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CARBON BUDGETS FROM A FIELD SCALE MANIPULATION EXPERIMENT: THE EFFECTS OF CLIMATE CHANGE ON RAISED BOGS

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SUMMARY

Quantifying the response of raised bogs to climate change by using a field scale manipulation experiment which simulated warming, drought and warming and drought in a factorial designed experiment

KEY WORDS: Climate change, drought, warming

INTRODUCTION

Northern Europe is predicted to have a rise in temperature between 2.3-5.3°C by 2080-2099 (S.D. Solomon *et al.,* 2007) According to Wang *et al.,* (2010) 300-500 PgC is stored in Northern Peatlands. Increasing global temperatures will warm plants and soils and change global water distribution, with increased frequency of droughts predicted for temperate and arctic regions. Therefore, the question of how these carbon stores will respond to increased temperatures and increased drought frequency has been raised.

A raised bog on the Welsh coast (Cors Fochno), was subjected to a factorial designed climate change experiment. Treatments were designed to simulate climate change, with yearly 5 week summer drought treatments and a passive warming system providing year round warming. The sites were routinely monitored monthly and during drought periods monitored 5 times a week. Treatments were monitored for gas fluxes (CO_2, CH_4 and N_2O), water table depth (WTD), temperature (air and soil), soil moisture, PAR, plant composition (pin touch, quadrat survey) sphagnum growth (crank wire), and decomposition (litter bags).

METHODS

Treatments

Relative to a control, treatments were; warming, drought, warming and drought. All the treatments are 2x2m with each treatment replicated in triplicate. The control treatment consists of short (~0.5m) plastic dam piling with 25mm holes allowing water equilibration between the control plots and the surrounding area. The piling was used to mimic the disturbance created during the installation of the other treatments.

The warming treatment consists of short (~0.5m) dam piling with a modified ITEX (Marion *et al.,* 1997) chamber, consisting of an octagonal chamber which maximised the useable area under the open top chamber (OTC).

The drought treatment consisted of long piling (~1.5m) which hydrologically isolated a 2x2x1.5m block sufficiently that water could be removed, with pumps, and lower the WTD relative to the control plots. The blocks were unsealed at the bottom as it was theorised that peat becomes denser with depth, reducing hydraulic conductivity and allowed more water to be removed from the plots than was able to recharge via the open bottom of the plots. Water was removed from the plots by installing 4 ~1m deep 250mm diameter tubes in each corner of the plot. A hundreds of small holes allow rapid influx of water from the plot. Water was removed using 12v macerator pumps to deal with the volume and high sediment content of the water. The pumps were automated with a variable timer circuit (Super timer, REUK) allowing both the pumping time and rest time to be variable. This allowed the maximum amount of water to be removed from each plot.

The final treatment was a combination of drought and warming, consisting of an OTC, long (~1.5m) dam piling, and 4 pumping points.

Measurements

Within each plot 3 gas collars were installed, two smaller (200mm diameter) CO_2 collars used as attachment points for an infra-red gas analyser (IRGA – EGM4, PP systems, Firenze, Italy) and was used to measure net ecosystem exchange (NEE) and net ecosystem respiration (NER), and a large collar (350mm diameter) used to measure CH_4, CO_2, and N_2O. All the gases were monitored monthly, except during the summer drought period were IRGA CO_2 was measured daily (5 times a week), whilst CH_4, CO_2 and N_2O was measured weekly.

Water table depth within each plot was monitored at three points forming a transect across the plot to monitor any unevenness in the hydraulic profile due to topography or pumping. For each treatment WTD was logged every 30mins (Truetrak, New Zealand) in one location. The other WTD measurement points were measured manually monthly, except during the summer drought where WTD was measured 5 times a week.

Soil moisture was measured monthly (twice weekly during the drought period) using a TDR soil moisture profile probe (Pico Talk, Germany), allowing changes in soil moisture, both spatially and temporally, to be monitored.

Four of the plots, on from each treatment, were measured with a greater concentration of air and soil temperature probes. Measurements were air, 5cm, 10cm, 20cm and 40cm. All other treatments had temperature probes at air and 10cm’s depth.

RESULTS

Temperature

The air temperatures between warmed and non-warmed plots (Warmed, warmed and drought vs Control, drought) were analysed using ANOVA to find the amount of warming and the significance.

