Grazinglands & Global Climate Change: What is the Science Telling Us?
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Photos by Sam Cox
Greenhouse Gases Important in Earth’s Energy Balance

Estimate of the Earth’s annual and global mean energy balance (Kiehl and Trenberth 1997; Le Treut et al. 2007).
Link Between GHG & Climate Change

Increases in concentrations of these gases since 1750 are due to human activities in the industrial era (USGCRP 2009).

Increases in annual global surface temperature (over both oceans and land) since 1880. Red bars indicate temperatures above and blue bars represent temperatures below the average temperature period 1901–2000. The black line is atmospheric CO₂ concentration in parts per million (USGCRP 2009).
Projections of future temperature from 16 climate models. The maps feature a higher and lower greenhouse gas scenario. Brackets on the thermometers represent likely ranges of model predictions (USGCRP 2009).

The future is predicted to be decidedly warmer, with the actual outcome depending on the particular scenario and region.
Projected future changes in precipitation as simulated by 15 climate models. Confidence in projected changes is highest in hatched areas (USGCRP 2009).

Generally higher precipitation predicted for northern latitudes and less for southern latitudes, depending on time of year.
Warmer temperatures:
Longer growing season, phenology, pests
Altered hydrologic cycle (intense rainfall events, timing, more rainfall, more drought)
Differential species responses (diverse & individualistic species responses)
Temperature
- Reaction rates
- Evaporation

Plant Production
Often no response to warming
(Dukes et al. 2005; Klein et al. 2007; Pendall et al. 2010)

Positive
- Longer growing season
- Increased growth rates
- Greater N mineralization

Climate Zone
Humid to sub-humid
Temperate to boreal

Negative
- Desiccation
- Shorter growing season
  - water constrained
  - phenology

Climate Zone
Semi-arid to arid
Tropical to temperate
Direct responses of plants to increased atmospheric CO$_2$

Photosynthesis
Species effects
Functional types
$C_3$ vs $C_4$

Leaf Conductance
Water Relations
leaf transpiration
leaf & soil water dynamics
Higher WUE

Rangeland CO$_2$ Enrichment Experiments

- **Colorado Shortgrass**
- **Texas Prairie**
- **Kansas Tallgrass**
- **California Annual Grassland**
- **Free Air CO$_2$ Enrichment in Mojave Nevada**
Prairie Heating & CO₂ Enrichment Experiment

Infra-red Heater

Infra-red Radiometer

Free Air CO₂ Enrichment (FACE) Ring
Variety of Plant Responses to CO₂


- Colorado Shortgrass: Up to a doubling of productivity results from doubling ambient CO₂...tied to SWC. C₃ grasses and sub-shrub NPP increased; C₄ grasses did not respond. (Morgan et al. 2007. PNAS 104:14724-14729)

- Kansas Tallgrass: Plant Productivity increases in dry years, C₄ grasses respond; Forbs (C₃) and Cyperaceae spp. (C₃) most responsive to CO₂ over long term. (Owensby et al. 1999. Global Change Biology 5:497-506)

- Wyoming Mixed-grass Prairie: Combined warming and higher CO₂ increase especially C₄ grass production over 25%.

- Texas Tallgrass: CO₂ increased SWC and caused C₄ grass spp. shifts as if from mid-grass to tallgrass prairie. Responses varied in different soils. (Polley et al. 2012. Global Change Biology 18:700-710)
Climate Change/CO$_2$ likely leading to plants species shifts. Example: Woody plant encroachment in SW United States

Mesquite ($C_3$ woody legume) encroachment in southwest United States over past two centuries (photograph courtesy of ARS Jornada).

Honey locust tree islands in Kansas Tallgrass Prairie. Present-day encroachment?

Fire removal, overgrazing CO$_2$? CC?

(photograph courtesy of Alan K. Knapp)
Dalmatian toadflax invasion greatly increased under $\text{CO}_2$ enrichment & warming (due to both direct & indirect water-mediated effects of $\text{CO}_2$)

(Blumenthal et al. *in prep.*)
In the northern US, increased temperatures will likely improve livestock productivity (Baker et al. 1993, Echkert et al. 1995, Rotter and Van De Geijn 1999)

- Increased forage production
- Milder winters

Derek Bailey, New Mexico State University
In the southwest, livestock producers may need to change management if temperatures increase:

- Develop more water and shade
- Use heat adapted breeds (e.g., Brahmans, Senepol, Tuli)

Derek Bailey, New Mexico State University
Forage Availability & Quality

• Seasonality of production

• Species shifts

• Nutrient cycling
Conclusions

• CC/CO$_2$ have likely already affected world rangelands.

• Impacts on plant production and species shifts variable;
  – current climate, plant community, soils and management....complicated!

• CC/CO$_2$ likely increasing vulnerability to species shifts, including weed invasions.

• Forage quality is vulnerable.
Conclusions

• Southern latitude rangelands may be more vulnerable.

• Variability in weather patterns, including more extreme weather is likely to lead to increased uncertainty.