SGS LTER Annual Report 2013
DEB 102731

We continue our research activities as described in our proposal and the IM supplement, as well as our efforts to decommission our site and the project. In 2013 our research has led to 28 reports in peer-reviewed journals (25 published, 1 in press and 2 submitted). Our scientists have also completed 7 book chapters. Thirteen abstracts have been provided for meetings of research societies. Two PhD and two MS students have completed their dissertations/theses. Our IM team continues to prepare our experimental data sets for delivery to the LTER Network as part of our decommissioning. To date 100 of 133 datasets have been curated and are available on line. Below are the details for research, IM, outreach and project management.

A. Research Activities

Grazing Studies

Grazing Across a Succession Gradient - There are very few studies of mammalian grazing effects on early seral (abandoned fields, revegetated sites) compared with late seral communities (we are aware of one study), even though grazing effects on successional trajectories of late seral communities has historically been the basis for rangeland condition and trend analysis. There are also few studies of grazing effects on root production (we are aware of five studies) other than ones using temporal summations of positive seasonal increments in biomass from cores, which is known to produce unreliable, biased estimates (Milchunas 2012). We combined two treatments from our long-term grazing treatments study in never-disturbed shortgrass steppe with our CRP study of grazed and ungrazed early-seral (annual weed stage-planted 2003) and mid-seral (planted 1989) grassland in papers about community species composition trajectories, and about ANPP and root biomass (shown in previous annual report, and see current 2013 publications list). The last part of this study during the last years of treatment on the CRP fields has progressed through the laboratory stage where ANPP and BNPP will be used to address basic-research questions concerning plant C and N allocation in response to grazing in the three seral communities. The applied-research aspects of this study have been used to inform FSA in its policy on grazing of CRP and for local ranchers in decisions about fate of CRP lands during this period when many contracts are ending. The broad context of this study is noted in the possibly unique composition of authors on the study's first paper; a LTER scientist, a rangeland management specialist, a rancher, and a Washington DC administrator/economist (Milchunas et al. 2011).

Physiography

Pedology and Ecohydrological dynamics in the Shortgrass Steppe - The contemporary meteorologic history of the shortgrass steppe ecosystem displays great amount of spatial and temporal heterogeneity regarding quantity and quality of precipitation. Short- to long-term soil moisture status reflects both weather and the climatic history across this region, yet the soil hydrologic functioning is dependent upon the intrinsic edaphic properties of the landscape.

Native grasslands and agro-ecosystems of the SGS are particularly responsive to even slight changes in the climatic precipitation regimes, and the ability of soils in these regions to retain water available to plants is also variable between landscapes. Projections of regional climate from the SGS show that temperatures will be warmer and precipitation will become more variable, thus a need has arisen to quantify the historic range of precipitation in the semi-arid regions with specific attention in timing and spatial distribution of lasting droughts.

The complexity of global circulation models and the coarse resolution of projection outputs have limited fine scale biome modeling of ecosystem response to climate change drivers, thus models with more modest number of inputs have become desirable to link climate variability with soil and ecohydrologic responses. To model soil moisture in the shortgrass steppe ecosystem, we have quantified the historic range of soil moisture and hydrologic conditioning to climatic variables with the Newhall Simulation Model (NSM). The NSM is a relatively simple soil moisture model that requires only a few inputs (monthly precipitation, monthly temperature, and soil water holding capacity) and is based upon the Thornthwaite equation of evapotranspiration. By using moderate resolution (4km) prism climate data (PRISM, 2013) and water holding capacity values mined from NRCS soil survey (STATSGO), we have established regional soil moisture estimates for the contemporary record (1895-2012).

This analysis serves as a baseline in understanding the fate and distribution of soil moisture's response to global climate change as well as understanding trends of severe drought in the shortgrass steppe ecosystem. By establishing the efficacy of modeling spatial soil moisture patterns within the contemporary record, we have created a procedure that can be used to project soil moisture responses with estimates of climate change.

