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METHANE EMISSIONS FROM ORGANIC SOILS UNDER GRASSLAND: IMPACTS OF REWETTING

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SUMMARY

Grassland is a major land use category in the Republic of Ireland and a significant source of greenhouse (GHG) emissions. In reporting carbon (C) emissions from grassland on organic soils, the Republic of Ireland currently uses the Tier 1 default value of 0.25 t/C/ha. This value is at variance with Emissions Factors (EFs) used by countries in similar climatic zone and suggests that Ireland may have underestimated C emissions from this land use category.
The CALISTO project (www.ucd.ie/calisto) aims to provide a comprehensive overview of C dynamics in organic soils under grassland by quantifying the gaseous fluxes of carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and fluvial C losses (DOC, POC, pCO2, DIC) at four peatland sites under grassland and, therefore, move to Tier 2 level reporting. At the same time, we are investigating the impacts of re-establishing a high water table in order to reduce CO2 losses. However, an increase in CH4 emissions due to rewetting is also expected therefore compromising the full atmospheric impact of such mitigation measures. Preliminary results of CH4 fluxes will be presented and discussed in terms of an optimal water table to minimise CH4 emissions. This work is relevant in the context of the "2013 Supplement to 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands" whereby tiered methodological approaches are being discussed for the rewetting and restoration of peatlands.

KEY WORDS: climate change, methane, rewetting, grassland, organic soil.

INTRODUCTION

In Ireland, agriculture is the second largest producer of greenhouse gases (GHG) viz. nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) and grassland is the dominant land use category (LUC) (EPA 2008). It is estimated that organic soils under grassland cover between 295 kha (CRF Table 5.C, Inventory 2007-2009) and 345 kha (Renou-Wilson *et al.* 2011), corresponding to 8 – 9% of the total grassland area.

Organic soils contain high densities of carbon (C) accumulated over many centuries and therefore they are an important component of terrestrial C storage. They are deemed to contain more than 75% of all SOC in Ireland (Renou-Wilson *et al.* 2011). Organic soils were drained in the 18th and 19th centuries but this intensified in the 20th century in order to increase the area of grassland for beef production. Drainage stimulates the oxidation of the organic matter previously built up, producing high CO_2 and N_2O fluxes (Freibauer *et al.* 2004). In contrast, CH_4 emissions mostly cease following drainage of organic soils.

Management of organic soils has been proposed as a measure for mitigating GHG emissions from agricultural ecosystems (Smith *et al.* 2007). The most important mitigation practices are (1) avoiding the drainage of these soils in the first place, (2) re-establishing a high water table (Freibauer *et al.* 2004) or (3) optimising the position of the water table (Lloyd 2006). However, changes in the moisture regime may have implications for the biosphere–atmosphere exchange of GHGs, and in particular, may lead to an increase in CH_4 emissions (Best and Jacobs 1997, van den Pol-van Dasselaar *et al.* 1999, Soussana *et al.* 2004). It has been estimated that by maintaining the water table at a depth of 30 cm peat mineralization could be reduced to 30-40% and total GHG emissions to 50-60% of the maximum (Renger *et al.* 2002). Regina (2010) hypothesized that it would be possible to determine an optimum WT that would be suitable for grass cultivation but have lower than normal emissions of N_2O and CO_2 without an accompanying increase in CH_4 emissions. Her study in cultivated organic soils under grassland has so far showed that after re-wetting of organic soil, the sink of CH_4 declined as the water table rose but high emissions of CH_4 are not expected unless the water table reaches 20 cm.

Therefore the premise is that water level can be manipulated to various degrees thus causing different impacts on GHG emissions and removals from the organic soil.

In this study (www.ucd.ie/CALISTO), we examined the effects of a water table gradient on CO_2, N_2O and CH_4 emissions from an organic soil under grassland and we report here the dynamics of CH_4 emissions in particular during the first growing season. We hypothesised that an optimum water table can be achieved to minimise CH_4 emissions from re-wetted organic soils under grassland.

MATERIAL AND METHODS

Site study

This paper reports results from a grassland site located near Glenvar, Fanad Peninsula, in northwest Ireland (55°9'N, 8°34'W), about 50m above sea level. Annual mean precipitation as recorded from the closest meteorological station (Met Éireann - Malin Head, ~30km), is 1060mm and mean air temperature is 9.3°C.

