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The potential of responsible peatland management to reduce global soil carbon loss and greenhouse gas emissions

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Abstract

Peatlands represent the largest single global store of soil carbon. Despite providing a natural long-term CO_2 sink, drainage and conversion to agricultural and silivicultural management of peatlands has converted them into large net contributors to global greenhouse gas (GHG) emissions (~2.5% of all anthropogenic emissions, primarily from Europe and SE Asia). Drainage-based agriculture on peatlands is intrinsically unsustainable, causing oxidative loss of soil organic matter and land-subsidence, which ultimately reduce or negate their value for agriculture. Returning all drained peatlands to their natural wetland function could make a substantial contribution to reducing global GHG emissions, but socio-economic factors – namely the high realisable income from drained agricultural peatlands, intensifying demand for land in regions with growing populations, and lack of adequate financial incentives for conserving or restoring natural peatlands – make such an outcome unlikely in the short to medium term. We therefore consider the potential climate mitigation benefits of the adoption of an interim move towards 'responsible peatland management', which seeks to minimise GHG emissions from areas under ongoing agricultural use via the implementation of higher water level management strategies and alternative crops. We also discuss the possibility to create 'future carbon sinks' by restoring degraded agricultural peatlands to peat-forming systems.

Keywords: Peatlands, responsible management, water table, greenhouse gas emissions, methane

Introduction, scope and main objectives

Peatlands occupy around 4 million hectares of the earth's surface, and hold around one third of all soil carbon. Under natural conditions they can sequester CO_2 continually over millennia, thus having a net cooling impact on the global climate. However, the drainage-based utilisation of peatlands for agriculture, biomass production and peat extraction has converted peatlands into a major source of global anthropogenic CO_2 emissions. This process, which began centuries ago in Europe but accelerated with the onset of pumped drainage in the 20th century, is now increasingly widespread in other parts of the world, notably in the extensive peatlands of Southeast Asia where drained organic soils support economically important crops such as oil palm and Acacia pulpwood plantations. The drainage and cultivation of organic soils was estimated in the last IPCC assessment report (Ciais et al., 2013) to be producing around 0.9 Gt of CO_2 emissions per year from peat oxidation alone, which equates to ~2.5% of *all* anthropogenic CO_2 emissions. Along with this climate impact, oxidation and compaction of drained peat also lead to land subsidence, and eventual wastage of the peat, which increases energy costs for pumped drainage, exacerbates flood risk in low-lying coastal landscapes, and ultimately threatens the long-term viability of agricultural activity in peatland areas. Nevertheless, in the short-term agriculture on organic soils is highly profitable, supporting high-value horticulture and arable agriculture in many areas of Europe, and supporting economic and livelihood development for millions of people in countries such as Indonesia, Malaysia and Papua New Guinea.

Despite some attempts to portray drainage-based peatland agriculture as sustainable, most key peatland actors, including governments and plantation companies, now recognise that this activity is inherently unsustainable (Wijedasa et al, 2016a,b). Furthermore, the growing recognition that conserving peat soil carbon is important not only for the climate but also for the long-term agricultural and economic viability of peatland landscapes presents opportunities for governments, industry and academia to work together towards a mutually beneficial outcome. Attaining such an outcome does, however, require either financial mechanisms to adequately recompense individuals and countries for conserving and restoring peatlands to their natural condition, or the development of land-use practices that support the agricultural use of peatlands under conditions that do not require drainage. The concept of 'paludiculture' (productive wetland agriculture on peatlands) has been developed and demonstrated at the small scale, but as yet the comparatively low economic returns mean that it is difficult for such practices to 'compete' with conventional drainage-based agriculture, either in Europe or in SE Asia. Consequently, we consider whether there may be potential for significant emission reductions through interim measures aimed at mitigating GHG emissions from peatlands under conventional agricultural use. This approach, which has been termed 'responsible peatland agriculture (Clark & Rieley, 2010; Wijedasa et al., 2016a) may not halt emissions from peatlands, but could substantially reduce current emission rates while longer-term solutions are sought. However, such an approach requires a robust evidence base, to enable effective (and scientifically defensible) land-management practices to be put in place. Here, we describe the results of a major UK research programme, which seeks to quantify the controls on GHG emissions from agriculturally managed peatlands, and to identify potential options for emissions mitigation. These results are placed within a wider context of international land-use emissions reporting and global peatland emissions, and used to estimate that likely scale of global GHG emissions reductions that might be achieved via a more towards responsible peatland management.