Canopy Phenology

Twelve years of high resolution near surface radiometer data provides insight into controls on end of season in a dry grassland - The onset of dormancy has proven difficult to explain in nearly all ecosystems. Most research has focused on the end of season dynamics of deciduous forest ecosystems, where leaf coloration and leaf fall are the primary phenological responses. More complex are the end of season dynamics of grasslands, where the mechanism of dormancy is a gradual response to climatic variables. These complications are magnified in dry grasslands, where the effects of temperature on phenology are modulated by the availability of soil water. Our objectives were to identify the primary drivers influencing the timing of end of season on the shortgrass steppe and determine if the timing of start of season, end of season, or both influences the growing season length of the shortgrass steppe. Specifically our questions are 1) How does temperature, water, or a combination of temperature and water influence the timing of end of season (EOS) on the shortgrass steppe? 2) Is the growing season length (GSL) of the shortgrass steppe influenced by the timing of the start of season (SOS), EOS, or both?

In this study we compare 12 years of plant canopy development. We used two-channel radiometers and measured reflected radiation in the red and near infrared wavelengths on ungrazed shortgrass steppe. Reflectance measurements were polled daily, averaged and stored. We used these data to calculate a response variable, the greenness index (GI). Precipitation, air temperature, soil water and soil temperature were measured daily on-site and nearby. We calculated soil growing degree-days and accumulated chilling days (ACD). We calculated the ratio between soil water content (SWC) and potential evapotranspiration (PET) to represent the demand of water use by vegetation versus atmospheric demand (SW:PET).

A combination of photoperiod (PHOTO), accumulated chilling days (ACD) and volumetric soil water content (VSWC) provided the best explanation for the abiotic drivers of EOS. We found that a regression tree analysis showed that ACD was the primary driver of EOS (Figure 1). Very high values of ACD mean cool temperatures have been accumulating and will drive vegetation towards EOS dormancy. At ACD values close to 0 the vegetation remains in the growing season (GS), depending on how quickly the ACD changes this may include C_4 grasses. If the water demand for plant growth increases, then the vegetation will respond to ACD; the vegetation will enter dormancy. At low values of ACD, then depending on confounding factors such as unseasonably warm days or late season peaks, the vegetation may enter EOS or in some cases may continue to grow (Figure 1).

We found growing season length to be strongly negatively associated to the date of SOS and moderately positively associated to EOS. Growing season length was positively associated with accumulated chilling days (Figure 2). This association would be stronger except for the severe drought year of 2012. The growing season in 2012 was extended into October due to late season moisture accompanied by warm days and cool nighttime temperatures. No significant trend was found between GSL and year, although the positive slope with year hints at a lengthening over time (Figure 3).

The results of our study suggest that photoperiod, temperature and soil water interact to influence the timing of end of season in the shortgrass steppe and growing season length is strongly related to the date of start of season and less so to the date of end of season. Our findings bear important implications for understanding semiarid ecosystems under climate change. Because future precipitation and temperature tend to diverge, understanding responses in seasonality of greenness as well as productivity in general must take both precipitation and temperature into account.