This semi-improved wet grassland is typical of a high proportion of agricultural land found in the west and north west of Ireland; very low management inputs (last fertilisation and drainage took place more than ten years ago) and the grassland composition is quite similar to a natural sward (30% *Juncus effusus*). The organic soil is representative of the majority of organic soils under grassland in Ireland, being generally ombrotrophic in nature. Average depth is 57 +/- 8 cm, containing 42% organic carbon. Low management of the site has meant that the drainage system is poor and the lower part of the field is wet and can be used as a proxy for re-wetted drained site (Wet field). The rest of the drained field is well drained and dry (Dry field). A total of 18 sample plots were installed across the dry (n=9) and wet (n=9) fields following an increasing gradient of water table.

Methodology

We report here data from the first growing season only, April 2011 to October 2011, during which we measured CH_4 gas fluxes using the static chamber technique (Alm et al. 1997), at biweekly intervals. Dark chambers (60cm x 60cm x 20cm) were equipped with an air circulation fan, temperature sensor and port for syringe attachment. Following a 5 minute adaptation, four 50 ml samples were withdrawn into 60 ml polyproplylene syringes from the chamber headspeace at 10-minute intervals. During each measurement, air temperature inside the chamber and the soil temperature at 5, 10, 20 and 30cm depths and WT outside the chamber were recorded. Vegetation composition and leaf area index were measured at the same time. The syringes were taken to the UCD Soils Group laboratory at Belfield, Dublin within 24 hours and analysed on a Shimadzu GC-2014 gas chromatograph with an attached auto sampler unit. Grass was regularly clipped and biomass measured in order to mimic the cattle grazing regime.

RESULTS

The 2011 growing season was particularly wet with 25% more precipitation than the 30 year average.
The water table at the dry site averaged between -25 cm and -55 cm throughout the year. The wet site remained above -25 cm on average with above-surface levels during the winter months but variability is evident.

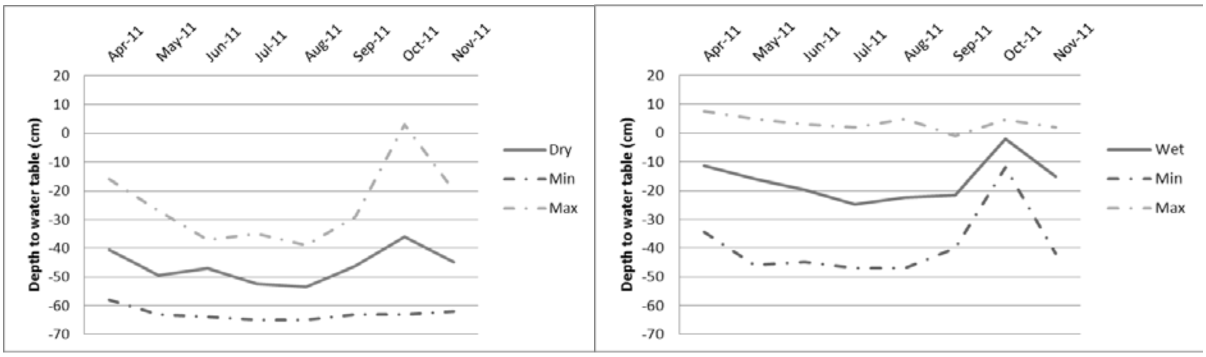

Fig. 1: Average water table levels (and minimum and maximum values) recorded from the dry (n=9) field and wet field (n=9) bi-weekly during the growing season.

In this study, CH_4 fluxes were very small or negative (uptake) in the dry field. Fluxes were higher in the wet field, with an average over the growing season of 0.9 mg CH_4 m^{-2} hr^{-1}, with higher fluxes in the summer months (Fig. 2). However, strong spatial variability was observed, with average fluxes over the growing season ranging from 0.3 to 3.8 mg CH_4 m^{-2} hr^{-1} between sample plots. CH_4 fluxes correlated with water table level (Fig. 3) with fluxes increasing with higher water table (i.e. closer to the surface) ($p<0.001$, r^2=0.26). While fluxes increased with increasing soil temperatures this was not statistically significant, probably due to the small range in temperatures experienced during the period.

