Initial Responses of Carbon Cycling to Elevated CO_2 and Warming in Native Semiarid Grassland, Wyoming, USA

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Introduction The effect of climate change on carbon (C) cycling, and potential feedbacks to global warming, constitute major uncertainties in prediction of future ecosystem sustainability. Decomposition of soil organic matter (SOM) pools may be stimulated by warming, but additional allocation of C belowground due to elevated atmospheric [CO_2] may offset warming-enhanced losses. Alternatively, warming may reduce SOM decomposition and if soil moisture becomes limiting, but elevated [CO_2] may ameliorate soil moisture conditions in semiarid grasslands. We measured C pools and fluxes to evaluate global change effects on the C cycle at the Prairie Heating and CO_2 Enrichment (PHACE) facility in Wyoming, USA. Microbial community structure and decomposition experiments demonstrated mechanisms driving C cycle changes.

Methods The native grassland at the PHACE site is dominated by C3 grasses (*Pascopyrum smithii* and *Stipa comata*) with important C4 grass (*Bouteloua gracilis*) and sub-shrub components. Within the 3-m diameter treatment rings, elevated [CO_2] is raised to 600 ppm by direct injection in daytime during the growth season, and air temperature is warmed to +1.5/+3°C day/night year-round with ceramic heaters. [CO_2] treatment started in 2006, warming in 2007, and will continue through 2010. Additional irrigation treatments allow estimation of CO_2 interactions mediated by soil moisture.

We measured net ecosystem exchange (NEE) of CO_2, gross primary production (GPP), and ecosystem respiration (Re) using a canopy gas exchange chamber, and soil respiration (Rs) using CO_2 concentration gradients and a closed chamber technique. Stable isotopes indicated the source of CO_2 in soil respiration (labile vs. stable C). Soil samples were collected near peak biomass. Laboratory incubations at 25C were used to determine active and slow SOM pool sizes and mean residence times (MRT). Quantitative PCR was used to assess microbial community structure.

Results and discussion Rates of C cycling were increased by elevated [CO_2], warming and irrigation. Additions of irrigation water immediately stimulated Re, and later GPP, and elevated [CO_2] further enhanced the component C flux rates. During the first year of elevated [CO_2], ecosystem and soil respiration were enhanced more than was GPP, leading to lower net C uptake rates under elevated [CO_2] than ambient conditions. Isotope partitioning will demonstrate the proportion of Rs derived from recent plant inputs vs. older soil organic matter. We speculate that enhanced respiration may be derived from priming (enhanced decomposition) of older SOM by labile C substrates allocated belowground in the elevated [CO_2] treatment.

The ecosystem warming treatment stimulated decomposition in the laboratory experiment, leading to lower MRT of SOM in the 5-15 cm soil depth. If this effect continues in future years, SOM storage rates could decline in a warmer climate. Warming also increased the fungi:bacteria ratio, possibly because fungi are more tolerant of warmer and drier conditions. Stable isotopic composition of microbial CO_2 suggested that warming enhanced the loss of labile C. Interactions between SOM quality and microbial community composition are expected to continue to adjust as global change treatments continue, making long-term predictions uncertain.

Conclusions Responses of C cycling to the first year of elevated CO_2 and warming in native semiarid grassland suggested that C storage in soils could be reduced in a future greenhouse world. If woody plants or grasses with lower litter qualities are favored by elevated CO_2 or warming, as suggested in a companion experiment, reductions in C storage could be offset. We anticipate that our long-term experiment will help reduce uncertainties of climate-C cycle feedbacks associated with soil processes.