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Rising atmospheric CO_2 effects on productivity: Feedbacks from soil moisture and species change in mesic, semi-arid, and arid systems

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Ecosystem responses to rising atmospheric CO_2 concentration are regulated by interactions with independent variables including climate and soil type, which set broad bounds on plant and soil water relations and the regional species pool. Local climate, soil moisture, and species composition and change are reciprocally coupled to ecosystem functional properties, for example aboveground net primary productivity (ANPP). Three CO_2 manipulation experiments in mesic, semi-arid and arid ecosystems were compared for the role that water and soil played in ecosystem responses to CO_2 enrichment. Results from a CO_2 experiment on mesic grassland (850 mm yr-1 precipitation) on three soils in Central Texas, USA show that ecosystem change (ANPP response to CO_2 enrichment to 500 μL L-1) was greatest on soils where elevated CO_2 increased soil moisture and favored a productive dominant grass species. Ecosystem change was muted on soils where both feedbacks were not present. Soil moisture and species change feedbacks were also present in semi-arid shortgrass steppe in Wyoming, USA (400 mm yr-1 precipitation). CO_2 enrichment to 600 μL L-1 increased soil moisture by 12%, ANPP by 33% and aboveground biomass of C3 grasses by 34%. However, soil moisture and species change feedbacks were both absent in Mojave Desert (135 mm yr-1 precipitation). Here, CO_2 enrichment to 575 μL L-1 caused no effect on ANPP, species composition, or soil moisture in most years, but did increase soil carbon. Together these experiments suggest that CO_2 effects on ANPP may be greater when there are feedbacks from CO_2 effects on soil moisture and species change. However, these feedbacks may vary in their effects on other aspects of ecosystem function such as soil carbon. The results also demonstrate mechanisms by which soils will likely cause spatial variation in CO_2 effects on ANPP and other aspects of ecosystem function.