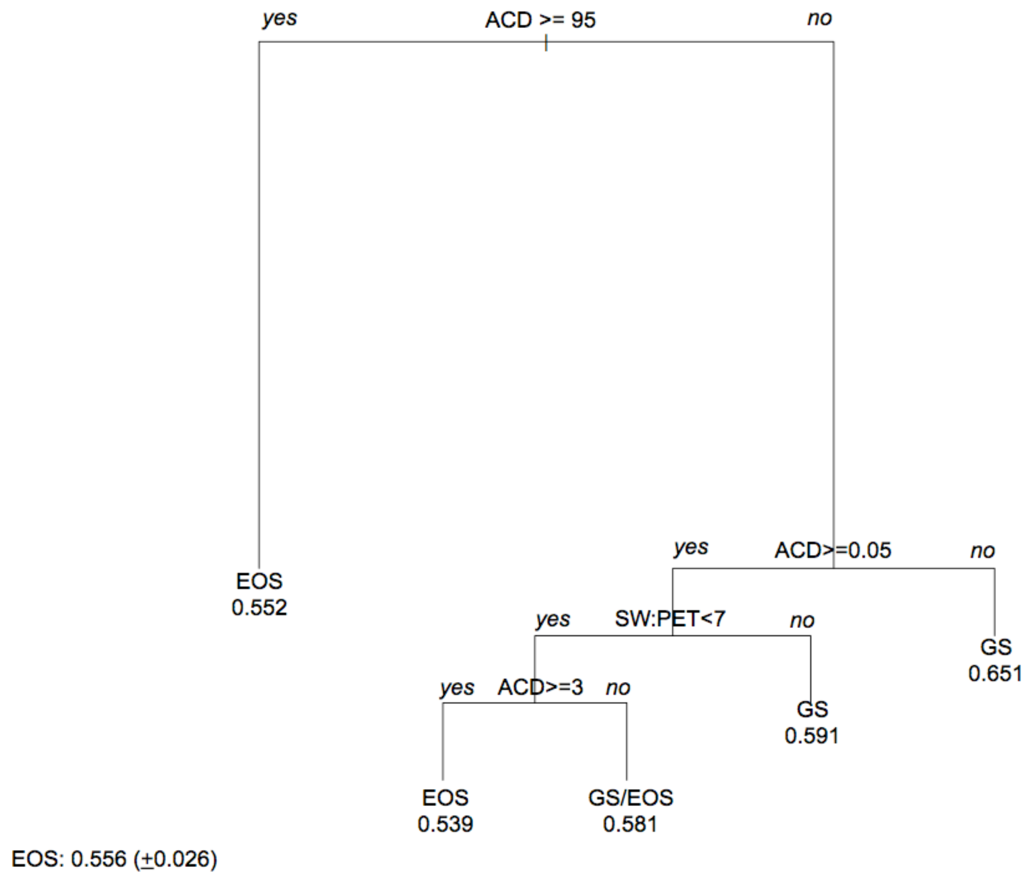

Figure 1. Regression tree analysis. EOS is the end of season indicated by GI value of dormant season mean of 0.056 (+ 0.026 confidence interval at p= 0.05). GS is growing season and indicates vegetation is still actively growing. ACD is accumulated chilling days at (7.5°C base value). SW:PET is the ratio between soil water content and potential evapotranspiration.

