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Reporting greenhouse gas emissions from organic soils in the European Union: **challenges and opportunities**

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Introduction

Both in the European Union (EU) and on a worldwide scale drained organic soils (incl. peatlands) contribute substantially to anthropogenic greenhouse gas (GHG) emissions. Reducing these emissions is the most space- and cost-effective climate change mitigation option within the land use and agricultural sectors. Crucial for monitoring mitigation progress is the comprehensive reporting of emissions.

This policy brief explains the importance of greenhouse gas emissions from organic soils, describes recent policy frameworks, discusses weaknesses in the National Inventory Submissions of EU countries, and provides recommendations to improve reporting.

Greenhouse gas emissions from organic soils

Compared to other soils, organic soils contain disproportionally much carbon: peatlands in the boreal zone hold in average seven times, in the tropics even 10 times more carbon per hectare than ecosystems on mineral soil (Parish et al. 2008). Organic soils have formed under permanently waterlogged conditions, which prevent the complete decomposition of dead biomass resulting in the accumulation of carbon rich soil organic matter. This organic matter is rapidly decomposed when the soil is no longer water-saturated. In this way, drainage causes huge GHG emissions.

Some 15% (650,000 km²) of the organic soils worldwide have been drained, mainly for cropland, grazing land, and forestry. This 0.4% of the global land area is responsible for some 5% of all global anthropogenic GHG emissions. The European Union is, after Indonesia, the second largest emitter of greenhouse gases from drained organic soils worldwide (cf. Figure 1).

