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Impact of inter-annual climatic variability on ecosystem carbon exchange in two grazed temperate grasslands with contrasting drainage regimes

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Temperate grasslands constitute over 30% of the Earth's naturally-occurring biomes and make an important contribution towards the partial mitigation of anthropogenic greenhouse gas emissions by terrestrial ecosystems. Accumulation of carbon (C) in grassland systems predominantly takes place in below-ground repositories, enhanced by the presence of a stable soil environment with low carbon turnover rates, active rhizodeposition and high levels of residue and organic inputs. Predicted future warming is expected to increase productivity in temperate zones, thereby enhancing rates of terrestrial carbon sequestration. However, the susceptibility of many ecosystems, including grasslands, to extreme climatic events and inter-annual variability has been demonstrated previously. Temperature anomalies as well as modifications in the temporal pattern and quantity of precipitation alter the balance between carbon uptake and release processes and a mechanistic understanding of ecosystem response to such changes is still lacking.

In the present study, the impact of extreme inter-annual variability in summer rainfall and temperature on carbon dynamics in two rotationally-grazed grasslands in Ireland was examined. The sites experience similar temperate climatic regimes but differ in soil drainage characteristics. Eddy covariance measurements of net ecosystem exchange of carbon were complemented by regular assessment of standing biomass, leaf cover, harvest exports and organic amendment inputs. The summers of 2012 and 2013 showed contrasting climatic conditions, with summer precipitation 93% higher and 25% lower respectively than long-term means. In addition, soil temperatures were 7% lower and 11% higher than expected. Cool, wet conditions in 2012 facilitated net carbon uptake for more than ten months of the year at the poorly-drained site, however the ecosystem switched to a net source of carbon in 2013 during months with significantly reduced rainfall. In contrast, net C accumulation continued at the well-drained site despite the summer drought conditions. Total cumulative annual ecosystem respiration was 20% higher at the poorly-drained site than at the well-drained site in 2013, while a more modest increase in cumulative gross production (9.6%) was observed at the poorly-drained site for the same period. This research highlights the susceptibility of poorly-drained soils to accelerated efflux of carbon during soil drying cycles and points towards potential negative impacts of future warming scenarios, with significant carbon balance implications for grassland ecosystems.