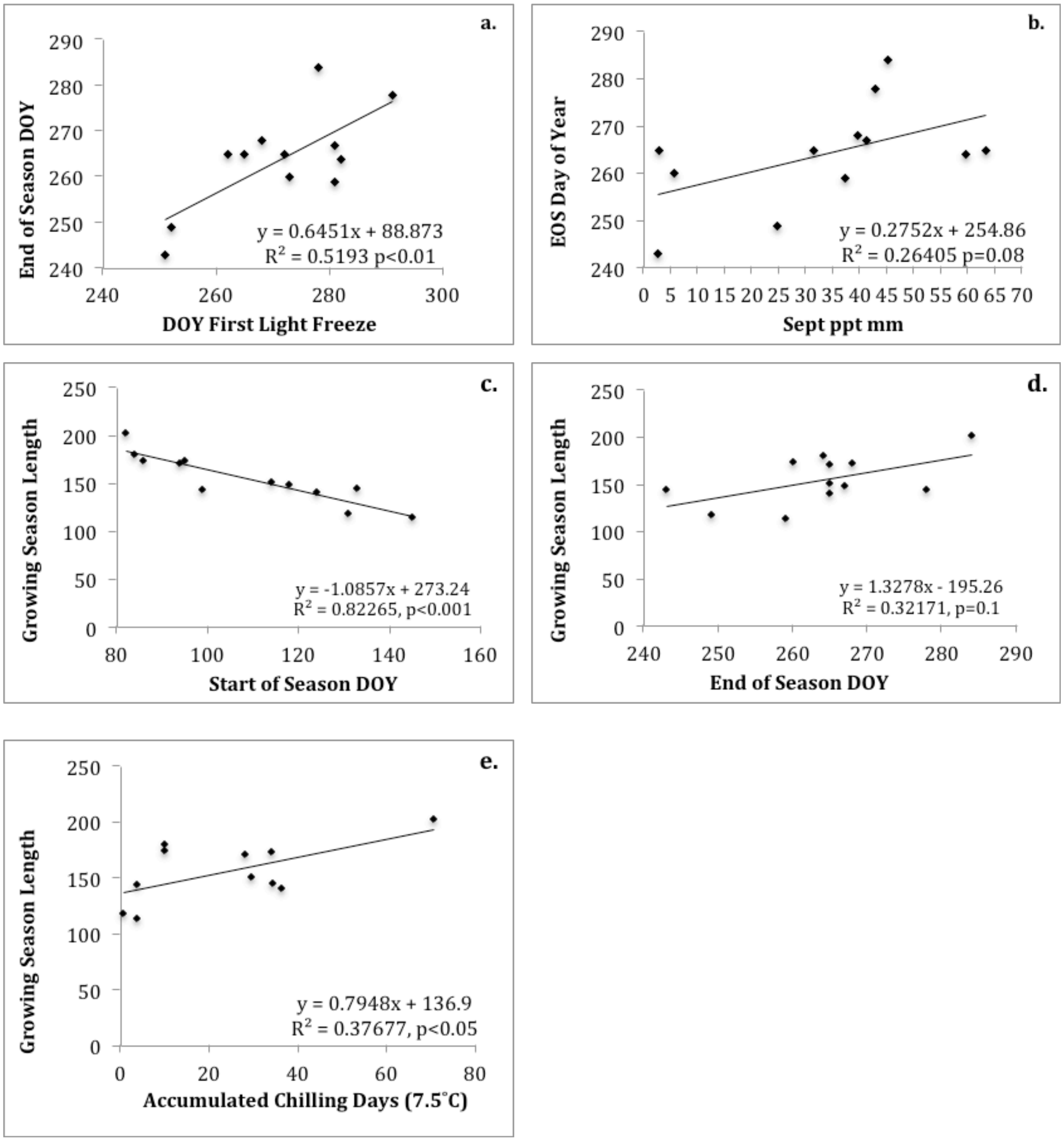

Figure 2. Relationship between EOS and first light freeze (a) EOS and September precipitation (b) GSL and SOS day of year (c) GSL and EOS day of year (d) and GSL and accumulated chilling days (e).

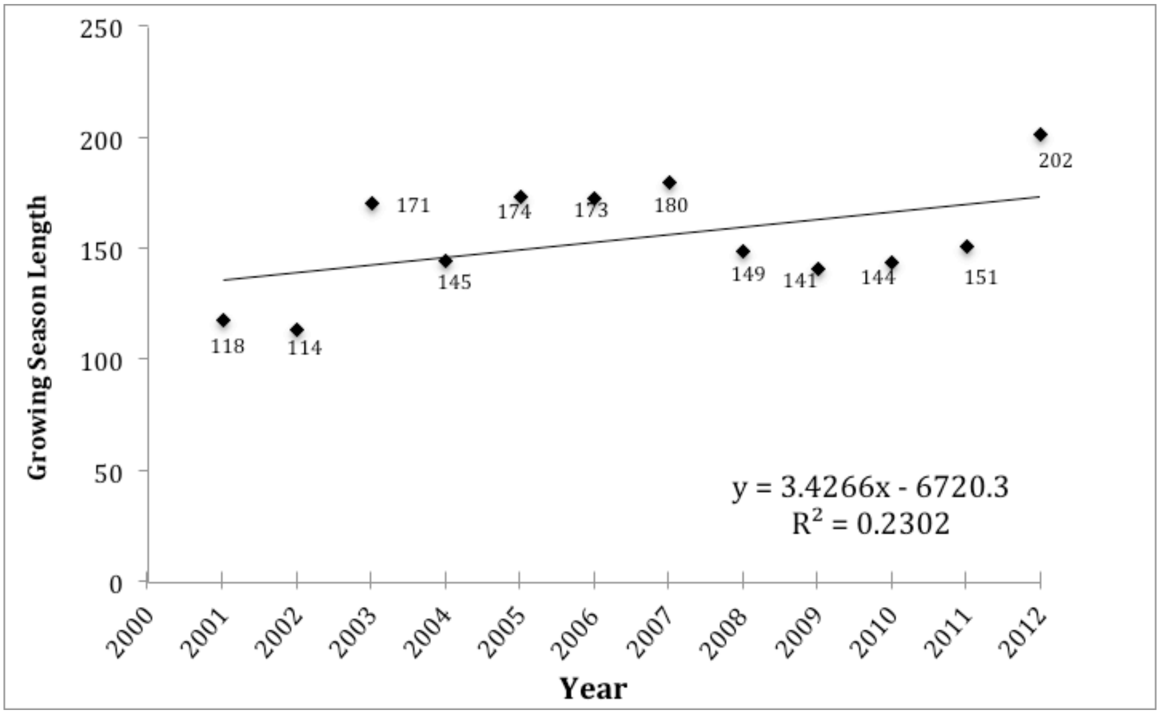

Figure 3. Plot showing GSL per year for 12 years of GI and field observations, numbers are GSL in days.