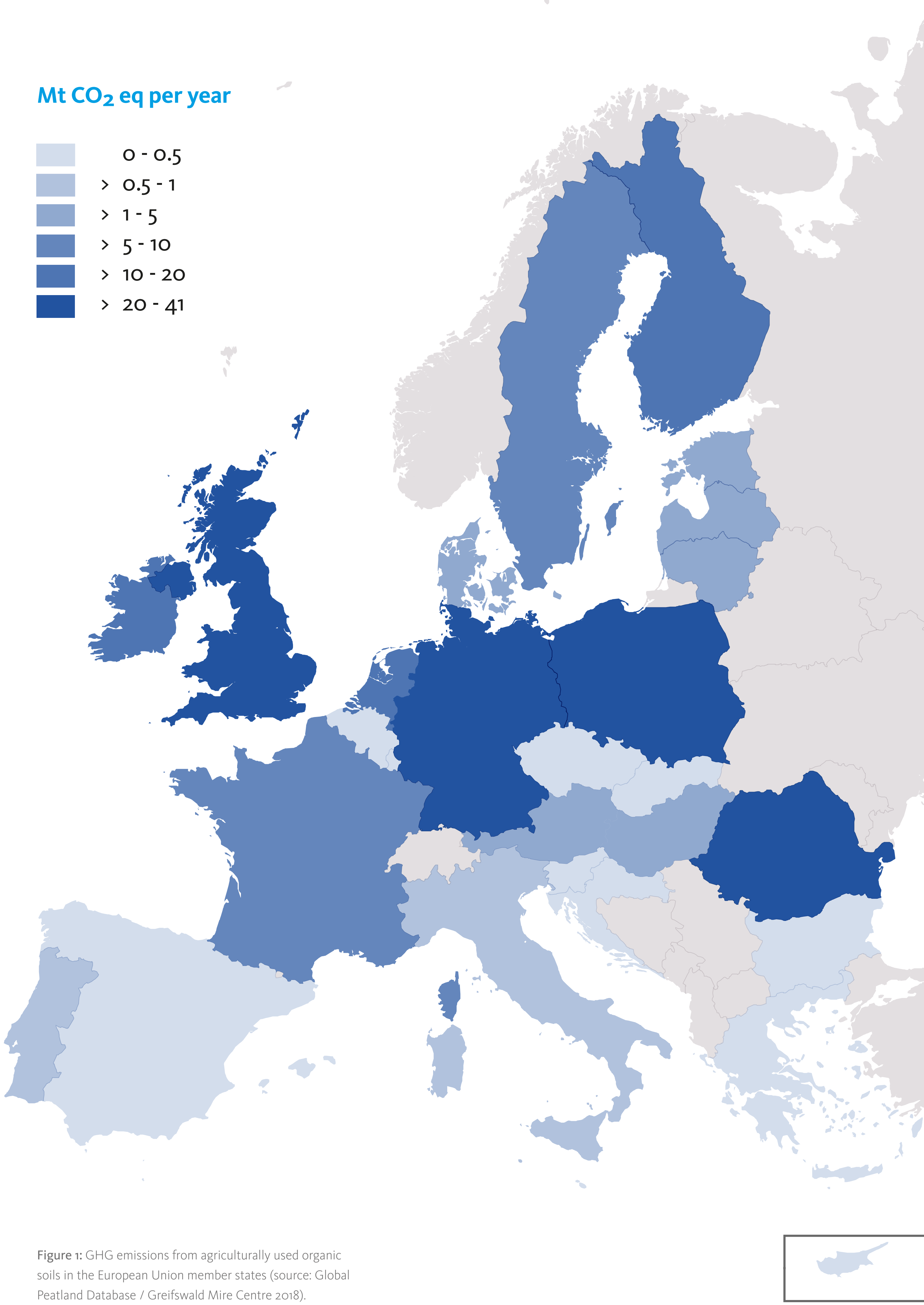


Figure 1: GHG emissions from agriculturally used organic soils in the European Union member states (source: Global Peatland Database / Greifswald Mire Centre 2018).

Fortunately, the emissions from drained organic soils can rather easily be reduced and even stopped. If the water table is restored to pre-drainage levels, emissions will become similar to pristine conditions again (IPCC 2014a). Only during the first years after rewetting, methane (CH_4) emissions on nutrient rich sites may be higher than those from pristine sites.
The immediate benefit of rewetting is that net GHG emissions (expressed as Global Warming Potential, GWP) are significantly lower than in the drained situation before rewetting (Table 1).

Table 1: Indicative emission reductions (in tCO_2-e ha^{-1} yr^{-1}) resulting from rewetting of drained organic soils with various initial land use types. Based on Wilson et al. (2016).

Land use category	Emission reduction after rewetting (t CO_2eq ha^{-1} yr^{-1})	
	Temperate zone	*Boreal zone*
Forest land	6	2
Cropland	28	34
Grassland	20	25
Wetlands (Peat extraction)	9	11

Rewetting of agricultural organic soils used to be associated with abandonment and loss of productive land. The new strategy of 'paludiculture' combines emission reduction by rewetting with continued productive land use, by cultivating wetness-adapted crops like reed, cattail, reed canary grass, alder, or peatmoss (Wichtmann et al. 2016).

Recent policy frameworks

In its recent report, IPCC (2018) shows that the Paris Agreement aim of limiting global warming to 1.5°C requires global anthropogenic CO_2 emissions to reach net zero around 2050. For limiting global warming to below 2°C, CO_2 emissions should reach net zero around 2075. Non-CO_2 emissions should in both cases decrease by 35% or more by 2030 relative to 2010 levels.
The European Union 2030 Climate and Energy Policy Framework targets at least 40% GHG emission reduction in 2030 compared to 1990 levels and integrates for the first time the land use sector (LULUCF)[1]. Accounting for Forest Management and Afforestation, Reforestation, Deforestation is already mandatory under UNFCCC rules, whereas accounting for cropland and managed grassland will become mandatory for all EU Member States from 2021 onwards[2]. Accounting for managed wetland will become mandatory in the EU in 2026. The 2018 LULUCF Decision[3] includes a 'no-debit rule', implying that LULUCF in total should not become a GHG source. The EU decision also prescribes the use of the most recently adopted IPCC reporting guidelines including the IPCC 2013 Wetlands Supplement concerning organic soils.

