Impacts of climate change factors (temperature, drought, elevated CO2) on CO2, N2O and CH4 fluxes in an upland grassland

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Introduction: Impacts of climate change on plant community structure and function have faced increasing attention in recent years. Of particular interest are the impacts of climate change on carbon dioxide) CO2 missions and trace greenhouse gases (GHGs) such as nitrous oxide (N2O) and methane (CH4) with a much higher global warming potential (GWP) than CO2 (*IPCC, 2007*).Climate change is predicted to have both direct and indirect impacts on GHGs fluxes *via* plant community structure (*Lavorel & Garnier, 2002;* **Figure 1**).

Material and Methods: We use a novel experiment to investigate the effects of climate change (temperature, drought and elevated CO2) on GHGs fluxes in an upland grassland in central France. We applied three factors in an additive experimental design (**Figure 2**): 3°C warming (obtained by transplanting monoliths along an altitudinal gradient); a 20% reduction in summer rainfall (using rain shelters); and a 200ppm increase of atmospheric CO2 concentration (using a free air CO2 enrichment; mini-FACE following *Miglietta et al., 2001*). The combination of all three factors (TDCO2) corresponds to the climate predicted for the Auvergne region in 2050. Prior to the start of the experiment, the study grassland was managed for 15 years with low levels of sheep grazing and no mineral or organic fertilization. The site was dominated by grass species and had a low species richness (15 species).

Experimental treatments were established in 2005, and all monoliths have since been managed with two cuts per year (April and October) and no fertiliser inputs. Temperature (5-10cm) and soil moisture content (0-20cm) are continuously measured. Plant productivity, plant traits and community structure are determined at each cut.

In January 2007, we started a two-year measurement campaign of N2O and CH4 fluxes using closed static chambers and a photoacoustic gas analyser (INNOVA). Measurements were carried out every two weeks on average, or according to specific climate events (rain, or freeze thaw). In addition, we measured CO2 fluxes and net photosynthesis at the patch scale using open flux techniques.

Results: Here we present the results after one year of N2O and CH4 flux measurements. Climate change treatments had no significant effect on either the frequency or the magnitude of N2O emissions (**Figure 3**). Nonetheless, we found a tendency towards increased N2O emissions under elevated temperature. N2O emissions were significantly affected by the season; emissions in spring were significantly greater compared with winter (**Figure 4**). Throughout the study period, CH4 fluxes were too low to be detected by the gas analyzer. We conclude that CH4 plays an insignificant role in the GHG budget of our system. When we examined possible links between N20 fluxes and plant data collected in April 2007, we found that N2O fluxes were driven by changes in aboveground production rather than in direct climate effects (**Table 1**). Plant traits had limited effects on N20 fluxes. However, abundance of one particular plant species (*Festuca arundinacea*) had a positive effect on net N20 fluxes.

Patterns of N2O fluxes observed in 2007 appeared to be maintained in 2008 (data set to be completed). Open fluxes CO2 measurements in 2008 indicated a significant increase in maximum photosynthetic rates (Amax) in response to elevated CO2 over the course of the growing season (**Table 2**). Surprisingly we found a decrease in Amax in response to increasing temperature.

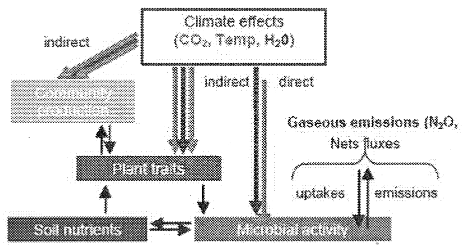

Figure1. Pathways of climate change effects on trace greenhouse gas emissions (adapted from Lavorel and Garnier, 2002).

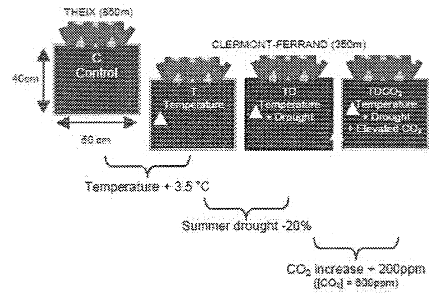

Figure2. Climate treatments applied to grassland monoliths

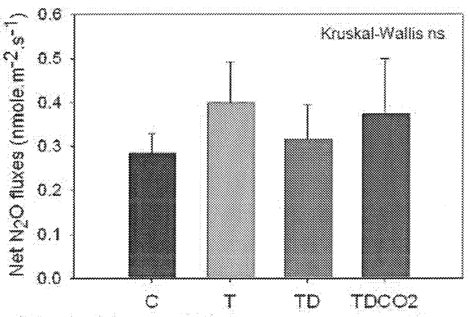

Figure3. Mean net N_2O fluxes in response to climate treatments.

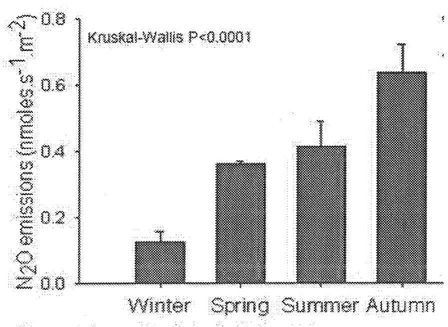

Figure4. Seasonal variation in N_2O emissions.

Table1. ANCOVA analyses for net trace gas fluxes with climate treatment as a fixed factor and biomass production as a covariable. P-values marked in bold are significant at P<0.05. All variables satisfy Shapiro-Wilks test of normality.

Flux	Factor	F	P	r^2	p-model
N_2O	Climate	1.41	0.27	38.05	**
	Biomass	11.03	**0.005**		
CH_4	Climate	3.45	**0.04**	35.67	**
	Biomass	0.02	0.89		

Table2. Repeated measures ANCOVA analyses for maximum photosynthetic rates at the patch scale. Climate treatment and campaign dates were included as fixed factors; vegetation height was used as a covariable. P-values marked in bold are significant at P<0.05.

CO2 effect					Temperature effect				
Factors	F	P	r^2	p-model	Factors	F	P	r^2	p-model
CO2 treatment	4.76	0.033	34.8	***	Temp treatment	19.55	0.0001	48.9	***
Campaign	2.68	0.008			Campaign	4.78	0.0001		
Height	2.88	0.095			Height	2.63	0.111		

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