Soil Food Webs

A Cross-Site Comparison – We compared the structure of the microarthropod communities from tropical forests (OTS Field Station, La Selva, CR), temperate grasslands (SGS-LTER) and forests (Niwot-LTER), and Arctic tundra (ARC-LTER) as part of a broader effort to study 1) the extent to which differences in plant communities influence soil food web architecture; 2) how soil food webs maintain key interactions as organic matter (OM) inputs differ; 3) the consequences for interactions between C and N cycling and soil development.

In a preliminary study microarthropods were collected from in surface litter and soil (0-15 cm) from mountain lodgepole pine forest (Niwot Ridge-LTER), arctic tundra (Toolik-Arctic LTER), temperate grassland (SGS-LTER), mature wet-tropical forest (Bosque-La Selva, CR), planted *Hieronyma alchorneoides* (Phyllanthaceae) (HIAL)-dominated forest (La Selva, CR), and planted *Pentaclethra macroloba* (Fabaceae) (PEMA)-dominated forest (La Selva, CR). The arthropods were placed into a common set of functional groups and compared using Canonical Discriminant Analysis (Figure 1).

The relative abundances of fungal feeding (FF) and predatory (P) microarthropods were the primary drivers of the differences and similarities by canonical discriminant analysis. The FF:P ratio was highest in the *Hieronyma*-dominated tropical forest, temperate systems, Arctic systems suggesting lower fungal densities and levels of fungal derived amino sugars and/or

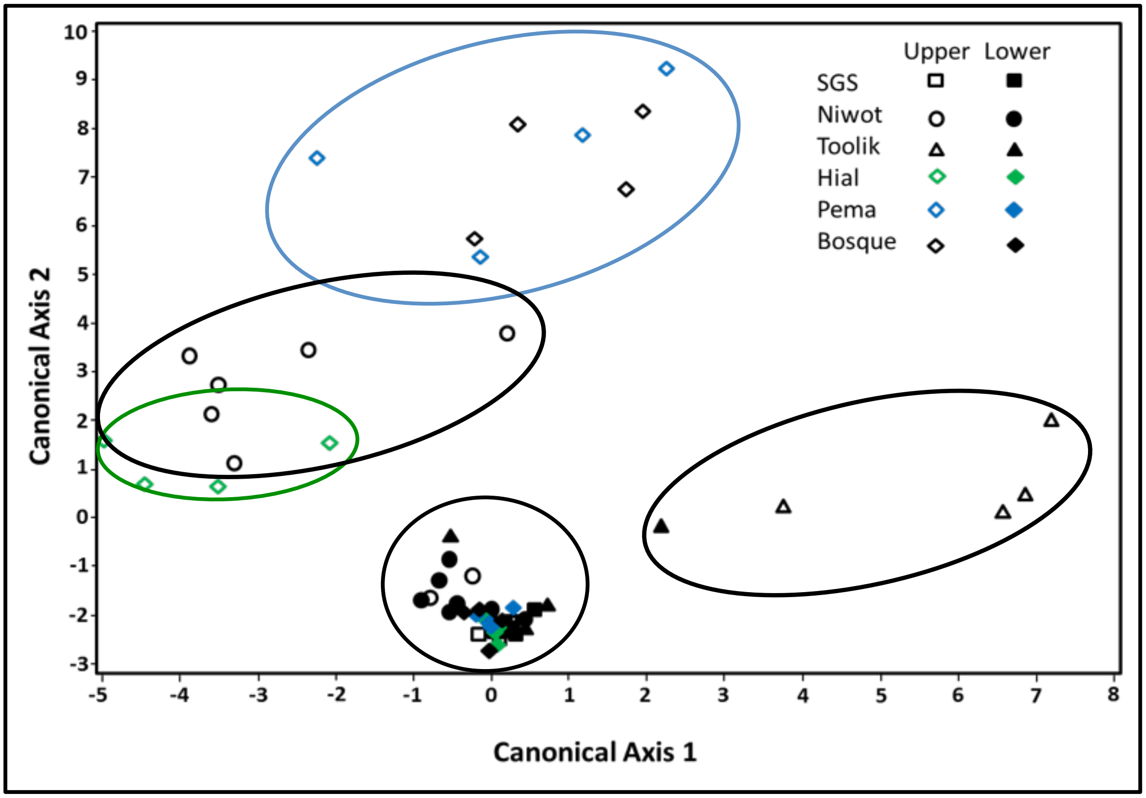

Fig. 2. Canonical Discriminant Analysis ordination of mature tropical forest – Bosque (◇), *Pentaclethra macroloba* – PEMA (◇), *Hieronyma alchorneoides* – HIAL (◇), Shortgrass Steppe, CO – SGS (□), Lodgepole Pine Forest, CO –NIWOT (○), and Arctic Tundra, AK – TOOLIK (△) for litter (open symbols) and soil (closed symbols) using the microarthropod functional groups of Moore and de Ruiter (2012).