1 European Council (23 and 24 October 2014) Conclusions; EUCO 169/14

2 Decision No 529/2013/EU – Accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities

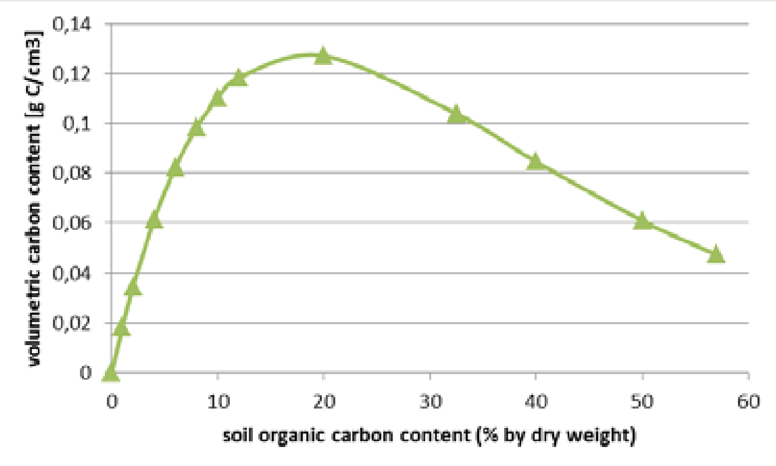
3 Regulation (EU) 2018/841 - Inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU

Organic soils and peatlands

IPCC (2006, 2014a) defines 'organic soil' as a soil with (dependent on the clay content) at least 12-18% (by weight) of organic carbon. In contrast to the underlying FAO definition, IPCC delineates no minimum thickness of the organic layer to allow countries to use their often historically determined, country-specific definitions.

A special type of organic soils is found in peatlands. Peatlands are areas with a thick layer of peat (dead, locally produced plant material) at the surface. The necessary thickness of the peat layer and the organic matter content of the peat are internationally not standardized and there are no IPCC definitions of peat and peatland.

In soil science organic and mineral soils are distinguished on the basis of the dry weight percentage of organic carbon (g C per g soil x 100). The boundary of 12-18% is not very appropriate from a climate point of view, however, because the percentage reveals little about the carbon density (g/cm^3), i.e. the amount of soil carbon that upon drainage is exposed to oxygen and that can thus be emitted as CO_2. Pure peat has a high percentage (57%) of carbon, but low overall weight; a mineral soil weights much more and with 5% of carbon can have just as much carbon per volume (see Figure below). After drainage both soils emit the same amount of CO_2. From a climate point of view, the boundary between organic and mineral soils could thus better be drawn at 5% C. The problem of low percentage - high density carbon soils has within the EU already been recognized by Germany, Denmark and Ireland (who report on emissions from 'peaty soils'), but needs more attention.



Volumetric carbon content vs. carbon by weight (%) in soils, based on Ruehlmann & Körschens (2009)

Weaknesses in the 2017 National Inventory Submissions

Emissions from organic soils are underexposed in the National Inventory Submissions (NIS) of European Union countries. General obstacles for transparent and meaningful reporting are the undifferentiated presentation of the total land use sector, in which organic soil sources are obscured by forest biomass sinks, and the split reporting of agricultural emissions over the two sectors Agriculture and LULUCF. These presentations conceal the fact that CO_2 emissions from organic soils, i.e. from a minor proportion of agricultural land, are of the same size as CH_4 emissions from all animal husbandry and N_2O emissions from all fertilization.

Emissions from drained organic soils are among the largest GHG sources from the LULUCF sector in many European countries and thus key categories for GHG reporting (cf. IPCC 2006). Nevertheless, organic soils are often insufficiently reported (Barthelmes et al. 2015, Houghton et al. 2012, Tubiello et al. 2015). Deficiencies relate to insufficient awareness, incomplete activity data and inappropriate and poor quality emission factors.

Insufficient awareness

IPCC (2014a, b) provides guidance for reporting and accounting emissions from drained and rewetted organic soils. Most EU countries indeed report these emissions, but often only fragmentarily (Figure 2).

