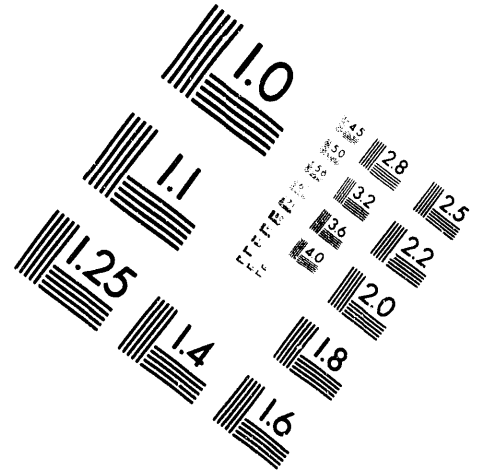
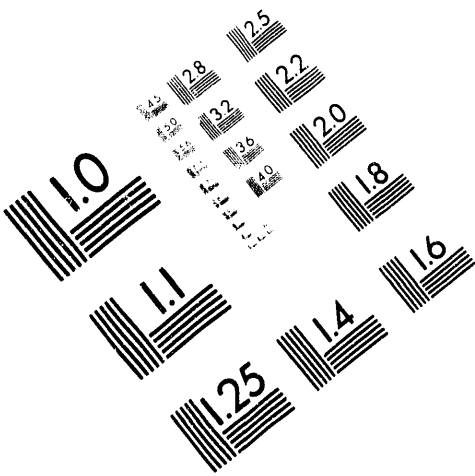




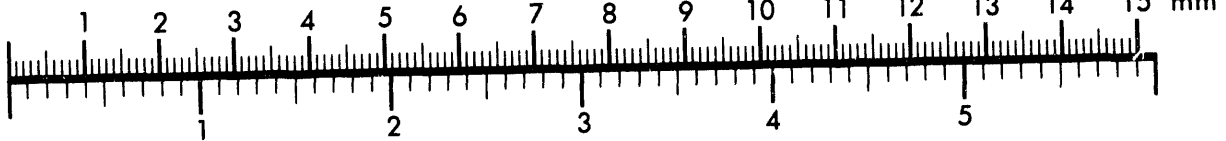
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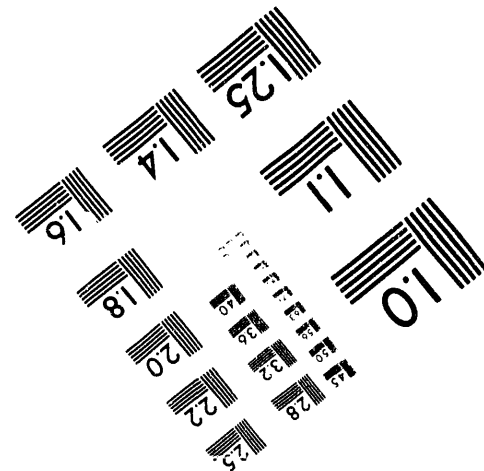
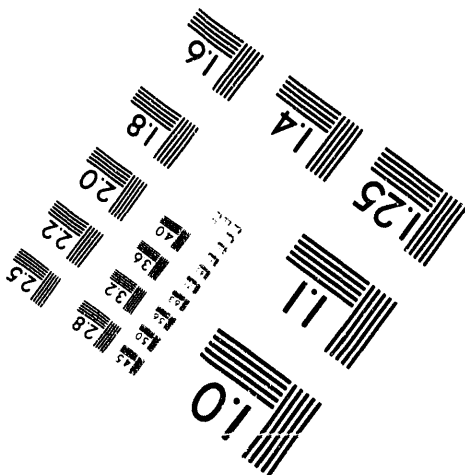
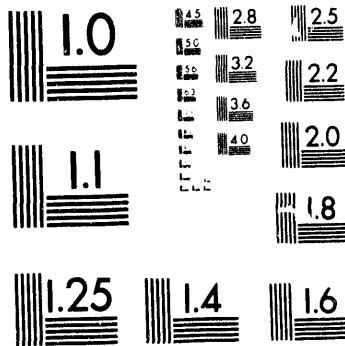
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Progress Report

