Long-Term Ecological Research on Colorado Shortgrass Steppe

SGS–LTER

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Abstract

The Shortgrass Steppe Long Term Ecological Research (SGS-LTER) project is entering its final year of a more than 30-year history (1982-2014) of research and engagement within the LTER network. During this transition we are simultaneously bringing closure to several of our experiments and expanding our infrastructure in the field to position our community of scientists for future work. New initiatives and infrastructure include the following: 1) a common garden experiment to assess the genetic plasticity and response of the dominant grass species, *Bouteloua gracilis*, to climate change. Field collections were made for our common garden experiment in 2011 and representative plants will be installed at the new SGS Research and Interpretation Center garden this fall; 2) A new grazing experiment designed to investigate the response of shortgrass steppe plant communities (e.g., species composition and abundance) to changing climate and grazer populations; and 3) New rainout shelters to understand more fully responses of the plant and microbial communities to changes in rainfall frequency and abundance. In addition to new science initiatives, our information management team is creating an extensive digital archive of our experimental data and metadata collected during our tenure with the LTER Network, but also undertaking an ambitious effort to capture the history of how and why experimental protocols have changed.

1. Common garden investigation of genetic plasticity and response to climate change

(I) Samples of *Bouteloua gracilis* (blue grama) were collected across its native range during the 2011 field season (Fig. 1).
(II) Plants were maintained in greenhouses over the winter, seeds were collected and various traits measured.
(III) Representatives of the range will be planted in replicate at the new Shortgrass Steppe Research and Interpretation Center where the garden can be used for research and as a demonstration area for classes and other groups visiting the site.