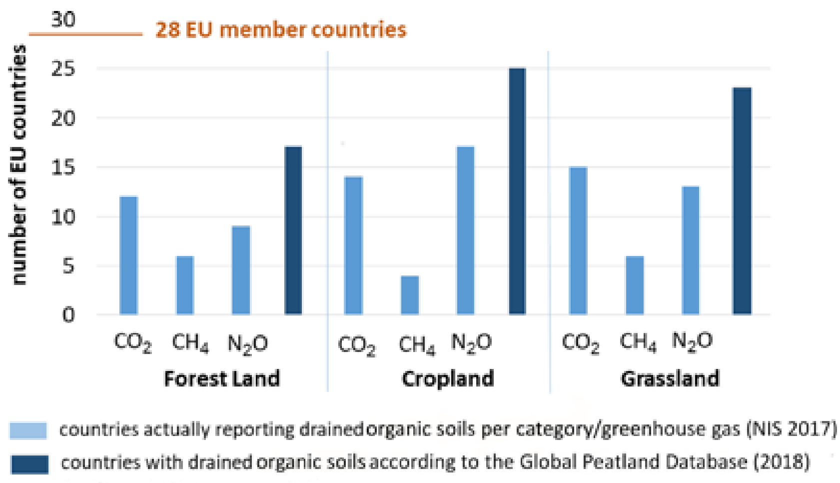


Figure 2: Number of EU countries that report emissions of CO_2, CH_4 and N_2O from drained organic soils under forest land, cropland and grassland in their 2017 NIS (light blue bars) and number of countries that use drained peatlands as forest-, crop- and grassland according to the Global Peatland Database/ Greifswald Mire Centre (2018, dark blue bars)

Only Denmark, Germany, Latvia and Sweden cover all relevant gases under forest land, cropland and grassland (Table 2). Many EU countries do report CO_2 emissions from cropland and grassland under the sector LULUCF and N_2O under the sector Agriculture (Figure 2). For various European countries, however, the activity data for the same land use categories differ between these sectors.

Only rarely countries report CH_4 emissions from drained land and drainage ditches (Table 2), although methodology and emission factors are available in IPCC (2014a, b), which actually prescribes these emissions to be mandatorily reported under the sector Agriculture.

Table 2: National Reporting of EU countries to the UNFCCC (National Inventory Submission 2017). T1 = tier 1 from IPCC guidance (year), CS = country specific, empty cells = no emissions reported

Country	NATIONAL INVENTORY SUBMISSION								
	Forest Land			Cropland			Grassland		
	CO_2	CH_4 land / ditch	N_2O	CO_2	CH_4 land / ditch	N_2O	CO_2	CH_4 land / ditch	N_2O
Austria							T1 (2014)	T1 (2014)	T1 (2014)
Belgium				T1 (2003)		T1 (2006)	T1 (2003)		T1 (2006)
Bulgaria									
Croatia				T1 (2003)		T1 (2006)	T1 (2003)		T1 (2006)
Cyprus									
Czech Republic									
Denmark	T1 (2014)	T1 (2014)	T1 (2014)	CS	T1 (2014)	CS	CS	T1 (2014)	CS
Estonia	CS			T1 (2006)		T1 (2006)	CS		
Finland	CS	CS/ T1 (2014)	CS	T1 (2014)		T1 (2014)	CS		CS
France						T1 (2006)			T1 (2006)
Germany	CS	CS/ T1 (2014)	CS	CS	CS/ T1 (2014)	CS	CS	CS/T1 (2014)	CS
Greece				T1 (2006)		T1 (2006)			
Hungary	T1 (2006)								
Ireland	CS	T1 (2014)	CS/ T1 (2014)				T1 (2014)	T1 (2014)	T1 (2014)
Italy				T1 (2006)		T1 (2006)	T1 (2014)		T1 (2006)
Latvia	T1 (2014)	T1 (2014)	T1 (2014)	T1 (2014)	T1 (2014)	T1 (2014)	T1 (2014)	T1 (2014)	T1 (2014)
Lithuania	T1 (2006)		T1 (2006)	T1 (2006)		T1 (2006)	T1 (2006)		T1 (2006)
Luxembourg									
Malta	no organic soils								
Netherlands				CS		CS	CS		CS
Poland	T1 (2006)			T1 (2006)		T1 (2006)	T1 (2006)		T1 (2006)
Portugal									
Romania	T1 (2006)		T1 (2006)			T1 (2006)			T1 (2006)
Slovakia									
Slovenia				T1 (2006)		T1 (2006)			
Spain									
Sweden	T1 (2014)	T1 (2014)	T1 (2014)	CS	T1 (2014)	T1 (2014)	T1 (2014)	CS	T1 (2014)
United Kingdom	T1 (2006)		T1 (2006)	T1 (2006)		T1 (2006)	T1 (2006)		T1 (2006)

Incomplete activity data

Comparison of activity data (i.e. the area of land use types) as reported by EU countries with data from the Global Peatland Database (GPD) shows that countries generally underestimate the area of drained organic soils (Figure 3). The difference between national reporting and the GPD is considerable for Estonia, Romania, Ireland, the UK, Austria and Hungary. For Ireland and the UK, the domestically used peatlands may partly not be included in the NIS. Despite their low emissions per area, the total emissions may be considerable because of the huge area they cover.

