Shortgrass Steppe Long Term Ecological Research

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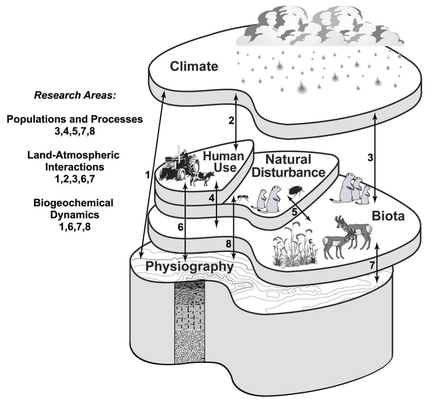
SGS-LTER

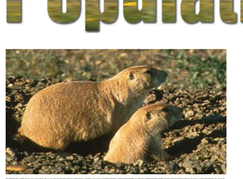
The shortgrass steppe (SGS) Long Term Ecological Research (LTER) site is part of a network of long-term research sites supported by the National Science Foundation. The network consists of 26 sites representing diverse ecosystems and research emphases, yet maintaining a common mission and sharing expertise and data.

We assert that the ecological structure and function of the shortgrass steppe is governed by climate, human use, natural disturbance, biota and physiography. Our conceptual framework, right, depicts the relationship between these factors and our core research areas.

Determinants of SGS Structure and Function:



Population Dynamics

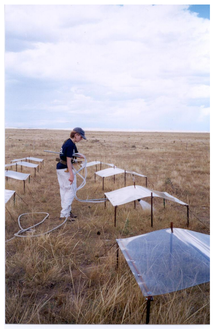


Work in this area is organized by the idea that two kinds of populations are most important in the long-term dynamics and sustainability of the SGS. The first are dominant species, such as the shortgrass blue grama (*Bouteloua gracilis*) which overwhelmingly dominates the vegetation of the SGS. The second type of important populations are those that have a large effect on the ecosystem because of their unique traits. Populations of interest for the SGS LTER are prairie dogs (*Cynomys ludovicianus*), prickly pear cactus (*Opuntia polyacantha*), and invasive plant species.

Research Findings:
- Blue grama is the largest contributor to biomass and net primary production.
- SGS has a long evolutionary history of herbivory. Vegetation has adapted to grazing, and is among the communities most resistant to grazing in the world.
- Spiny growth form of prickly pear cactus affords protection from grazing to other species, serves as a refuge for seed production, and provides a degree of resilience to heavy grazing and other disturbances, and therefore may have a large effect under cattle grazing.
- The SGS has so far proved resistant to invasion by exotic plant species. They are found along roadsides but very seldom in undisturbed areas.
- Prairie dog colonies are a key feature of SGS landscapes for maintaining species assemblages.
- Cattle neither avoid nor prefer grazing on prairie dog towns.
- Black-tailed prairie dogs continue to forage throughout the winter and practice facultative torpor during severe cold and dry periods. The size of colonies has expanded exponentially during the last 10 years of monitoring.
- Small mammal populations can vary greatly year-to-year, but declined during the drought of the last five years.
- Long term monitoring has shown that some organisms respond positively (e.g., mountain plover and blue grama) to grazing while others respond negatively.

Current Endeavors:
- Selective herbivory and granivory by small mammals, although quantitatively little, may have as much effect on plant diversity as the grazing by cattle. We are monitoring plants and soils inside and outside large, and large+small mammal exclosures.
- Even though SGS has proven resistant to exotic species, we propose to continue surveying for invasive species and attempt to identify the factors contributing to success of invading species.
- Small mammal monitoring
- Examination of prairie dog dynamics as affected by plague

Land-Atmosphere Interactions

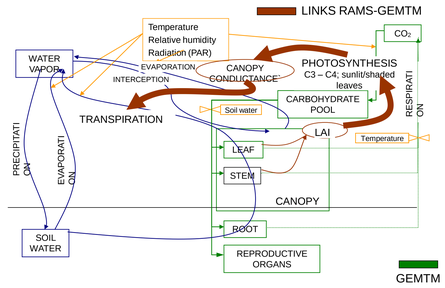


Variables influencing the SGS include water availability, heat transfers and carbon fluxes; much of our work focuses on ecosystem responses to and influences over these factors. This includes the study of how ecosystem processes in SGS influence regional dynamics (e.g., trace gas emissions and sinks, radiative and water balance influencing climate), and feedback interactions with human impacts.

Research Findings:
- Bowen ratio energy balance measurements show that while recommended livestock grazing practices generally have only minor impacts on net ecosystem CO_2 exchange, cattle grazing substantially reduces the capacity of shortgrass steppe to assimilate CO_2 during drought.
- Coarse-textured soils have a larger deep water resource than fine soils, and are associated with a greater cover of shrubs. Additional water in coarse soils results in higher plant productivity.
- Bare soil evaporation influenced soil water content to a depth of 40 cm in all textures, in contrast to previous assumptions that bare soil evaporation only influenced the top 10-20 cm.
- The evaluation of surface heat content as 'moist enthalpy' provides a more complete measure of heat content and varies significantly during the growing season between locations just a short distance apart.

