Background

Modelling soil carbon dynamics has received remarkable attention over the past 20 years, mainly because of the large soil organic carbon (SOC) stocks and the potential climate feedbacks (e.g. Cox et al. 2000). However, there is a lack in representing pedogenesis (e.g. humus types) and thus inclusion of organic soils (i.e. peat). Better understanding and model representation of key soil-ecological hydraulic processes are required. Surprisingly, global models still do not adequately represent soil C-rich peatlands and CH4 fluxes and thus climate feedback predictions are very uncertain. Moreover, water table depth (WTD) and thus peat moisture changes might have important implications on plant and other upland biodiversity, specifically birds.

We discuss the MILLENNIA peat cohort model around: (1) variable past Holocene climate change with corresponding dynamic WTD, plant communities and litter quality; (2) recent changes in climate and peatland development; (3) up-scaling across the landscape; and (4) present preliminary data on climate change scenarios and peatland moisture feedback on upland bird species.

Key issues

1. SOC stocks: currently a) models do not adequately represent C-rich humus and litter layers, and b) global models struggle to represent peatland water table dynamics regulating CH4, CO2 fluxes, and lifecycle of SOC (SOC) stocks and the potential climate feedbacks (e.g. Cox et al. 2000).

2. Climate: determines both net primary productivity (NPP) and decomposition via actual evapotranspiration (AET). Luttenberg et al. 1972 and Berg 1986, respectively. Moreover, peat soils evolved over millennia (e.g. Holocene) with changes in WTD and PFTs.

3. Litter quality: reflecting different plant communities as affected by climate, soil and WTD (e.g. Egli et al. 1992) and determines decomposition rates and humus build-up (e.g. Frolking et al. 2001).

4. Up-scaling: how to link plot level studies to larger scales (i.e. chamber to eddy covariance tower fluxes), and how to relate model output to landscape scale ecosystem services.

5. Implications: alterations in climate will affect peatland hydrology with feedback implications on soil moisture and on invertebrates, an important food source for upland birds.

Summary

1. SOC stocks: currently global models do not capture total SOC stocks and likely misrepresent C-fluxes, SOC sequestration and climate feedback potential. They also do not predict CH4 accurately due to inadequate water table dynamics and peat growth.

2. Climate: the common average climate SOC equilibrium spin-up is not applicable to peatlands and is also questionable for mineral soil systems (Lysgaard et al. 2008). Moreover, it prevents “C-age validation of SOC accumulation over depth and time.

3. Litter quality: determines SOC decomposition and is plant community dependent, linked to climate and WTD dynamics. A main factor for peat accumulation is lignin content and root litter SOC input.

4. Up-scaling: chamber-based fluxes provide reliable C-fluxes but need to be short-term while peat and SOC stock.

5. Implications: The MILLENNIA model is an exciting tool offering landscape-scale applications in relation to peat development and key ecosystem services (i.e. carbon stocks, water and biodiversity).

The MILLENNIA peat cohort model concept. Mean annual temperature (MAT) and precipitation (MAP) drives both C input (NPP) and decomposition. Annual cohorts are added via shoot litter and throughout via root litter. Decomposition is regulated by climate and WTD resulting in C-fluxes, including CH4. Note: top 10 cm is root/moss layer.

MILLENNIA model output of annual C-fluxes (left, blue) and CH4 (right, red) for Moor House with corresponding WTD during 1931-2005. Note: a) a noticeable decline in WTD with C-flux implications (left CH4, yr. more CO2); b) MAR model only provides "C fluxes for C-fluxes and modeled evapotranspiration (E) of plants; c) WTD after ~1000 yrs; d) this validation in (Garrett M.J. et al. 2009).

Note: strong correlation was found between WTD and CH4 fluxes and MAR model only provides "C-fluxes and modeled evapotranspiration (E) of plants.

The data (CO2) collected at a Welsh peatland site Vyrnwy with different methods: 1 eddy covariance tower; 1 net ecosystem exchange (NEE) chamber (either light or dark) and soil respiration in those areas using a li-Cor 8100 analyser. Crucially, hardly any decomposition-only fluxes (i.e. excluding root respiration) yet available from the literature.

Note: site average NPP is ~450 g C m-2 and SOC is ~135 kg C m-2.