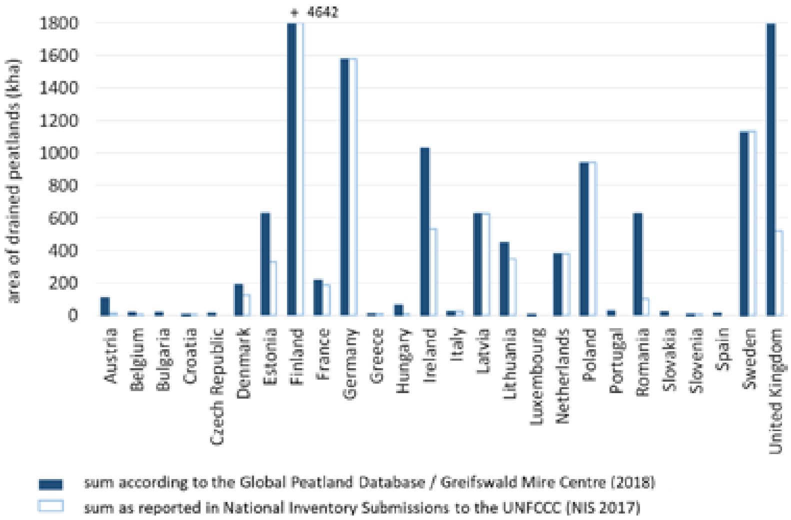


Figure 3: Comparison of area ('activity') data of the land use categories forest land, cropland and grassland in the 2017 NIS and in the Global Peatland Database 2018.

Romania fails to report drained organic soils along the Danube River and in the Danube delta (cf. Florea et al. 1963-1993; NIS Romania 2017). France reports N_2O emissions from major areas with 'Cultivation of Histosols' under the sector Agriculture, but – inconsistently – fails to report the corresponding CO_2 emissions in the LULUCF sector (and the associated CH_4 emissions from the ditches under Agriculture), where these are reported to be 'not occurring' or 'not estimated' (NIS France 2017).

Hungary claims to have no cultivated organic soils, except for a small area of forest land (NIS Hungary 2017). The new national soil map of Hungary (Pásztora et al. 2018), however, shows more than 72,000 ha of 'peat soil' and approximately 67,000 ha of 'peaty meadow soils', which are largely drained and used for forestry or agriculture. The incomplete reporting in the 2017 NIS of Hungary might be caused by a different understanding of 'managed land'.

The IPCC 'managed land proxy' assumes all emissions and removals occurring on managed land to be anthropogenic. Managed land is "land where human interventions and practices have been applied to perform production, ecological or social functions" (IPCC 2006). All drained and rewetted organic soils thus fall under managed land and all emissions and removals from these lands should be reported accordingly.

Causes of wrong activity data

- Wrong application of the 'managed land proxy', e.g. when organic soils formerly used for agriculture are given a nature conservation status and are no longer considered to be 'managed' (independent of whether they remain drained or not)
- Application of land use data, that exclude fallows and areas with ceased land use but still with active drainage
- The scarcity of geo-referenced profiles in organic soils in several national and European databases – the use of these biased input data for modelling will result in low coverage of organic soils
- The inability to capture organic soil occurrence directly via remote sensing (so far)
- Automatic mapping approaches that extrapolate over large areas that may include different soil, vegetation and land use types

Inappropriate and poor quality emission factors

Approximately half of the emission factors applied by EU countries for CO_2 from forest land, cropland and grassland are the default (tier 1) emission factors from the latest (2014) IPCC guidance, or are country-specific higher tier emission factors (Figure 4). More than one third of the applied emission factors for CO_2 are taken from IPCC (2006), whereas some are still used from IPCC (2003), although it is *good practice* to use the most recent guidelines (i.e. IPCC 2014). The use of emission factors from different IPCC guidelines leads to considerable differences in the reported emissions. Furthermore, the use of tier 1 emission factors should acknowledge the IPCC climate stratification in which e.g. considerable parts of Scandinavia and the entire Baltic states are located in the cool temperate, not in the boreal zone.

