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THE EFFECT OF WIND TURBINE-INDUCED MICROCLIMATES ON A CARBON BUDGET OF A BLANKET BOG

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SUMMARY

In this paper we present data from Black Law Wind Farm, Scotland, to examine the effect of wind turbines on (1) peatland surface and subsurface temperatures, soil moisture and water table depth and (2) greenhouse gas fluxes and pore water dissolved organic carbon concentrations. Moreover, within our experimental framework we examine the impact of the three main plant functional types (shrubs, mosses and sedges) and their interaction with wind turbine affect to allow both upscaling and the implications of changes in plant composition, over the long-term, on carbon fluxes to be elucidated. The results indicate that there are relationships between wind turbines, plant functional type and their interactions and carbon fluxes. Consequently, the long-term effects of wind farms on carbon cycling needs to be taken into account when considering their life cycle carbon budget.

KEY WORDS: Wind turbines, carbon dioxide, methane, dissolve organic carbon, plant functional type

INTRODUCTION

Wind farms affect the local climate as they remove energy and increase turbulence: a recent study showed a cooling of 1.5°C during the day (Baidya Roy *et al.*, 2010). The UK has more than 4 GW of installed onshore wind capacity in operation and by 2020 it is expected that the installed capacity will reach 13 GW, representing an annual growth rate of 13% (DECC, 2011). The growth of onshore wind was greater than the capacity of any other renewable energy source from 2006-2010 but while there have been environmental studies on the direct effects of installation, no studies in the UK have examined the effect of wind farms on the energy balance and resulting microclimate.

Research, both theoretical and empirical, in the USA, has shown that wind farms affect the local climatic conditions. Surface temperature (at 5 m) was found to be significantly different upwind and downwind of the prevailing wind direction at San Gorgonio wind farm, California (Baidya Roy and Traiteur, 2010). During the day the temperatures were significantly cooler, up to 1.5 C, downwind of the turbines and during the night the temperatures were warmer. The differences in temperature were attributed to enhanced vertical mixing due to turbulence generated by the turbines as demonstrated theoretically by

Baidya Roy *et al.* (2004). Wake effects of turbines are thought to extend by up to 20 km, dependent on atmospheric conditions, wind speed and direction, and thus these significant changes in microclimate could occur beyond the boundary of the wind farm.

A 1.5°C cooling in temperature is considerable in any environment and will have substantial effects on biological processes (Clark *et al.*, 2009; Dorrepaal *et al.*, 2009). In the UK, and more so in Scotland, such changes in temperature is of greater concern given wind farms are commonly located in carbon-rich landscapes. Changes in microclimate will affect plant productivity and decomposition and consequently change the carbon storage and processing rates on these wind farm sites. Therefore, the effect of wind farms on the local microclimate needs to be assessed to enable the complete environmental impacts of operations to be established.

MATERIAL AND METHODS

For one year, at monthly intervals, we have sampled water table depth, greenhouse gas flux and pore water dissolved organic carbon concentration from 48 plots (Fig. 1) across a 12 km^2 area of a Scottish blanket bog hosting a wind farm. We also monitored surface temperature, temperature and soil moisture at – 5cm at 36 of the plots at 30 minute intervals. The sampling plots are divided into four sites along a hypothesized wind farm-induced microclimatic gradient. At each site twelve sampling plots were established, four each in areas dominated by mosses, sedges and shrubs. From each plot samples were collected from piezometers and tension samplers, representing free-flowing pore water and that held under tension respectively. Net ecosystem exchange and respiration were measured using infrared gas analysers with photosynthesis calculated by difference. Methane was collected using closed static chambers with samples analysed using a gas chromatograph in the laboratory. Dissolved organic carbon concentration and absorbance (190 to 1100 nm) were measured for each pore water sample.

Figure 1. Photographs of the fieldwork equipment at each of the sampling plots.

RESULTS

We found [DOC] ranged from 2-197 mg l^{-1}. Net ecosystem exchange varied from -4667 to 3245 mg CO_2/m2/hr with a mean of -127 mg CO_2/m2/hr. Ecosystem respiration varied from 0 to 10,160 CO_2 mg/m2/hr with a mean of 421 mg CO_2/m2/hr. Methane flux varied from -43 to 238 mg CH_4/m2/hr with an average of 4.9 mg CH_4/m2/hr. These variables are hypothesized to vary with time of year, site and plant functional type. Some of the higher gas fluxes may be attributable to ebullition events.

CONCLUSION

In conclusion, our results indicate that time of year, site and plant functional type are related to [DOC] and greenhouse gas fluxes. This indicates that the operational effects of turbines on microclimates may need to be considered. Furthermore, changes in the relative proportions of plant functional type as a result of (micro)climatic change which will also affect [DOC] and greenhouse gas flux.

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