied emission factors for Poland, Lithuania and Sweden are below the range of the Tier 1 emission factors by the IPCC 2013 Wetlands Supplement (IPCC 2014) for drained grassland in the temperate region (3.1 to 6.1 t CO_2/ha/year) or cropland (7.9 t CO_2/ha/year) in the boreal and temperate region. The NIS data for 2018 do not show significant changes in the emissions and activity data reported since 2008, which still implies relatively low emissions from organic soils in most of the nine EU countries in Table 2-1

Some countries (Denmark, Ireland, Latvia, Sweden) developed separate key categories[4] to identify emissions from peatlands, which underlines their importance for GHG in the national LULUCF sector (Barthelmes 2018). Although in Germany GHG emissions from drained organic soils are 6.6 % of the total national GHG emissions in 2014 (Tiemeyer et al. 2020), they are not reported in separate key categories. Also Finland and Poland show high GHG emissions from drained organic soils but do not consider them separately (Barthelmes 2018).

In general, more research is needed on below ground carbon fluxes for different kinds of management activities on grassland and especially forests on drained organic soils to improve emission factors and accounting. For rewetted organic soils and new land use options, such as paludiculture, emission factors must still be developed. More knowledge is also needed on the emissions from dissolved organic and inorganic carbon as well as dissolved particulate carbon from managed peatlands. Studies indicate that managed peatlands lose a high proportion of carbon via fluvial transport, resulting into high CH_4 emissions from ditches and CO_2 emissions from adjacent waterbodies (Evans et al. 2016; Vermaat et al. 2011). The IPCC Wetlands Supplement (IPCC 2014) already started to address the problem by providing emission factors for CH_4 emissions in canals.

2.4.2. Implications for incentives

The review of the current reporting and accounting practice by MS especially shows deficits in data accuracy leading to the following implications:

- Incomplete data of organic soils can lead to significant underestimation of emissions from categories of managed cropland, grassland and forests that include organic soils.
- Inaccurate accounts of organic soils also reduce the mitigation potential for countries and thus lead to wrong priorities for implementing mitigation measures.
- Mitigation measures for organic soils are highly time critical as they lose more and more carbon and thus the mitigation potential gets reduced quickly over time without any means to compensate for the loss of potential at a later point in time.

2.4.3. Conclusions

Our review shows that large differences exist between national statistics and alternative sources of information regarding the extent of organic soils, their status and resulting emissions. Discrepancies between different emission estimates can be up to an order of magnitude of 10. In order to improve

[4] Key categories are identified in terms of their contribution to the absolute level of national emissions and removals and to the trend of emissions and removals. Key categories are those that, when summed together in descending order of magnitude, add up to 95% of the total level (IPCC 2006b)

estimates of emissions from organic soils there are several options for the European Commission and MS:

- **There is a need to further improve the quality of the activity data for organic soils.** The land use data should be spatially all-inclusive and comply with IPCC land use categories. It is important to include land that is not actively used, fallow or protected but has been or still is drained. All information available must be integrated to get a comprehensive national coverage of organic soils, e.g. LUCAS or Corine Landcover data, high resolution elevation data for water table estimates and data on drainage networks. Also, peatland surveys could be conducted like in Estonia (Barthelmes 2018).

- The most recent IPCC 2013 Wetlands Supplement (IPCC 2014) Tier 1 default emission factors should be applied that are based on a larger amount of literature. If new land use categories emerge like paludiculture it is also necessary to develop appropriate emission factors for them.

- **Country-specific, higher tier emission factors should be used if emissions from organic soils are key sources (contributing to cumulated 95 % of total national GHG emissions).** In general, the concept of key categories currently hides organic soils as emission sources within categories where removals from biomass occur.

- With mandatory accounting of managed wetlands there could be initial checks applied by the EC to national GHG inventories specifically for organic soils and wetlands. **Such checks should use independent information for assessing activity data and emission factors used by MS. This can form the basis for improving the quality and accuracy of wetland and organic soil reporting**. According to LULUCF Regulation Article 2(4), the EC reserves the right to propose postponing the mandatory accounting for managed wetland for an additional period of five years if the implementation of the reporting guidelines turns out to be too challenging for MS.

3. Overall conclusions

- With the European Climate Law the Commission proposes a legally binding target of net zero greenhouse gas emissions by 2050 and thereby establishes a framework not only for the reduction of greenhouse gas emissions but also for the enhancement of removals by natural or other sinks in the EU.
- This requires more than a critical review of completeness, accuracy and consistency of LULUCF reporting and accounting. It demands that rules be designed to really set incentives for land management improvement.
- We have identified potential issues of completeness, consistency and accuracy in current reporting and accounting rules and procedures for EU MS and their implications for incentives to change land management within the EU.
- Countries are more likely to increase their ambition level in LULUCF if there is a closer connection between concrete management practices, co-benefits of other policy targets (e.g. area of organic farming, hectares of ecosystems restored) and GHG inventories.
- In general, coarse reporting approaches tend to make the effects of land management changes on carbon stocks less visible and therefore disincentivise MS to take action. This holds for all examples that were discussed: cropland, harvested wood products, managed forests and organic soils.
- Most issues of accuracy and completeness identified can be overcome by an increased level of detail and improved data sources applied for reporting. However, such improvements do not always benefit MS, because they involve higher costs for monitoring.
- Improved estimates for GHG emissions and removals might indirectly increase the ambition level already by making hidden emission visible. Eventually they are essential for an effective planning and implementation of mitigation measures that can reduce costs for MS in the long run.

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