1993

Rangeland - Plant Response to Elevated CO₂

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Progress Report

Rangeland - Plant Response to Elevated CO₂

Summary

Plots of a tallgrass prairie ecosystem were exposed to ambient and twice-ambient CO₂ concentrations in open-top chambers and compared to unchambered ambient CO₂ plots during the entire growing season from 1989 through 1992. Dominant species were *Andropogon gerardii*, *A. scoparius*, and *Sorghastrum nutans* (C₄) and *Poa pratensis* (C₃). Aboveground biomass and leaf area were estimated by periodic sampling throughout the growing season in 1989 and 1990. In 1991 and 1992, peak biomass and leaf area were estimated by an early August harvest. Relative root production among treatments was estimated using root ingrowth bags which remained in place throughout the growing season. Latent heat flux was simulated with and without water stress. Botanical composition was estimated annually in all treatments. Compared to ambient CO₂ levels, elevated CO₂ increased production of C₄ grass species in 1989-1991, but in 1992, a wet year, there was no difference in C₄ biomass production among treatments. Biomass production of C₃ grass species did not differ among treatments any year. Species composition of C₄ grasses did not change, but *Poa pratensis* (C₃) declined, and C₃ forbs increased in the stand with elevated CO₂ compared to ambient. Open-top chambers appeared to reduce latent heat flux and increase water use efficiency similar to elevated CO₂ when water stress was not severe, but under severe water stress, chamber effect on water use efficiency was limited. In natural ecosystems with periodic moisture stress, increased water use efficiency under elevated CO₂ apparently would have a greater impact on productivity than photosynthetic pathway. Root ingrowth biomass was greater in 1990 and 1991 on elevated CO₂ plots compared to ambient or chambered-ambient plots. In 1992, there was no difference in root ingrowth biomass among treatments.

Nitrogen and phosphorus concentrations in Ange, Popr, and forb aboveground biomass were estimated by periodic sampling throughout the growing season in 1989 and 1990. In 1991 and 1992, N and P concentrations in peak biomass were estimated by an early August harvest. N and P concentration in root production among treatments was estimated using root ingrowth bags which remained in place throughout the growing season. Above- and belowground biomass total N and P were calculated as a product of N concentration and peak biomass by groups. As a rule, N concentration in 1989-1991 of Ange and forb aboveground biomass was

lower and total N higher in elevated CO₂ plots than in ambient CO₂ plots. In 1992, N concentration and total N did not differ in Ange and forb biomass. N concentration in 1989-1992 of Popr aboveground biomass was lower in elevated CO₂ plots than in ambient, but total N did not differ among treatments. In 1990, N concentration in root ingrowth bag biomass was lower and total N greater in elevated CO₂ than in ambient CO₂ plots. Root ingrowth bag biomass N concentration did not differ among treatments in 1991, but total N was greater in elevated CO₂ plots than in ambient CO₂ plots. In all years, total P in aboveground Ange and root ingrowth bag biomass was greater under elevated CO₂ than ambient. P concentration and total P in Popr usually was similar among treatments. Increased biomass production of C₄ plants under elevated CO₂ compared to ambient likely diluted the available N, but it is likely that carboxylation enzyme may have been responsible for a part of the reduction in N concentration. We plan to measure Rubisco and PEPc concentration during 1993. Increased carbon allocation below ground appeared to increase P uptake, probably mediated through increased mycorrhizal activity. Reduced N concentration in above- and belowground biomass will influence herbivory and reduce litter decomposition rates.

Forage quality was estimated on samples collected for biomass production and on samples collected using esophageally-fistulated sheep. Samples from elevated CO₂ treatments were higher in acid detergent fiber (ADF) and lower in in vitro dry matter digestibility (IVDMD) than samples collected from ambient CO₂ plots. Diet samples collected by esophageally-fistulated sheep were lower in ADF and higher in IVDMD than those hand-clipped, but diet selection by the sheep did not affect the relative differences in forage quality among treatments. Therefore, we conclude that diet quality for ruminants will be reduced under elevated CO₂.