Table 1. Significance of warming treatment relative to non-warmed treatment.

	Air	5cm	10cm	20cm	40cm
P value	0.000	0.000	0.000	0.000	0.000
R^2	0.16%	0.98%	0.88%	0.61%	0.39%
Difference of means	+0.68°C	+1.14°C	+1.01°C	+0.76°C	+0.51°C

All treatments were significant with warmed treatments being warmer than non-warmed treatments. There was also a discrepancy between air and soil temperature, with the air temperature having a lower increase in mean temperature than the 5cm soil temperature. There is also a decrease in the amount of warming down the peat profile where warming was 1.14°C above non-warmed treatments compared to 0.51°C at 40cm's.

Having found a difference between the warmed and non-warmed treatments, the individual treatments were tested to find if there were difference between the two non-warmed treatments and the two warmed treatments, and all treatments relative to the control.

Table 2. Analysis of temperatures between control and other treatments

	Air	5cm	10cm	20cm	40cm
Control vs Drought	-0.46°C P=0.000	-0.64°C P=0.000	-0.03°C P=0.955	+0.02°C P=0.986	-0.14°C P=0.019
Control vs Warming	+0.87°C P=0.000	+0.95°C P=0.000	+1.19°C P=0.000	+0.91°C P=0.000	+0.39°C P=0.000
Control vs Warming and Drought	+0.07°C P=0.000	+0.76°C P=0.000	+0.80°C P=0.000	+0.62°C P=0.000	+0.50°C P=0.000
Drought vs OTC	+1.33°C P=0.000	+1.59°C P=0.000	+1.22°C P=0.000	+0.89°C P=0.000	+0.53°C P=0.000
Drought vs OTC and Drought	+0.53°C P=0.000	+1.40°C P=0.000	+0.84°C P=0.000	+0.60°C P=0.000	+0.64°C P=0.000

Air temperature between control and warmed was 0.87°C warmer (P=0.000). The mean temperatures were control = 10.75°C and warming = 11.61°C. When the soil temperature at 5cm depth was compared between the control and warmed plots it was found that the soil temperature, on average, was warmer than the average air temperature, the soil temperature at 5cm was also significantly different.

Graphically, using the means of the data set, shows the trends in temperature. From the average temperature graphs (Fig.1) the difference between the non-warmed treatments and the warmed treatments becomes clearer, especially with depth.

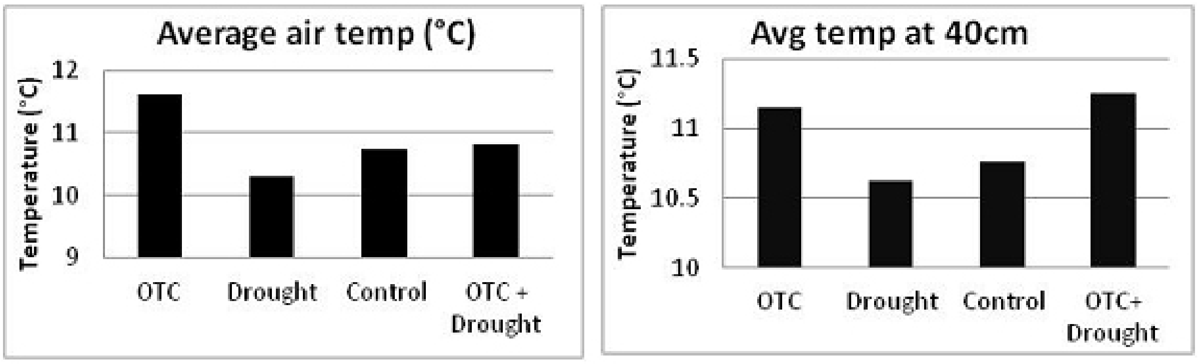

Figure1. Average temperatures for air and 40cm below the surface.

Drought

Six of the plots were subjected to two summer drought treatments of two five week periods. Approximately 138,000 litres of water were extracted over a five week period from all six plots. Data were analysed using a nested approach where three measurement points within each plot were nested within plot, and plot was nested with treatment. Overall, nested ANOVA is significant (P=0.000). Post hoc testing (Table 3) shows the relationship between the treatments. The relationship between the control plots and the warmed plots is insignificant, which is to be expected as both treatments have not had the water table manipulated. However, the two treatments that have been manipulated are also significantly different from each other, suggesting that the pumping was not consistent across treatments. This was visually observed during the drought period. Some of the plots were notably drier than others, with the pumping points filling quicker allowing more water to be removed from the plots.

