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Assessing the role of artificially drained agricultural land for climate change mitigation in Ireland

Carsten Paul[a,b,*], Réamonn Fealy[c], Owen Fenton[a], Gary Lanigan[a], Lilian O'Sullivan[a], Rogier P.O. Schulte[a,d]

[a] Teagasc, Crops, Environment and Land Use Programme, Johnstown Castle, Wexford, Ireland
[b] Leibniz Centre for Agricultural Landscape Research (ZALF), Muencheberg, Germany
[c] Teagasc, Rural Economy and Development Programme, Ashtown, Dublin, Ireland
[d] Wageningen University and Research, Wageningen, Netherlands

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ABSTRACT

In 2014 temperate zone emission factor revisions were published in the IPCC Wetlands Supplement. Default values for direct CO_2 emissions of artificially drained organic soils were increased by a factor of 1.6 for cropland sites and by factors ranging from 14 to 24 for grassland sites. This highlights the role of drained organic soils as emission hotspots and makes their rewetting more attractive as climate change mitigation measures. Drainage emissions of humic soils are lower on a per hectare basis and not covered by IPCC default values. However, drainage of great areas can turn them into nationally relevant emission sources. National policy making that recognizes the importance of preserving organic and humic soils' carbon stock requires data that is not readily available. Taking Ireland as a case study, this article demonstrates how a dataset of policy relevant information can be generated. Total area of histic and humic soils drained for agriculture, resulting greenhouse gas emissions and climate change mitigation potential were assessed. For emissions from histic soils, calculations were based on IPCC emission factors, for humic soils, a modified version of the ECOSSE model was used. Results indicated 370,000 ha of histic and 426,000 ha of humic soils under drained agricultural land use in Ireland (8% and 9% of total farmed area). Calculated annual drainage emissions were 8.7 Tg CO_2e from histic and 1.8 Tg CO_2e from humic soils (equal to 56% of Ireland's agricultural emissions in 2014, excluding emissions from land use). If half the area of drained histic soils was rewetted, annual saving would amount to 3.2 Tg CO_2e. If on half of the deep drained, nutrient rich grasslands drainage spacing was decreased to control the average water table at −25 cm or higher, annual savings would amount to 0.4 Tg CO_2e.

1. Introduction

The amount of organic carbon (OC) stored in soils up to a depth of 100 cm is considered to be nearly three times as large as the amount stored in aboveground biomass and twice the amount present in the atmosphere (Ciais et al., 2013). Success or failure at a global level to maintain or increase this stock will be decisive for mitigating climate change. In this respect, peatland soils play a pivotal role, covering only 3% of the global land area but estimated to contain between 20% and 25% of global soil organic carbon (SOC) (Smith et al., 2014). In intact peatlands, wet soil conditions impede aerobic biomass decomposition. Production is higher than decomposition and carbon is sequestered. The climatic effect depends on the timeframe applied: while over millennia peatlands have exerted a global cooling effect by removing long lived carbon dioxide (CO_2) from the atmosphere, under the 100-year timeframe used in international climate negotiations the emissions of short lived methane (CH_4) balance the carbon sequestration and result in a neutral or small global warming effect (Frolking and Roulet, 2007; Dise, 2009; IPCC, 2014). Therefore, the importance of peatlands for climate change mitigation is not in their potential for active carbon sequestration but relates to protecting their existing carbon stock. However, where peat soils are used for agriculture, artificial drainage facilitates cultivation and increases carrying capacity and yield. At the same time, increased aeration of the topsoil results in rapid decomposition of the organic stock and strongly increases emissions of CO_2 and nitrous oxide (N_2O). Like CO_2, N_2O is a long lived greenhouse gas (GHG). After carbon dioxide and methane it is the third most important gas contributing to global warming (Hartmann et al., 2013). Emissions of CO_2 and N_2O continue as long as soils remain in a drained state and elevated levels of OC persist (IPCC, 2014). These emissions are

* Corresponding author at: Leibniz Centre for Agricultural Landscape Research (ZALF), Muencheberg, Germany.
E-mail address: carsten.paul@zalf.de (C. Paul).

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influenced by multiple management-, soil- and climatic factors like drainage depth, fertilization regime, mechanical stress, soil organic matter, redox potential, water filled pore space, pH or temperature (Coyne, 2008; Maljanen et al., 2010).

While the underlying processes are still not fully understood, emission levels of drained peatlands are of global relevance. Excluding emissions from South-East Asia, Joosten and Couwenberg (2008) calculated annual CO_2 emissions from agricultural peatland drainage at 900 million tons. Europe is considered to contribute more than a third to global emissions from agricultural peatland use (FAOSTAT, 2015).

While peat soils are the most prominent representatives, increased greenhouse gas emission following artificial drainage are also typical for other wet, carbon rich soils. In the definition of the Irish Soil Information System (SIS) used in this study, peat soils possess an organic layer with at least 20% OC and a minimum thickness of 40 cm. For histic soils, the minimum thickness is only 7.5 cm. In humic soils, minimum thickness is 7.5 cm and OC content is lower, but at least 3.5–6.0% (depending on the clay content) (Creamer et al., 2014). This study uses carbon rich soils as a collective term for both histic and humic soils. Drainage emissions are mostly unaffected by organic layer thickness above a critical value. For this reason, the IPCC uses the definition of organic soils where the thickness is 10 cm or higher and the minimum OC 12–18% (depending on clay content) (IPCC, 2014). On the other hand, the lower carbon content in humic soils clearly affects drainage emission intensities and results in much lower per hectare emissions of those soils.