Ange plants exposed to elevated CO₂ had a higher photosynthetic rate at internal CO₂ levels from 150 to 800 ppm than plants exposed to ambient CO₂ in 1990, a dry year, but in 1992 did not differ. The increased photosynthesis in 1990 appeared to be from a more efficient photosynthetic system, since photosynthetic rate was higher under elevated than ambient CO₂ at light intensities from 500 to 1750 $\mu\text{mol m}^{-2} \text{s}^{-1}$ when exposed to 350 and 700 ppm CO₂ atmospheres. Dynamic stomatal response of Ange stomates to sun/shade events was altered by elevated CO₂. Ange stomates tended to open and close more rapidly under elevated CO₂, thereby imparting an increased water use efficiency. We estimated that there was an 8% increase in water use efficiency due to the more rapid response of stomates of Ange. Midday

and diurnal xylem pressure potentials indicated that there was less water stress for Ange plants exposed to elevated CO₂ compared to ambient CO₂.

Soil microbial biomass carbon and nitrogen were higher under elevated CO₂ early and late in the growing season when carbon translocation was greatest in the tallgrass prairie ecosystem. Soil respiration was much higher under elevated CO₂ than ambient, indicating a significant increase in carbon allocation below ground under elevated CO₂.

CENTURY ecosystem model output using data collected during the first three years of the study to parameterize the model indicated that soil carbon will likely increase, N mineralization decrease, and litter decay rates decrease with elevated CO₂. Ecosystem sensitivity to the temporal and regional resolution of climate change (changes in annual mean climate vs. seasonally varying changes) was evaluated by driving a regional ecosystem model with two different general circulation model (GCM) climate outputs, Canadian Climate Center and the Geophysical Fluid Dynamics Laboratory models as described in the 1990 IPCC report (Houghton et al., 1990). The grassland model of CENTURY (Parton et al., 1987, Parton et al submitted), was used for the simulations of aboveground net primary productivity (NPP) and soil organic carbon (SOC) for 31 sites across the globe. CENTURY simulations for each site were run to equilibrium (approx. 5000 model years) based on current climatologies. We tested the sensitivity of grassland ecosystems to the following global change effects:

- climate change effects (+CC, i.e., alternations to temperature and precipitation);
- double CO₂ response (+CO₂, i.e., modified plant production response by increasing plant production rates due to changes in potential evapotranspiration rates and nitrogen use efficiency to increased atmospheric CO₂ concentrations;
- combined effect of climate change and doubling of atmospheric CO₂ (+CC+CO₂)

We modified the plant production parameters under a 2 X CO₂ climate by changing production relative to potential evapotranspiration PET and to nitrogen use efficiency (NUE). The magnitude of the effect is to cause a 20% increase in plant production with a change in atmospheric CO₂ concentration from 350 to 700 ppm. The effect of modified NUE and PET on plant production is a simple linear effect on these processes. In addition, with changes in NUE, litter quality of the resulting plant material produced is lessened. This results in a slower decomposition of this material under a given temperature and moisture conditions. The net

result of the CO₂ and climate change impacts will depend on the increase in decomposition rates with climate derived changes, the effect on decomposition rates due to biotic feedbacks of lower litter quality material, changes to decomposition and plant production due to altered soil water dynamics due to plant mediated ET, and net change in plant inputs into the soil system.

Future research plans include a more detailed analysis of the GRASS model developed by Dr. Michael Coughenour linked with CENTURY to evaluate the CO₂ impact of grassland dynamics. The modelling activities will further investigate the sensitivity of different grassland communities (e.g., C₃ communities relative to C₄ communities). This will entail refinements in the species level parameterizations relative to the CO₂ impact on plant C fluxes. This will be conducted in conjunction with Drs. Coughenour, Parton and Ojima using both CENTURY and GRASS.

Below is a listing of the papers that have been written on research completed on the project. Recent papers that are in press or review from work completed on the project are printed in their entirety.

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