CHAIRS' SUMMARY PAPER: Climate Change - Implication and Role of Grasslands

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It is apparent that the composition of our atmosphere has changed, in particular, concentrations of the greenhouse gases carbon dioxide, nitrous oxide and methane have increased significantly in the past 100 years due to anthropogenic emissions. Although these changes may be responsible for current global warming (1), less certain is the impact that projected concentrations will have on the climate. Even more ambiguous is the role of grassland ecosystems in this global picture of climate and atmospheric change. Shifts in plant productivity, forage quality and species composition in response to changing temperature, moisture and atmospheric CO_2 concentration may affect both the economic viability and ecological functioning of managed and native grasslands. These changes may, in turn, alter the role that grasslands, including their herbivores, play in the global carbon budget.

Much of the research to date on the grassland - climate change linkage has focussed on the physiological responses of plants to changing CO_2, temperature, water and nitrogen resources. In an invited paper, Jones drew several tentative conclusions regarding these plant responses. Published studies suggest that the above ground productivity of C_3 grasses and forbs increases, on average, 0.10-0.12% per ppm of increased CO_2 concentration. Poster presentations reported productivity increases of 30-50% for C_3 species with a doubling of CO_2 and elevated temperature (Lilley et al.; Bolger et al.; Boote et al.). Jones pointed out that temperature alone has a significant impact on production, where a 3%C increase equates to doubling of the current CO_2 concentration. However, the combination of these factors was not cumulative. Although species with the C_4 photosynthetic pathway are thought to be unresponsive to increased CO_2, several posters (LeCain and Morgan, Boote et al.) reported significant productivity increases for C_4 species, although still less than those of C_3 species.

Based on single species physiological studies, Jones concluded that temperate grasslands may have already had an increase in yields of 7.5-9% since pre-industrial times in response to rising CO_2 concentration. Modelling grassland productivity in response to increased CO_2 and climate change showed varied results. Fuhrer and Riedo showed that temperate managed grasslands (Switzerland) will increase by 6-24%, while Sasaki et al. predicted decreased yields in many regions of Japan. The scaling up of plant responses to enriched CO_2 often requires using functional group responses, such as native and introduced perennial grasses. However, it was discussed that this approach may not be appropriate at smaller spatial scales where individual plant species responses vary widely.

Jones suggested several limitations of these physiological studies. First, there are complex interactions under field conditions between CO_2, water and nitrogen limitation, that are not addressed in many studies. Skinner et al. reported a significant species (legume, C_3 and C_4) by treatment (CO_2 concentration and soil nitrogen level) interaction. As Owensby stressed in his invited paper, CO_2 enrichment may alleviate moisture stress for both C_4 and C_3 species, but it may also aggravate soil N limitation. Second, species respond individually to increased CO_2. Jones concluded that it was useful to group species into "functional groups" to gauge plant responds to climate change. However, attempts to group C_4 grasses (LeCain and Morgan) and Australian C_3 grasses and forbs (Bolger et al.) into useful groups based on responsiveness to increased CO_2 failed. Finally, Jones concluded that we cannot currently predict the response of a mixed species sward to elevated CO_2 from single species stands or experiments, a conclusion echoed by Lilley et al. Although elevated CO_2 and climate change may cause shifts in productivity, drought sensitivity and forage quality within species, the differences in these traits between species (e.g., legumes vs grasses, or C_3 vs C_4) are often much greater. As a result, shifts in species composition in response to climate change may dominate over the effects of intraspecific plasticity documented by many physiological studies.

The invited paper by Owensby reiterated many of these points, but went beyond the individual species and plant community levels to discuss the overall ecosystem response of grasslands to CO_2 enrichment and climate change. In CO_2 enrichment experiments with tallgrass prairie in Kansas (USA), Owensby's group has observed a strong interaction between moisture limitation and CO_2, with dominant C_4 grasses showing increased photosynthetic rates of up to 50% under dry conditions. Increased water and nitrogen use efficiency occurred for both C_3 and C_4 species, and in Owensby's case, favoured the C_4 grasses. These changes have consequences for both soil processes and herbivores.

Owensby reported large increases in both root biomass and soil organic matter (SOM) in response to CO_2 enrichment at their tallgrass prairie site. The ability of forests to store carbon and serve as a sink for carbon dioxide has been widely discussed, but both temperate and tropical grasslands have a large capacity to store carbon in soil organic matter (Scharpenseel and Becker-Heidmann). In this regard, grasslands are suggested to be as important as forests, contributing about 23% to the captured and stored carbon flux annually (2). The study by Oku et al. of net annual CO_2 fluxes from Japanese pastures underscored, however, the variability in grassland C fluxes.

There are limitations to carbon sequestration in grassland soils. Soil respiration may increase with warming, a pattern seen in the negative correlation of SOM quantity and annual temperature (3). Hence, climate warming would lessen the mitigation role of grasslands. The direction of precipitation changes will also affect soil respiration and carbon balance. As water-use efficiency increases with increased CO_2 concentrations, soil moisture levels may increase, altering fluxes of greenhouse gases. Increased root biomass and labile SOM will also affect microbial activity.

Grasslands in tropical regions offer considerable potential in building SOM by sequestering carbon in deep root systems (4). Unfortunately, one conclusion of this session was that most of the research on grassland responses to elevated CO_2 and climate change has occurred in temperate regions. Grasslands may be important in mitigating tropical deforestation, but key studies addressing the methane from termites following clear cutting are few (5). Reducing methane emission from grassland ecosystems, which include grazing ruminants, may be yet another mitigation strategy. Ruminants contribute roughly 15% of the annual global emissions of methane (Owensby), a level that might be reduced by modifying rumen fermentation and grazing management (McCaughey et al.)

Owensby stressed the role of management in predicting grassland responses to climate change. Although grazing animals are central to grassland ecosystem functioning, they have not been incorporated into CO_2 enrichment experiments and models to date. The increased forage production widely predicted in response to CO_2 enrichment may not compensate for the decreased forage quality (increased neutral detergent fibre and decreased protein) that Owensby and others have observed. In addition, Skinner et al. reported that elevated CO_2 and the resulting increased carbohydrate reserves of plants did not improve plant regrowth potential following defoliation. Decisions regarding stocking rates, which lands are grazed, and the conversion of grassland to arable land or other uses will have larger impact on grassland C storage than climate change and CO_2 enrichment. Generally, any perturbation of the system will have an enormous impact on the role of grasslands in C cycling. Therefore, sequestering atmospheric CO_2 via root carbon inputs into grassland soils requires a long-term commitment from land managers and policy makers.

Future studies incorporating field scale, multi-species and interactions between CO_2, temperature and nutrient would help to unravel questions about changing composition of plant communities. However, the usefulness of functional groups at a community level is yet unclear. Jones recognized the need for improvements in modelling ecosystems, where validation is critical and relies on an underlying knowledge of community responses. Another area not well understood is that of plant acclimation to enriched CO_2. There is also a gap in our understanding of some indirect effects of elevated CO_2 on grasslands, such as the impact on diseases (Chakraborty) and insects.

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