higher microbial turnover rates. The *Pentaclethra* –dominated tropical forest and the mature tropical forest separated into a class of their own. This result was primarily driven by the high predator densities relative to fungal feeders (low FF:P ratios) in the food web. In contrast, *Hieronyma* grouped with Niwot, suggesting a commonality between a mountain lodgepole pine forest and tropical forest, owing to their similarities in litter quality (relatively high C:N) and lower predator densities relative to fungal feeders.

NutNet

We continue to maintain and sample at the SGS NutNet site and to collaborate with the larger Nutrient Network. Herbivore exclosures were removed 21 December 2012 to prevent artifacts from snow accumulation. Fences were reinstalled and nutrients were applied on 13 and 14 May 2013. Early-season species composition and cover were sampled 27 June. Litterbags were collected, dried and weighed. Late-season species composition and cover, aboveground biomass, and light availability were measured 13 and 20 August.

Production response of the dominant grasses drives the ANPP response to nutrient availability; however, the relative responses of rare grasses and forbs were greater than those of the dominant grasses to experimental nutrient additions, thus potentially driving species turnover with chronic nutrient additions. Specifically, nutrient additions increase forb biomass, resulting in a decrease in the grass:forb ratio and increased species evenness in shortgrass steppe, where gaps in the canopy are common and light availability is not limiting.

Plant tissue quality in shortgrass steppe is relatively high and therefore no changes in invertebrate abundances were observed with nutrient additions. However, leaf-chewing herbivores increased their per capita feeding rate with nutrient additions, indicative of compensatory feeding, likely because the most limiting resource at this site is not N or P. This trend observed in shortgrass steppe was opposite the pattern observed in more mesic grassland sites, where plant tissue quality is generally low.

B. Information Management

The IM team (Nicole Kaplan and Bob Flynn) continued to work with Shortgrass Steppe Long Term Ecological Research (SGS-LTER) scientists on information management in support of data integration, QAQC and metadata documentation to facilitate publication of scientific findings in peer-reviewed journals and data accessibility through the LTER Data Portal and the Colorado State University Institutional Repository (CSU IR). We are improving data access and metadata documentation in accordance with the recommendations in the 2012 LTER revised guidelines (network communication, LTER Executive Board). We are satisfying data access requirements by assuring delivery of Level 5 EML 2.1.0 compliant SGS-LTER data packages through the LTER Data Portal, hosted by the LTER Network Office. Lastly, we are addressing new information management needs associated with decommissioning an interdisciplinary, long-term, place-based research project.

The SGS-LTER Information Management team has organized a collection of digital objects, which provide background information and document the evolution of science and education at SGS-LTER over more than 30 years. Our goals are to support the use, curation, and access to data packages and other digital objects, including proposals, progress and technical reports, site review presentations, species lists, field manuals, etc. The specific objectives of our work are to:

1. preserve the local knowledge of scientists, staff and students who have worked on the SGS-LTER research site.

2. create open access and promote information discovery though enhanced search capabilities.

3. ensure data continue to be available to SGS researchers after the project ends.

4. ensure interoperability between domain repositories (e.g. PASTA, DataONE) and SGS-LTER data.

5. promote data citation and integration of different types of information through persistent object identifiers, for SGS-LTER data packages and other digital objects.

6. create embeddable links to SGS-LTER digital objects for use in various web pages and information processing systems of organizations who continue to leverage and build upon the shortgrass steppe knowledgebase, e.g., Natural Resource Ecology Laboratory (NREL), SGS Research and Interpretation Center (SGS-RIC), USDA Agricultural Research Service (USDA-ARS).