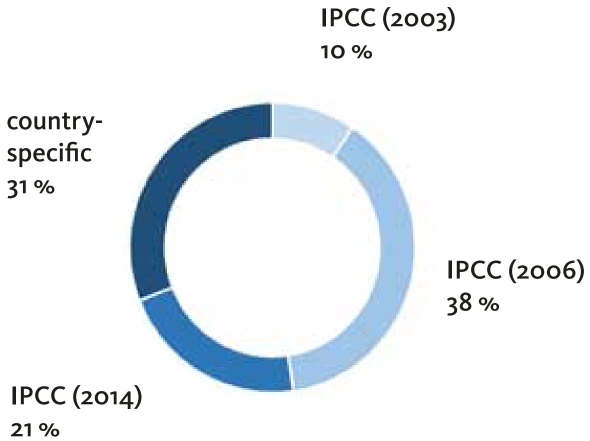


Figure 4: Source of the individual emission factors for CO_2 used in the NIS (2017) of the EU countries (N=42).

Table 3: EU-countries that treat drained peatlands as key categories in the LULUCF sector in their 2017 National Inventory Submissions and the emission factor approach they use for reporting. CS = country-specific. NO = not occurring according to national reporting.

Country	CO_2			CH_4 (land and ditch)			N_2O
	Forest Land	Cropland	Grassland	Forest Land	Cropland	Grassland	Forest Land
Denmark	IPCC 2014	CS	CS	IPCC 2014	IPCC 2014	IPCC 2014	IPCC 2014
Ireland	IPCC 2014	NO	IPCC 2006	IPCC 2014 CS	NO	IPCC 2014	IPCC 2014
Latvia	IPCC 2014 CS	IPCC 2014	IPCC 2014	IPCC 2014	IPCC 2014	IPCC 2014	IPCC 2014
Sweden	IPCC 2014	CS	IPCC 2014	IPCC 2014	IPCC 2014	IPCC 2014	IPCC 2014

Denmark, Ireland, Latvia, and Sweden identify emissions from peatlands as separate key categories, but country-specific emission factors and methodology (tier 2 or 3) are rarely applied (Table 3). Considering the thorough review of available emission measurements provided by IPCC (2014a), the use of IPCC (2014a) default values is not problematic, however. For several other countries, emissions from drained peatlands contribute significantly to key categories in LULUCF (e.g. for Finland, Germany and Poland) but are not considered as separate key categories.
More attention should also be paid to grasslands, as these have a very different management practices in Eastern and Western Europe, which may strongly affects emissions.

In general emissions from forested sites are difficult to assess, because hardly any comprehensive scientific data are available to calibrate proxy approaches and the emission factor will vary strongly over the harvest cycle. The emission factors used will, however, have large consequences for the 'no-debit' approach and for concepts of renewability and climate neutrality of forest resources. Emission factors will also have to be developed for the land use options for rewetted peatlands (paludicultures).

Emissions from drained forests in Finland

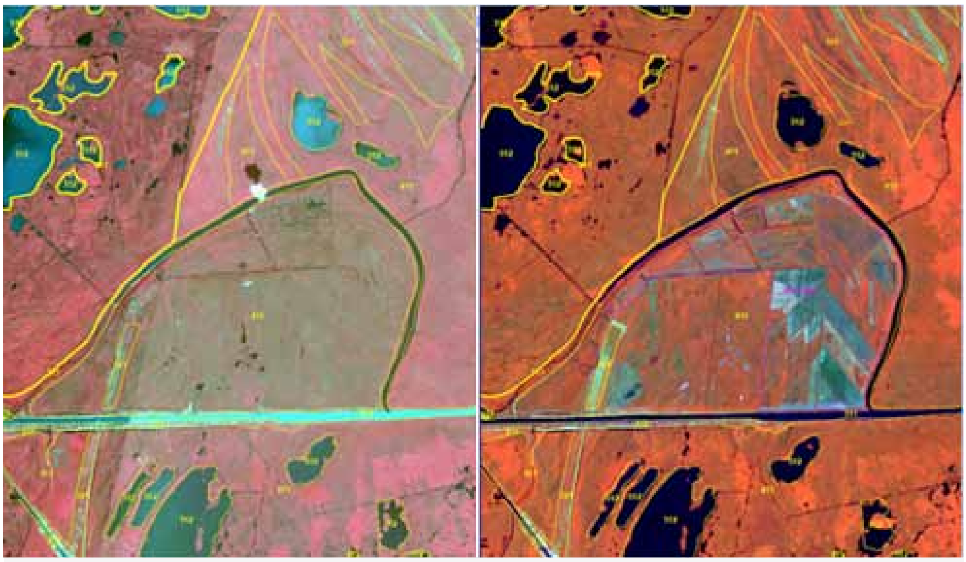
The carbon balance of boreal peatlands is of major interest in Finland, where more than half of the peatlands (originally 104,000 km^2) have been drained during the 20th century, mainly for forestry.
Recent studies indicate that the soils of drained nutrient poor sites act as a carbon sink and those of nutrient rich sites as a carbon source (Ojanen et al. 2013, 2014). However, the large carbon stock change dataset of Simola