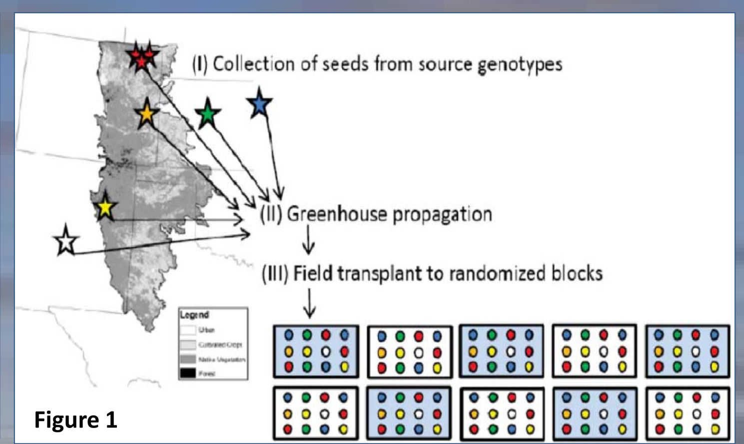


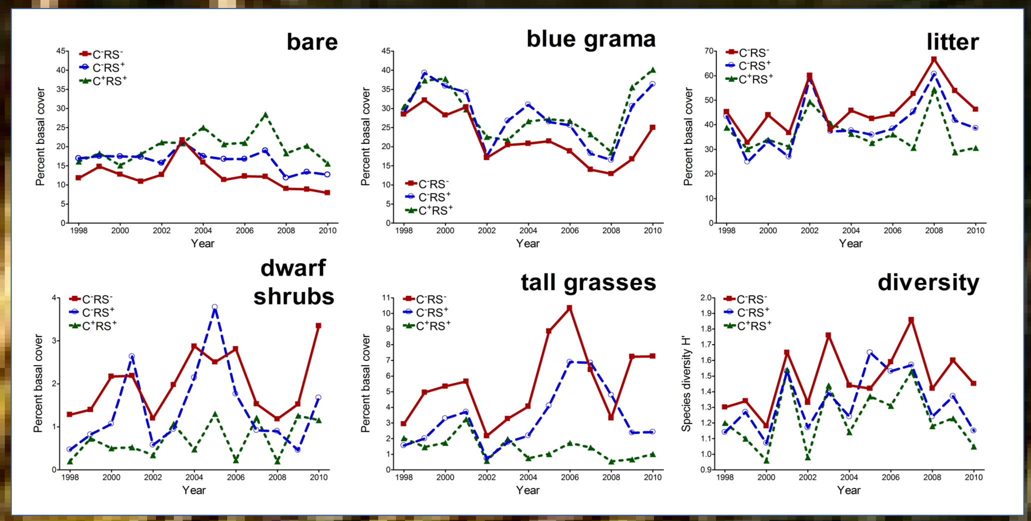
Figure 1

2. Do interactions between large and small herbivores mediate effects of climate change on SGS plant communities?

The effects of cattle grazing on shortgrass steppe (SGS) plant communities are well-established, but the roles of smaller herbivores, such as rabbits and small rodents, remain poorly understood. Small herbivores consume less plant biomass overall, but may be more selective, and may be an important source of soil disturbance. Both of these factors may alter the abundance of rarer plant species, either directly or indirectly, by influencing the dominance of blue grama, the foundation species in this system (Fig. 2). Past SGS-LTER research suggests that climate change may alter the distribution of cool-season grasses and shrubs, especially at the northern boundary of SGS with mixed-grass prairie, and we have evidence of increases over the past decade in the abundance of these plant groups. Herbivory may alter the trajectory of these changes, but the independent and synergistic effects of large and smaller mammalian herbivores are not known. In turn, increases in the distribution and abundance of cool-season grasses and shrubs may alter habitat and food resources for consumers that are sensitive to vegetation structure.

In 2012 we established a new experiment (**CAREX**; **CA**ttle and **R**abbit **EX**closures) to investigate the interactions between small and large herbivores and their effects on SGS plant communities. **The main objective of this large-scale, long-term (10+ years) experiment is to quantify the effects of small and large herbivores, singly and in combination, on plant community dynamics and vegetation structure.** Given recent and projected changes in plant community composition at CPER, we will focus particularly on changes in abundance of cool-season grasses and shrubs. At five separate locations we established a series of four 45-x-45 m plots, representing four treatments that differ in access to cattle (C) and rabbit (R; rabbits). Three plots are exclosures: C-R+, cattle excluded with barbed wire fence; C+R-, rabbits excluded with chicken wire and barbed wire, with individual steers added intermittently to provide grazing; C-R-, both cattle and rabbits excluded by chicken wire and barbed wire. An adjacent plot serves as an unfenced control that is accessible to all herbivores (C+R+). In addition, 10-x-10 m hardware-cloth exclosures will be erected in each plot to separate the effects of rabbits from small rodent herbivores (kangaroo rats, ground squirrels, pocket gophers; S-). In each plot we measure basal and canopy cover, density of cool-season grasses, cactus and shrubs, vegetation height, and shrub area. We also record the density and size of animal burrows and soil disturbances, as well as the number of rabbits and pronghorn pellets as an index of herbivore activity.

Figure 2. Results from one of our long-term grazing experiments (GZTX) revealed different effects of small and large herbivores on % cover of substrate and key plant functional groups and plant species diversity. In this experiment, exclosures eliminated cattle only (C-, blue dashed lines, open circles) or both cattle and all small herbivores collectively (RS-, red solid lines, squares), and therefore could not separate the effects of rabbits (R) from other small herbivores (S). Controls were open to all herbivores (C+RS+, green dotted lines, triangles).



3. How do plant community, soil biogeochemistry and water reserves change with inter-annual variability in precipitation?

The importance of precipitation for explaining spatial patterns in production is best illustrated in the iconic study of Sala et al. (1988). From a database of >9,000 sites across the U.S. Great Plains, they found that mean annual precipitation explained 90% of the variation in time-averaged aboveground net primary production (ANPP). Precipitation also appears to drive the temporal pattern for inter-annual variation in ANPP within sites, but the story becomes more complex and interesting here (see Fig. 3). At both the dry Shortgrass Steppe grassland in eastern Colorado and at the wetter Konza grassland in eastern Kansas, inter-annual variation in ANPP was positively correlated with precipitation, but the slope of the temporal relationships were much shallower such that, in wet years, ANPP under-performed as compared to the spatial pattern, while in dry years ANPP over-performed (Lauenroth, Knapp).

Previous studies have generally attributed the difference between spatial and temporal responses to differences in the local species pool. The reasoning is that, as MAP increases, species sorting effects will entrain new plant species that are better adapted to take advantage of the increased precipitation. For example, the dominant grass on the Shortgrass Steppe, *Bouteloua gracilis*, reaches a maximum height of ~35cm, while the dominant grass at Konza, *Andropogon gerardii*, can grow to >2m tall. While this reasoning works to explain the underperformance of ANPP during wet years, it cannot explain over-performance in dry years. Instead, we argue that the overall spatial-temporal pattern arises because the ANPP of a site is buffered against interannual variability in precipitation as compared to the spatial pattern. This buffering can arise when the legacy of precipitation history allows a local plant community to develop an "infrastructure" for converting precipitation into biomass (Fig. 4). This infrastructure, comprised of plant infrastructure (e.g., root biomass, crown meristems and seeds) soil nutrient dynamics and deep water storage, achieves a magnitude commensurate with the average precipitation of the site. Then during dry years, the relatively large infrastructure allows for greater precipitation capture and growth as compared to a site that is always that dry; likewise in wet years there is insufficient infrastructure to utilize the precipitation as effectively as sites that are usually wetter.