Our new partnership with the CSU IR ensures that collections of artifacts, digital data and other objects remain open and available to local researchers who will continue their research on the shortgrass steppe by other means and may seek to append, revise and (re-)use their data. The CSU Library has online experience with a digital repository (Zimmerman et al., 2009), is a member of the Digital Collections of Colorado (http://digitool.library.colostate.edu/about), and is first to curate research data as a comprehensive collection using SGS-LTER data packages and related digital objects, such as images, digital datasheets, and electronic theses and dissertations. SGS-LTER Information managers have expertise in rich metadata documentation and standardization, data integration, and data organization (Stafford et al. 2002) and have been working closely with CSU digital services librarians over the past year. The new SGS LTER IM strategy has also included incorporating a Library Information Science graduate student (Karen Baker, University of Illinois, at Urbana-Champaign) with a history of LTER work in information management. Ms. Baker is currently carrying out a comparative study, for her dissertation, of three scientific sites with data collections to help in bridging the transition from an LTER data repository to an institutional repository. It is recognized that in times of transition, system design characteristics and data issues are more visible for review and evaluation. The SGS-LTER data collection represents the test case for incorporating data into an institutional repository. This arrangement between the SGS-LTER project and CSU IR ensures that storage and curation of this extensive collection will not burden (financially or otherwise) any single research-based entity when LTER funding for the SGS-LTER project ends.

The rich legacy of data and information, in a variety of forms and file types, will be preserved to continue to support local research efforts as well as contribute to advancing our understanding of ecology through data re-use. Our system design supports data discovery through indexing by internet search engines, e.g., Google. Data packages are situated within CSU IR in relation to other digital objects, which are required to gain a better understanding of the data (e.g., plot images, scanned datasheets, species lists), and/or that contain background information and give more context to the research project (e.g. proposals, posters, pamphlets). Objects within other collections in the IR, such as electronic theses and dissertations and published papers, also point back to datasets included in those works. More than a dozen kinds of materials have been identified, described and categorized, including over 130 research datasets, 10 geospatial layers, and hundreds of digital photographs. We are currently implementing workflows to ingest these objects and build relationships within the CSU IR. We are also evaluating EML and SGS-LTER data on the PASTA staging server and will begin uploading them to the production server in January 2014. The SGS-LTER data packages are interoperable with the PASTA framework and the local institutional repository, and both repositories assign persistent identifiers as DOIs and Handles, respectively, to ensure digital objects which are re-used will be cited and SGS-LTER scientists will receive attribution. In addition, we have situated and formatted the data within the CSU IR so that the International Biological Information System, hosted by the Natural Resource Ecology Lab at CSU, can ingest, integrate and visualize the data within their online system to create value-added data products. As new projects are funded and/or proposed for the shortgrass steppe research site, the SGS-LTER collection can be leveraged through this system to serve SGS-LTER content online or access data for information processing systems. A poster documenting this process, the issues we have revealed , and how we have addressed them, has been accepted for presentation at the International Digital Curation Conference in February 2014 (Kaplan et al, 2014. Data Curation Issues in Transitioning a Field Science Collection of Long-Term Research Data and Artifacts from a Local Repository to an Institutional Repository).

As the project nears its end, it is a good time for reflection, so we are collecting and sharing stories from people working on the SGS-LTER project. We have interviewed over 30 scientists and support staff who have worked on the shortgrass steppe with the LTER project over the course of their careers. Their experiences and perspectives represent an important pool of knowledge about the site and working collaboratively. Kaplan is collaborating with Dr. Helena Karasti (Finnish LTSER Network), an interdisciplinary scholar located at University of Oulu, Finland and Luleå Technical University, Sweden. She has worked with LTER networks since 2002, incorporating similar stories into publications and presentations. Different perspectives provide insight about conducting interdisciplinary science over the long-term in the shortgrass steppe and historical features of the LTER Network. It is also an opportunity to recognize formally the many contributions SGS-LTER has made to science and to the LTER Program.

Stafford, S.G., Kaplan, N., & Bennett, C.W. 2002. Through the Looking Glass: What do we see, What have we Learned, What can we Share? Information Management at the Shortgrasse Steppe Long Term Ecological Research Site, Proceedings of the Systematics, Cybernetics and Informatics Conference, Orlando, p.414-419.

Zimmerman, D., & Paschal, D. B. (2009). An exploratory usability evaluation of Colorado State University Libraries' digital collections and the Western Waters Digital Library web sites. *The Journal of Academic Librarianship, 35*(3), 227-240.