- The conversion of landscape from the 'natural' to the 'current' landscape has been shown with the high resolution model version of GEMRAMS to result in significant changes in surface heat and moisture fluxes at the SGS LTER. The same modeling approach is being applied at the SGS LTER.

Current Endeavors:
- One of the most important alternations that has occurred and continues to occur on the SGS LTER is land use change. We will continue to evaluate the interactions of human land use, biotic responses, and atmospheric processes at scales from local to regional. We will also evaluate micrometeorological methods for their ability to accurately monitor fluxes of mass and energy.



Cross-Site Projects

SGS LTER has a substantial involvement in cross-site work with other LTER sites and institutions. These activities enrich our science at a local scale by providing important context, and allow us to extrapolate short- and long-term site level studies to larger spatial extents and longer time scales. Examples of cross-site projects include a study of nitrogen mineralization across a Great Plains precipitation gradient, isotopic analysis of carbon and water fluxes comparing grassland, forest and tundra systems, examination of the influence of soil organic carbon and soil texture on nitrogen retention along a north-south Great Plains gradient, and comparison of the origin and paleoclimatic significance of loess deposits in eastern Colorado and western Nebraska.

Education

We support a variety of programs for students of all ages. The NSF Schoolyard LTER allows students and teachers from nine schools in Colorado to conduct related research under the guidance of LTER scientists. Research Assistantships for Minority High School Students (NSF) allows students from under-represented minority groups to participate in summer research projects at the university. The NSF GK-12 program pairs graduate students in science with K-12 teachers to provide teaching and research experience, respectively. The Center for Learning and Teaching is a new NSF program that will provide teacher professional development and research on how the different ways of knowing and learning for students from different backgrounds influence teaching and learning. The NSF Teacher Enhancement program provides a summer research internship for K-12 teachers. The Teachers on the Prairie program is designed to provide K-12 teachers with focused professional development in prairie ecology.

Biogeochemistry

Work in this area focuses on the key abiotic and biotic variables that control biogeochemical dynamics, including primary productivity, nutrient cycling, and nutrient input and export, including trace gas fluxes. The key abiotic factors are water availability and temperature, as they vary across landscapes and regions. The key biotic variables are the presence and distribution of individual plants and the composition of plant communities.

Research Findings:
- The majority of biomass on the SGS is belowground, so estimates of belowground net primary production are important. BNPP estimates may be influenced by ^{14}C in soil 1) embedded in growing roots, 2) a small proportion of roots that live a much longer time than the majority, and 3) methods of separating roots from soil organic matter.
- Experimentally doubling CO_2 concentration caused enhanced production on the SGS, ranging from 20% in 1998 to 71% in 2000, among the highest increases reported in grassland CO_2 enrichment studies. Physiological measurements suggest that water use efficiency is one of the major causes. CO_2 enrichment leads to large increases in BNPP. Trace gas flux data showed no detectable CO_2 effect on ecosystem respiration, CH_4 oxidation, or emissions of Nox and N_2O.
- Water, N, daytime temperature, and their interactions are important controls of trace gas flux, N mineralization, decomposition, and total C and N. Alteration of resource availability has immediate consequences on the biogeochemistry of the SGS.
- An investigation of alluvial terraces soils as old as 600,000 y indicates that significant changes in chemical constituents occur over geologic time scales. Changes are a function of a slow rate of primary mineral weathering and the atmospheric deposition of several elements, resulting in losses of Si and net accumulations of Ca, Fe, and Al in soils over time.
- Biogenic silica storage in grassland soils is inversely related to aboveground production, suggesting transformation or loss of this material occurs at higher mean annual precipitation zones. Shortgrass steppe ecosystems have greatest accumulations of biogenic silica in soil and the lowest storage in biomass; tallgrass ecosystems have greatest storage in biomass and lowest accumulation in soils.
- Assuming a relative constancy of atmospheric dust inputs, mass balance calculations show that cycling of Si through grasses should enhance weathering of primary minerals at the SGS.

Current Endeavors:
- Long-term annual sampling of NPP and plant N
- Response of shortgrass steppe to fluctuations in precipitation, temperature, and nitrogen availability
- Experiment to separate the effects of soil texture and topography on NPP and nutrient turnover dynamics.
- Long-term studies of nutrient enrichment on biogeochemistry
- Investigation of silica cycling by grasses and the affect on silicate mineral weathering, CO_2 consumption and silica export to rivers and oceans
- The effect of urbanization on shortgrass steppe ecosystems

Synthesis

SGS LTER is involved in many synthesis activities through review papers, modeling, and our synthesis book, Ecology of the Shortgrass Steppe: Perspectives from Long-Term Research. We recently published a new model of SGS trace gas fluxes, analyzed the role of grazing in influencing regional climate, developed a model that integrates grazing and belowground processes, reviewed the role of prairie dogs in the Great Plains, and evaluated the relationship between BNPP and environmental variables. We contributed to development of the CENTURY global model, the daily CENTURY model (DAYCENT), and the TRAGNET global data set for trace gas fluxes.