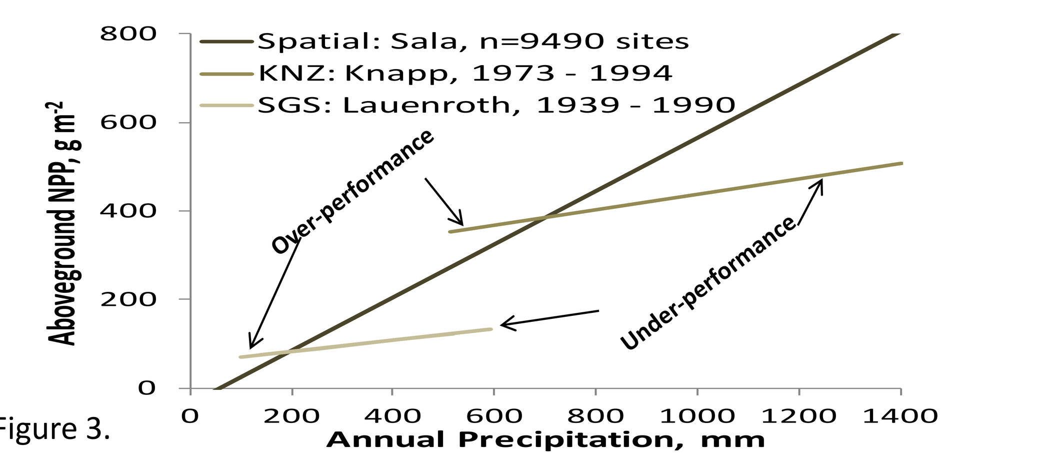


Figure 3.