Table 3. Post-hoc result of each treatment relative to water table depth

	Difference of means	T value	P value
OTC & Drought vs Control	-6.74cm	-23.11	0.000
OTC & Drought vs OTC	-7.32cm	-25.11	0.000
OTC & Drought vs Drought	+2.67cm	9.22	0.000
Control vs OTC	-0.58cm	-1.98	0.194
Control vs Drought	+9.42cm	32.33	0.000

Gas fluxes

CO_2 fluxes were measured from two points within each plot. These results were modelled in relation to temperature, water table depth, and season using a modified Lloyd and Taylor (1994) equation. Model fits to net ecosystem respiration (NER) were as follows; control R^2= 52.9%, OTC R^2=30.1%, drought R^2=32.0%, OTC and drought R^2=44.1%. Using a modified Bubier (1993) equation model fits to PP (primary productivity) are; control R^2=56.9%, OTC R^2=43.1%, drought R^2= 60.4%, OTC and drought R^2= 63.8%

CO_2 budgets for the treatments shows the effect the different treatments have had on the carbon budgets (Figure 2).

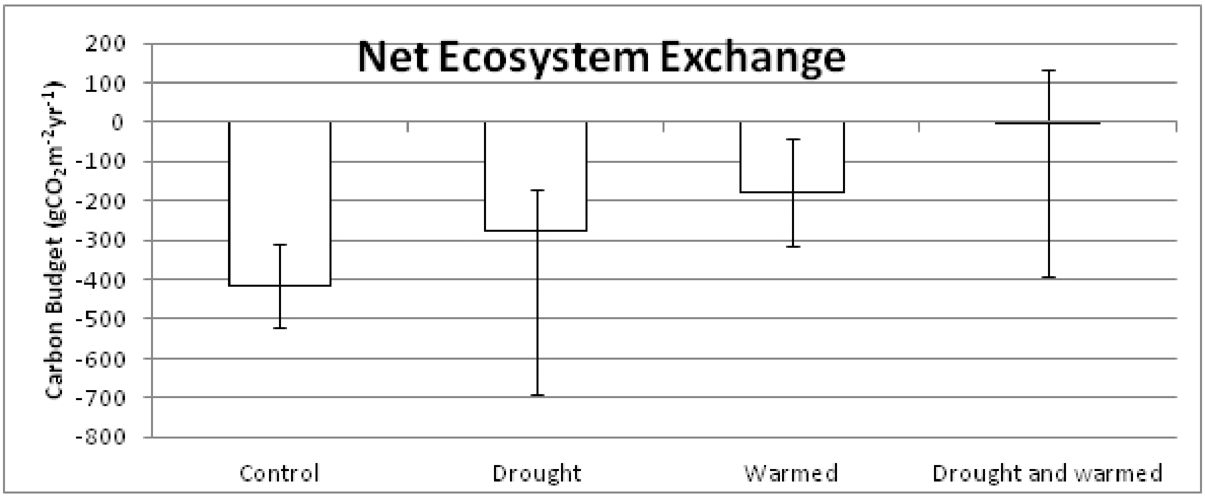

Figure 2. Net ecosystem exchange (CO_2) for all treatments

CONCLUSIONS

From table 1, it can be seen that the plots receiving a warming treatment (OTC, OTC and drought) are statistically warmer than non-warmed treatments (Control and drought). When individual treatments were considered (Table 2) it was found there were significant differences between most of the treatments apart from control vs drought at 10 and 20cm's. This would suggest that there is little difference between the control treatment and the drought treatment especially at depth. This is expected because both treatments have not received any form of artificial warming.

Water table depth has been successfully and significantly lowered when compared to control treatments, however, pumping treatment appears to have been inconsistent between treatments as the two pumping treatments (drought and OTC and drought) are significantly different.

Carbon dioxide budgets for the site shows that all treatments lower the amount of carbon taken up relative to the control site, with the warming and drought treatment have a greater than cumulative effect and reduces the OTC and drought treatment to effectively carbon neutral.

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