Revised figures published in the IPCC Wetlands Supplement (2014) imply that CO_2 drainage emissions from organic soils in the temperate zone had been severely underestimated. Default values for direct CO_2 emissions from drained cropland sites were increased by a factor of 1.6 and for different grassland types by factors ranging from 14 to 24 (IPCC 2006, 2014). Considering all relevant emission pools, this increases the default annual emissions for cropland sites from 22.1 to 37.6 Mg $CO_2e\ ha^{-1}$ and for grassland sites from 4.7 to between 16.7 and 29.2 Mg $CO_2e\ ha^{-1}$.

Recent years have seen a strong increase in awareness amongst policy makers of the role that organic soils' carbon stocks plays for climate change mitigation. *Wetland drainage and rewetting (WDR)* was adopted as an optional accounting category during the second period of the Kyoto Protocol (2013–2020) (UNFCCC, 2011), allowing parties to obtain carbon credits for rewetting drained organic soils and reducing emissions. Even where this option is not chosen, rewetting is accounted for if it occurs under forests as a result of the mandatory forest management category (FM) or, where parties have elected to account for cropland management (CM) or grazing land management (GLM), if it occurs under the respective land uses. Accounting rules are designed to make electing to account for the land use sector attractive: electing to include additional emission categories does not result in tougher mitigation targets, even though with higher emissions in the reference year the relative emission reduction in percent will be lower. Furthermore, for WDR, CM and GLM net–net accounting is used, i.e. emissions in the year 1990 are subtracted from emissions in the current accounting year. Where emissions have remained constant, the budget is unaffected while emission decreases generate carbon credits.

At European climate policy level, changes in carbon stock of non-forest soils are currently not accounted for and rewetting of these soils cannot contribute to meeting Member States' obligations under the European Effort Sharing Decision (ESD). However, in 2014 the European Council announced that a new policy for including the land use sector into the Union's climate and energy policy framework would be finalized before 2020 (European Council, 2014). The new regulation will form the basis for including the land use sector into the European Union's intended nationally determined contribution (INDC) under the Paris Agreement. In 2016, the European Commission presented a legislative proposal intended to come into force in 2021(European Commission, 2016a). It aims to make accounting for cropland management and grassland management mandatory which includes accounting for drainage and rewetting on agricultural land. Accounting for managed wetlands can be elected as an additional accounting category. Analogous to regulations under the Kyoto Protocol, net–net accounting is to be used with the average annual emissions of the years 2005–2007 as reference amount. According to a second proposal for "binding annual greenhouse gas emission reductions by Member States", a limited amount of carbon credits from the land use sector can be used to fulfil targets. (European Commission, 2016b). Rewetting of artificially drained organic soils may become an interesting mitigation measure, made even more attractive by the revised IPCC emission factors. The now increased difference in default emissions between drained and rewetted soils translates into an increase in carbon credits for rewetting.

This analysis builds upon the conceptual framework of Functional Land Management (FLM) defined by Schulte et al. (2014). FLM seeks to utilize land in a way that makes best use of its unique capabilities to deliver ecosystem services (MEA, 2005) in order to satisfy demand for these services at various geographical scales. The delivery of soil functions is determined by soil type and its complex interactions with land use. Under FLM, management of carbon rich soils must consider the high potential of these soils for providing climate regulating services through carbon storage. In order to assess this policy option, information on distribution of carbon rich soils, their land use, associated emissions and effects of drainage on economic performance are required. Usually, this data is not readily available and especially data on privately run drainage schemes is incomplete in many countries. Using the Republic of Ireland (Ireland) where agricultural drainage works are generally managed by land owners themselves and where registration of drainage schemes is not required as a case study, this article demonstrates how a dataset of policy relevant information for the management of this land resource can be created under conditions of limited data availability.

1.1. Objectives

The objectives of this study were to:

1) Assess the area of histic and humic soils artificially drained for agriculture in Ireland.
2) Assess drainage related GHG emissions from soils identified in 1) and analyse the contribution of different soil/land use combinations to total drainage emissions.
3) Calculate climate change mitigation potential of rewetting histic soils identified in 1) and assess associated income losses for pasture based beef farms.

2. Material & methods

2.1. Case study area

This study focuses on Ireland, and specifically on *cropland*, *managed grassland* and *other pasture* areas on poorly draining, carbon rich soils.

Agriculture plays an important role in Ireland, for both the country's economy and for its GHG emissions. Production is focussed on milk and beef for export, benefitting from low input-costs by using grass based feeding systems (Breen et al., 2010; Schulte and Donnellan, 2012). Of about 4.5 million hectares farmed, 81% is used for grass based production and 11% for rough grazing (DAFM, 2017). Bovines remain in the field for the major part of the year and milk production is aligned to the seasonality of the grass growth cycle (IFA, 2015). High rainfall rates combined with mild seasonal temperatures throughout the year allow for high levels of grass growth and make farmers largely independent from feed imports (Donnellan et al., 2011). However, where soils are poorly draining, high soil moisture rates cause problems for farmers, as they reduce both the length of the grass growing season through