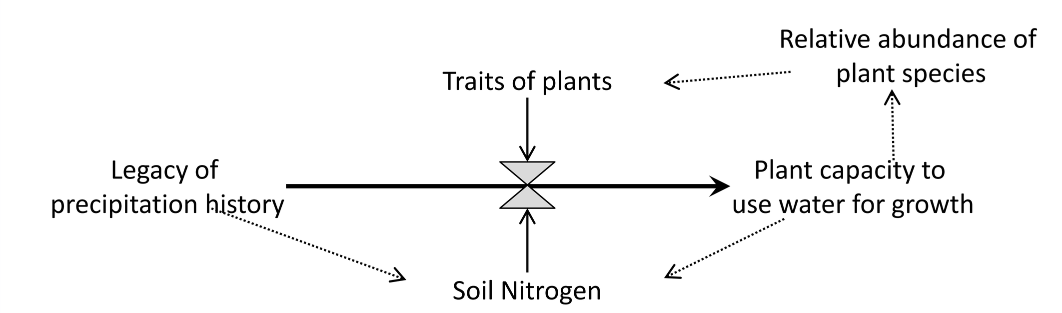


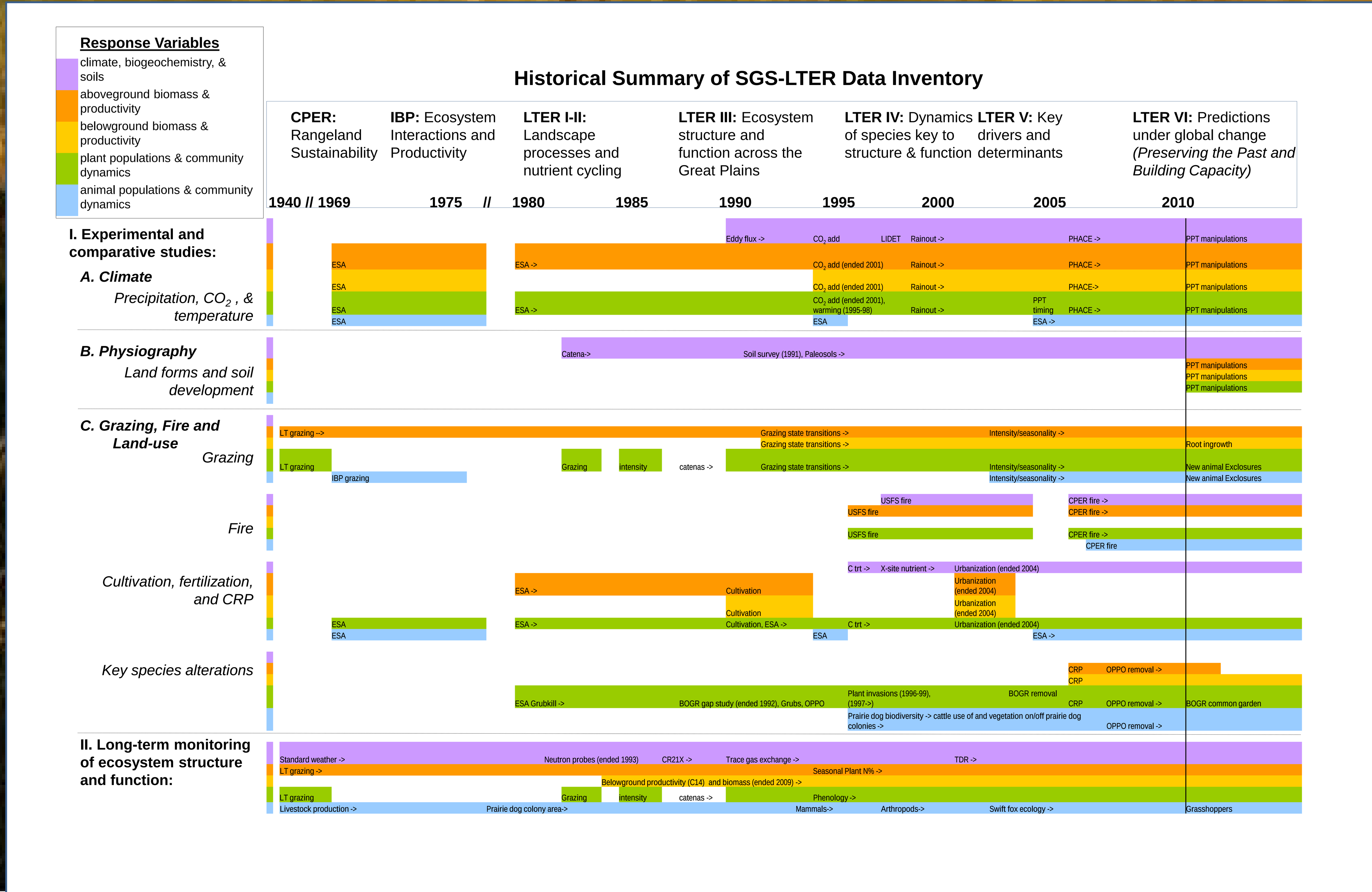
Figure 4.

Information Management

SGS-LTER Information managers work closely with staff, researchers, and graduates students to support data integration, analysis and documentation so that data may easily be re-used. We work closely with the LTER Information Management community to develop and implement best practices and standards for the organization and content of our data packages, which include datasets and required descriptive information in Ecological Metadata Language. Thirty years on, we possess an annotated inventory of over 150 datasets that contribute to the legacy of the SGS-LTER research site (Figure Y). These flagship datasets will be preserved and made available through the LTER Network Data Portal and will be PASTA-ready to be incorporated into the LTER Network Information System. This inventory contains data packages and descriptive information, e.g., abstracts, field and lab protocols, defined units, and related publications. We use a Relational Database Management System to archive data and metadata, build relationships between linked information, and generate EML packages for the LTER Metacat, a metadata catalog available to the LTER Data Portal.

The curation of this information will help build future capacity for understanding the structure and function of shortgrass steppe and other grassland ecosystems around the world. After 30 years of continuous data collection, the termination of the SGS-LTER project presents a unique opportunity to implement innovative pathways so that data, information, samples and other products associated with the SGS legacy remain readily accessible. Many of the founding members of the SGS-LTER are still involved with the project and/or SGS research. These individuals, the scientists and the support staff who have followed them represent an important pool of knowledge about working on the shortgrass steppe ecosystem. We are now collecting supplemental documentation from researchers, as narratives about the research process, to enrich our invaluable archive of SGS-LTER data packages. We are capturing stories about the breakthroughs in the conceptualization of shortgrass steppe ecosystem or influential moments in mentoring students, junior scientists, or support staff. We hope to learn how data processing and changing methodologies can shape results and influence new approaches. Our stories from the SGS-LTER site will strengthen our understanding of how SGS-LTER has contributed to the LTER Network and provide valuable information for future research at the SGS site. Ultimately, as information managers at the SGS-LTER, we provide PASTA-compliant data packages, archive sample inventory, and develop dynamic web content and backend databases to manage and serve data packages and supporting documentation for ecological researchers around the world.

Figure 5. Studies are organized by research areas on the left and presented along a timeline on top. Principal Investigators have produced multiple datasets from their studies over time. Our annotated SGS-LTER data inventory contains 150 datasets related to historic studies prior to the LTER program, core LTER research areas and supplemental research conducted by graduate students and visiting scientists. In the RDBMS and through the LTER Data Portal, longitudinal datasets are integrated and available as a set of records from the course of the study. Metadata is available in EML 2.1.0.



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