C. Education, Outreach and Training

In the 2012-2013 school year, one LTER Schoolyard mini grants were given to schools in Poudre and Weld County District 6 School Districts. We provided stipends to 4 teachers for professional development activities, workshops and/or research internships. We received logistical support from the Niwot-LTER and financial support with the LTER Network Office for the Summer Soil Institute.

Schoolyard LTER

Mini grant awarded to Mary Richmond, Cache La Poudre Middle School During the 2012-2013 school year, funds in the amount of $750 were provided through the Schoolyard LTER project for Cache La Poudre Middle School to buy materials in order to study the effects of the local High Park Fire. With supplies, 6th grade science students learned about the impact of the 2012 wildfire on their local river ecosystem by conducting water quality tests, allowing student to use state-of-the-art technology to gather and analyze data. Materials were also used in a carbon cycling unit that was taught during the Ecology unit in the Fall of 2012.

Teacher	School	State	Affiliation	Grade Taught
Martin Buehler	Hastings High School	Michigan	Michigan State University	9^{th} - 12th
David Swartz	Rocky Mountain High School	Colorado	Colorado State University	10th
Carol Seemueller	Rocky Mountain High School	Colorado	Colorado State University	9^{th} - 12th
Mary Hunter-Laszlo	Preston Middle School	Colorado	Colorado State University	6th and 8th

Teacher Professional Development

During the 2012-2013 academic year, we recruited 4 K-12 teachers (Table above) from districts within the NSF-funded Mathematics and Science Partnership project (John Moore is PI) *Culturally relevant ecology, learning progressions and environmental literacy* (DUE 0832173). Teachers from Michigan working with the KBS-LTER and Colorado working with the SGS-LTER were selected to participate in the Soil Summer Institute discussed below and/or to assist in a cross-site study of soil fauna involving the SGS-LTER, Niwot-LTER, and ARC-LTER, and a plant biomass harvest at the ARC-LTER. Three K-12 middle and high school science teachers participated as part of the field team at the ARC-LTER at Toolik Lake in 2013 (Beuhler, Seemueller, and Swartz) and one teacher (Hunter-Lazlo) participated in the NSF site visit at Toolik in June. At Toolik they harvested soil arthropods to contribute to knowledge of the soil food web. They also spent 9 days in the lab with graduate students separating roots and rhizomes from soil, and separating plant species, which are currently being dried in ovens and will be weighed to determine plant biomass. Hunter-Lazso (K-12 teacher and Teacher in Residence at CSU) coordinated follow-up activities during the AY 2012-2013, and presented a poster of their findings at Toolik Field Station in June 2013 during the ARC-LTER site review. All were also provided with opportunities to experience other research projects based at Toolik Field Station.

Soil Science Institute

During July 2013, elements of the project were included in the CSU Summer Soil Institute. Concepts and techniques from this project were used in the lectures and training sessions. The two-week institute included instructional, field and laboratory sessions on soil physics, chemistry, and biology, the questions and methods integral to our project, as well as sessions in the use of the DayCent and Food Web models that are featured in our project. Participants compared mountain pine forest to grassland soils. The 23 participants included faculty, graduate students, postdoctoral fellows and K-12 teachers and were from the United States, the Netherlands, Spain, and China.

D. Project Management

Project management at SGS-LTER continues as it has since it was changed in 2009. Central management of the project is by an Executive Committee (SGS-EC), Mike Antolin (lead PI until 11/1/2010), John Moore (lead PI since 11/1/2010), Justin Derner, Eugene Kelly, and Nicole Kaplan (Information Manager). The Executive committee works with the PI's, both to manage project budgets and to map out the general scientific directions of the project. Justin Derner is a scientist with the USDA ARS Rangeland Resource Research Unit (ARS-RRU) stationed in Cheyenne, WY, and represents our partners with the Central Plains Experimental Range where the majority of SGS LTER research has been conducted. We use video-conferencing to include members from several institutions at different locations.

Under this award the SGS LTER has two ongoing subcontracts: with collaborators at the University of Wyoming (Drs. Indy Burke and William Lauenroth) for continued work on long term ANPP and plant phenology, long-term biogeochemistry and climate manipulation experiments; and with our USDA-ARS collaborators (Drs. Justin Derner, David Augustine, Dana Blumenthal and Jack Morgan) to continue long-term experiments on the Central Plains Experimental Range.