Effects of experimental warming and drought on gaseous carbon fluxes and the carbon balance of a Welsh raised bog

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Peatlands are important carbon sinks and stores, however this function is threatened by climate change. Experimental field studies are used to examine peatland responses to climate manipulations, but most studies are short-lived, few manipulate both temperature and hydrology, and those that do usually simulate a permanent water table change. Here we report the results of a ten year, fully-factorial climate manipulation experiment on a Welsh raised bog. We used open top chambers to passively warm plots by an average of 0.8 °C all year, and we simulated four one-month droughts (water table approximately 15 cm lower than controls) by subsurface water pumping during the summers of 2010, 2011, 2014 and 2019. We measured fluxes of CO_2 and CH_4 and calculated multi-year annual gaseous carbon budgets for each plot.

Net ecosystem exchange in the control plots averaged -221 g CO_2 m^{-2} yr^{-1}, similar to that reported from other ombrotrophic bogs. Ten years of warming combined with episodic summer drought caused the plots to switch from a net CO_2 sink to a source of 14.3 g CO_2 m^{-2} yr^{-1}. This change was due to a large increase in the rate of ecosystem respiration in the warmed+droughted plots. The warmed-alone and drought-alone treatments showed declining trends in CO_2 removal and increasing trends in respiration, but these were not significant. Methane emissions accounted for only about 5 % of total annual gaseous carbon fluxes and decreased in the warmed+droughted plots. This may relate to increases in surface aeration and small but significant increase in ericaceous shrubs, potentially affecting the soil microbial community. Since CH_4 fluxes were very low, random fluctuations in CH_4 production and consumption also cannot be ruled out.

Our study indicates that peatlands may shift from a long-term carbon sink to a carbon source in response to a moderate climate change driver of approximately 1 ^{o}C warming and summer drought at a recurrence frequency of ca 2-4 years. This expands the zone of likely negative impacts on peatland carbon storage to regions where climate change is expected to be less severe than at high latitudes. This work also emphasizes the value of long-term experiments for simulating realistic environmental change to detect cumulative and non-linear effects of environmental drivers.