Climate Extremes Affect Grassland Ecosystem Functioning

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Abstract

Climate change is likely to alter ecosystem functioning through shifts in plant and soil communities and direct effects on biogeochemical processes. Models predict there will be changes in the net amount and seasonal distribution of rainfall in the UK by the end of the century. We are investigating the effects of these changes on plant communities, soil communities, and rates of carbon and nutrient cycling. **We hypothesized that decreases in summer rainfall would slow ecosystem processes, and that reductions in rainfall frequency would have bigger effects than reductions in rainfall amount.**

By experimentally manipulating rainfall, we found that altered precipitation led to changes in plant community composition, slower rates of nutrient turnover, and lower rates of photosynthesis and ecosystem respiration, leading to a net loss of carbon in some cases. By simultaneously looking at plant community, soil community and biogeochemical responses over time, we are building a detailed picture of the links between the aboveground and belowground subsystems and their stability under contrasting rainfall regimes.

DIRECT Experimental System

Diversity, Rainfall and Elemental Cycling in a Terrestrial Ecosystem

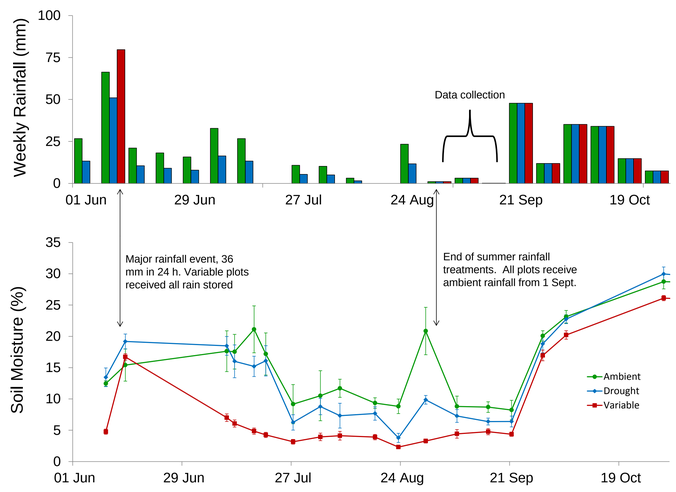
DIRECT was established at Imperial College's Silwood Park campus in 2008 and includes three experiments looking at the effects of global change on ecosystem functioning. The rainfall manipulations are based on Murphy *et al.* (2009). Transparent roofs are used to collect rainfall, which is redistributed to maintain the climate treatments.

The **Rainfall Extremes** experiment is reported here. It includes two climate treatments and a control:

- **Drought**: Spring and summer drought, winter flood (-30% March-August, +15% December-February).
- **Variable**: Highly variable summer rainfall (all rainfall is stored until there is natural rainfall >20 mm in 24 h, then all stored rainfall is applied).
- **Ambient**: Roofed control (ambient rainfall).

Rainfall Extremes Experiment

The extremes experiment includes an extended drought treatment (**Drought**), a highly variable treatment (**Variable**), and roofed controls which receive ambient rainfall (**Ambient**). Results from September 2012 are presented, with rainfall and soil moisture data from the previous 3 months for context. For methods, see Fry *et al.* (2013).



Results

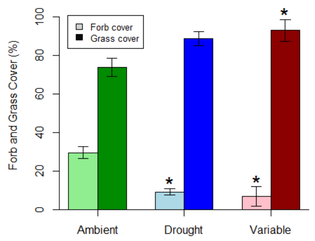
Mean results (±SEM) in September 2012, analysed using lme in R (Pinheiro *et al* 2012). * denotes significant difference from ambient at p<0.05.

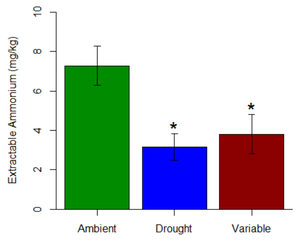
Aboveground

Decreased forb cover and increased grass cover. No difference in total cover.

Belowground

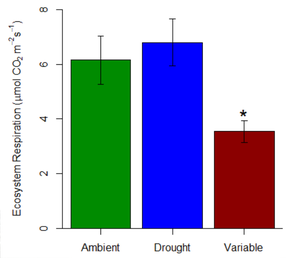
Decreased extractable ammonium. No difference in extractable nitrate.

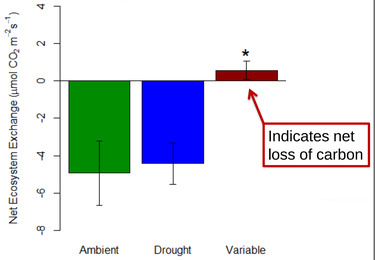




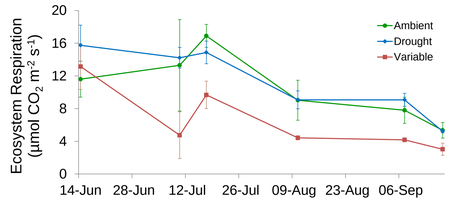
Ecosystem Processes

Reduced respiration. Small, positive net ecosystem exchange in variable treatment.





Trends Over Time



Ecosystem respiration was consistently lower in the variable treatment from July through September.

Discussion

Extreme and variable rainfall treatments reduced soil moisture and led to more grass-dominated plant communities. The decrease in extractable ammonium, with no significant difference in nitrate, indicates a reduction in ammonification by the microbial community. Decreased respiration supports our hypothesis of slowing ecosystem processes, and positive net ecosystem exchange suggests a loss of carbon from the variable treatment. **These results show that altered rainfall patterns can have substantial impacts on plant biodiversity and ecosystem processes**.

Next Steps

- Determine if effects are consistent over time by comparing data from 2009-2013.
- Analyse soil microbial communities for changes which affect ecosystem processes.
- Measure soil C pools and methane flux to estimate net effect on C sequestration.
- Use structural equation modelling to assess mechanisms behind changes.

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References

Fry, E.L. *et al.* 2013. Plant functional group composition modifies the effects of precipitation change on grassland ecosystem function. PLOS ONE. 8, 2, e57027.
IPCC. 2007. Climate Change 2007: Synthesis Report. Intergovernmental Panel on Climate Change.
Murphy, J. *et al.* 2009. UK Climate Projections Science Report: Climate change projections. Met Office Hadley Centre, Exeter.
Jose Pinheiro, Douglas Bates, Saikat DebRoy, Deepayan Sarkar and the R Development Core Team (2012). nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-104.