et al. (2012) indicates an average loss of 150 g C m^{-2} $year^{-1}$ from Finnish peatland soils. Other factors impacting carbon balance include groundwater level, temperature and forest coverage. Moreover, the sequestration of carbon into plant biomass plays an important role in the total carbon balance after drainage. Recent research has shown large emissions after clearcutting (Korkiakoski et al. 2018). A better understanding of below-ground carbon fluxes is needed and in view of recent research, a reassessment of the national LULUCF accounting is called for.

Drained nutrient poor peatlands (left) may act as small C sinks and drained nutrient rich peatlands (right) as large sources

Recommendations for better national reporting of emissions from organic soils

- Take into account the relevant decisions of the UNFCCC, the European Parliament, and the European Commission
- Strive for best possible activity (area) data that comply with IPCC land use categories, preferably in a spatial ('wall-to-wall') approach:
  - Collate and integrate all available information to get a nationwide, comprehensive coverage of organic soils. Use proxy sources (e.g. LUCAS or Corine land cover data, high resolution elevation data, data on drainage networks) to identify possible occurrences of organic soils
  - Conduct peatland surveys as has been done e.g. in Estonia (cf. Paal & Leibak 2011)
  - Also include land that is fallow, protected or otherwise not actively used, certainly when it is or has been drained
- Use IPCC (2014) tier 1 default emission factors as a minimum
- Perform key category analysis to identify whether managed organic soils are key emission sources in Agriculture and LULUCF
- Use country-specific, higher tier emission factors if emissions from organic soils are key sources
- Develop appropriate emission factors when developing and implementing new land use options on rewetted organic soils ('paludiculture').



Example of change from 'Inland marshes' (411) to 'Non-irrigated agricultural land' (211) between 2012 and 2017 covering 2027.8 ha in the Danube Delta (Romania).

Using Corine Land Cover for addressing land cover on organic soils

The Corine Land Cover (CLC)[4] inventory project of the European Environment Agency (EEA) covers 39 European countries and monitors land cover changes in a six year cycle. The minimum mapping unit is 25 hectares for land cover and 5 hectares for land cover changes. The main categories (artificial surfaces, agricultural areas, forests and semi-natural areas, wetlands, and water bodies) are subdivided in 44 land cover classes, of which 13 classes may include organic soils. The recent 'CLC2018' products (Büttner & Kosztra 2017) indicate for example for Romania a change of 9,898 ha of 'Inland marshes' to other classes since 2012.

The CLC dataset also comprises a high-resolution wetlands layer at 20m x 20m spatial resolution[5] that uses the reference years 2006, 2009, and 2012 for detecting the permanent presence of wetlands, i.e. areas where water is the primary factor controlling the environment and the associated plant and animal life. These include wetlands associated to permanent water bodies, wetlands not associated to permanent water bodies, wetlands with vegetation (macrophyte) cover or without vegetation, peatlands (with surface water) and coastal wetlands (salt marshes, salines, intertidal flats).

4 *https://land.copernicus.eu/pan-european/corine-land-cover*

5 *https://land.copernicus.eu/sandbox/high-resolution-layers*

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The opinions put forward in this policy brief are the sole responsibility of the authors and do not necessarily reflect the views of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

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Rewetting & Paludiculture:
Rewetted peatlands
Processing of reed for thatch
Peatmoss cultivation
Summer harvest of cattail