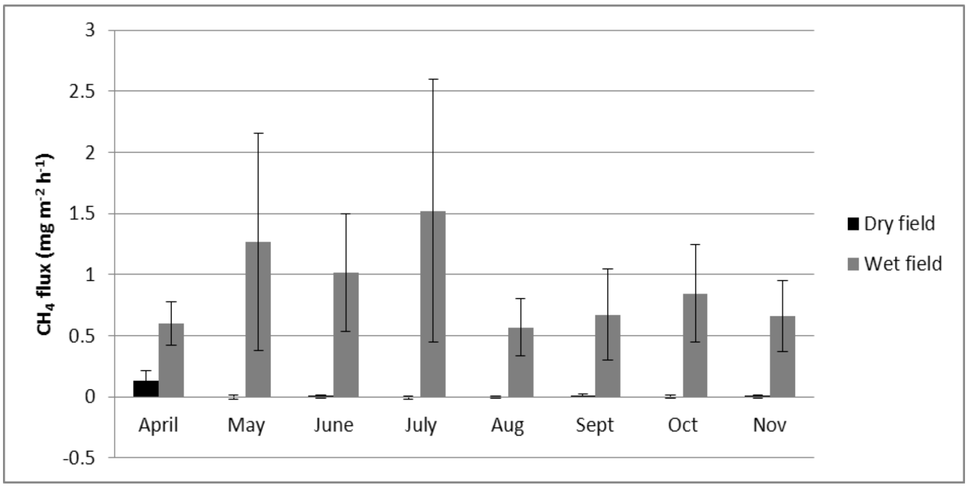

Fig. 2: Average monthly CH_4 fluxes (mg CH_4 m^{-2} hr^{-1}) recorded over the growing season in 2011 in a dry and wet organic soil under grassland (error bars denote standard deviation of the mean). Positive values indicate CH_4 emissions to the atmopshere.

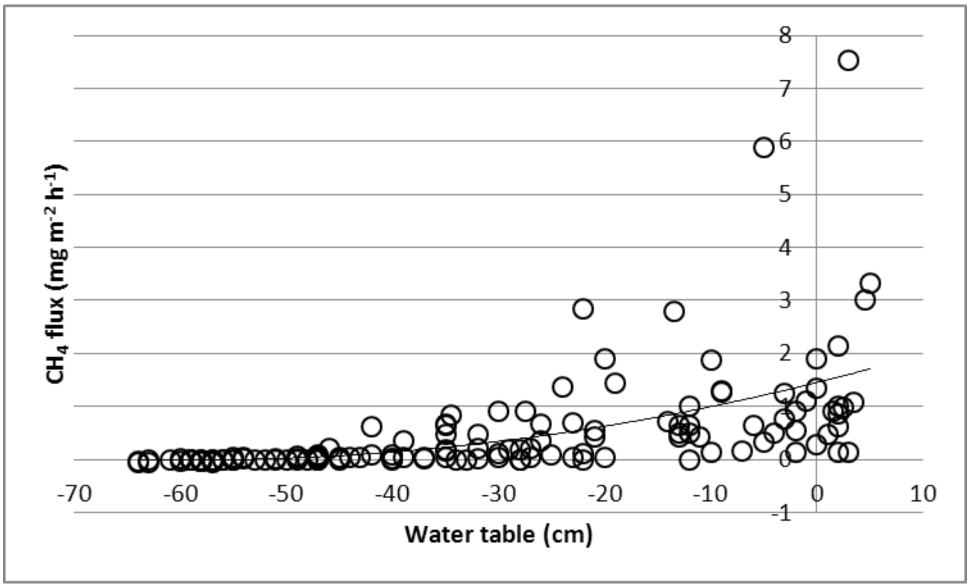

Fig. 3: Relationship between CH_4 fluxes (mg CH_4 m^{-2} h^{-1}) and water table depth.
Positive values indicate CH_4 emissions to the atmopshere.

DISCUSSION

CH_4 fluxes from the dry field reported here for the first growing season of this study were in the range of those published for well-drained organic soils (Maljanen *et al.* 2007, Regina and Alakukku 2010). Higher sinks were probably expected given that these soils are not cultivated. In contrast, high fluxes were recorded in the wet field and significant emissions were recorded once the water table was above -20 cm and much higher again when the water table was above the surface. This strong relationship with water table depth has been already found in many studies (Couwenberg and Fritz 2012). A complete annual study will provide information on whether a mean water table level threshold of –20 cm or lower may be applied below which emissions would not be significant. Furthermore, analysis of CO_2 and

N_2O will disclose the contribution of CH_4 emissions to the total atmospheric impact of wet organic soils under grassland.

The spatial variability recorded at the wet site is also likely to be a function of the vegetation composition which is known to play a critical role in CH_4 emissions by controlling substrate quality (litter quality) and, for certain aerenchynous species, by transporting CH_4 from the saturated soil to the atmosphere (Shannon and White 1996, Tuittila *et al.* 2000). The present of “shunt” species and mosses in the wet field may be a representation of the relative water table position as well as providing a conduit for CH_4 exchange with the atmosphere.

CONCLUSION

Wet organic soils under grassland display high CH_4 emissions especially if the water is close to the surface. However, maintaining the water table at – 20cm may be sufficient to reduce CO_2 losses from respiration while keeping CH_4 emissions low and therefore raising the water table could be used as a GHG mitigation tool in organic soils under grassland.

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