Methodology

We describe the results of a UK government-funded three-year integrated programme of GHG and carbon (C) flux measurements at 15 UK peatland sites, ranging from conservation-managed wetland systems to highly modified grassland, cropland and peat extraction sites (for full details, see Evans et al., 2017). Flux towers, static chambers, waterborne carbon and biomass offtake measurements were used to construct full C budgets, and site characteristics including peat depth and chemical properties (C and N content, pH, bulk density), hydrology (water input-output budgets, mean water table depth) and meteorology were also measured. Flux data were analysed against measured site characteristics in order to identify dominant controls on GHG emissions, and results were then evaluated against a wide range of published flux tower-based measurements from temperate and boreal peatland sites. We also used these and other flux data, together with spatial data on peat condition, to develop and apply an IPCC 'Tier 2' approach to estimate the magnitude and sources of peatland GHG emissions at a national level. The identified relationships between peat GHG emissions and controlling factors were combined with the recent IPCC estimate of total GHG emissions from organic soils under cropland and grassland (Ciais et al., 2013) in order to generate an indicative estimate of the magnitude of emissions reduction that could be achieved through altered peatland management.

Results

The UK study sites ranged from strong net CO_2 sinks under wetland conservation management (~5 t CO_2 ha^{-1} yr^{-1}) to major net emission sources (25-30 t CO_2 ha^{-1} yr^{-1}) under cropland. Emissions were very strongly related to mean water table depth (WTD, Figure 1), with no other measured site variable providing significant additional explanation of observed fluxes. Methane fluxes were high at the wetland sites (~4 t CO_2 ha^{-1} yr^{-1} based on a 100 year GWP) but near-zero when WTD was lower than 25 cm. Emission data derived from our data broadly conform to the IPCC's Tier 1 emission factors (IPCC, 2013) but indicate that it is the WTD associated with a land-use activity, rather than the activity per se, that determines emissions. Comparing our results to those obtained from other published flux tower studies suggests that WTD can account for the majority of all variability in peatland CO_2 balance. Other work in both high-latitude and tropical peatlands (Couwenberg et al, 2011) suggests that such relationships are essentially global.

Taking the combined UK/international dataset shown in Figure 1, we were able to simply estimate the reduction in CO_2 emissions that could be achieved by raising mean WTD from 80 cm (a typical value for both temperate and tropical croplands) to 25 cm, for the 250,000 km^2 of cultivated organic soils identified by Ciais et al. According to this analysis, CO_2 emissions could be expected to decline from 25 to 4 t CO_2 ha^{-1} yr^{-1}, equivalent to a reduction in global CO_2 emissions of 0.66 Gt CO_2 yr^{-1}. Since CH_4 fluxes are negligible at WTD > 25 cm, there would be little or no offsetting increase in CH_4 emissions.

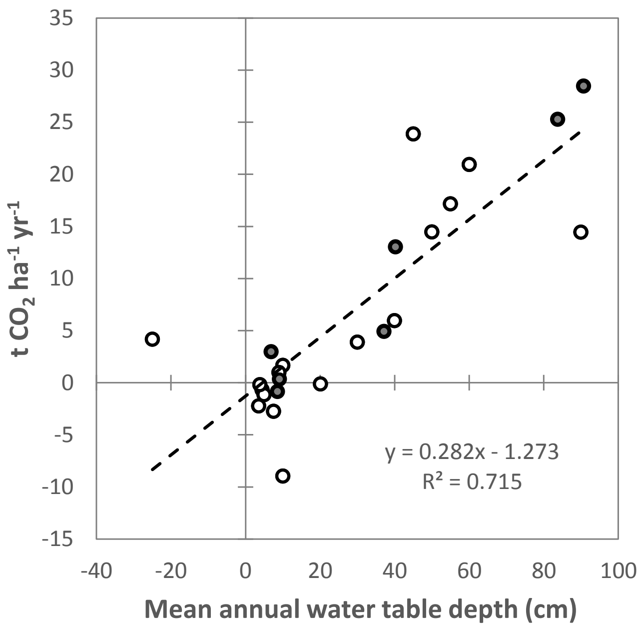

Fig. 1: Observed net CO_2 balance versus mean water table depth for temperate and boreal peatland sites with flux tower data. Filled circles: This study (Evans et al., 2017); Open circles: Other published data.

Discussion and Conclusions

Our analysis confirms the overriding importance of water table depth in controlling the C and GHG balance of managed peatlands. Whilst our extrapolation of CO_2 balance data to the global area of cultivated organic soils is inevitably uncertain, it seems clear that there is major potential to reduce global GHG emissions – perhaps by as much as 2%. Whilst this falls short of the cessation of all peatland emissions (and return to net CO_2 sequestration) that could be achieved by full re-wetting and restoration of cultivated organic soils, nevertheless we estimate that perhaps 80% of current emissions could be halted by responsible peatland management practices, whilst continuing to permit economically productive use of these socio-economically important areas. Our results present a challenge to agronomists and the agricultural industry to develop crops, cultivars and management practices that enable economic yields and food security to be maintained under higher water table conditions. For example, it may be possible to maintain biomass and crop yields under shallower water tables if the nutrients supplied through peat oxidation can be replaced by alternative fertilizer sources, without giving rise to large N_2O emissions. Whilst the development of such methods will require the investment of time and resources, and whilst they would still fall short of true sustainability, we argue that responsible peatland management has the potential to make a quantitatively significant, and realistically achievable, contribution to reducing global anthropogenic GHG emissions and rates of soil carbon loss.

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