

## **Preview of Award 1027319 - final Project Report**

### **Cover**

Federal Agency and Organization Element to Which Report is Submitted:

4900

Federal Grant or Other Identifying Number Assigned by Agency:

1027319

Project Title:

Shortgrass Steppe LTER VI: Examining Ecosystem Persistence and Responses to Global Change

PD/PI Name:

- John C Moore, Principal Investigator
- Michael F Antolin, Co-Principal Investigator
- Justin D Derner, Co-Principal Investigator
- Nicole E Kaplan, Co-Principal Investigator
- Eugene F Kelly, Co-Principal Investigator

Recipient Organization:

Colorado State University

Project/Grant Period:

02/01/2011 - 01/31/2015

Reporting Period:

02/01/2014 - 01/31/2015

Submitting Official (if other than PD\PI):

- Nicole E Kaplan
- Co-Principal Investigator

Submission Date:

05/01/2015

Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)

Nicole E Kaplan

## Accomplishments

### \* What are the major goals of the project?

Goals have not changed since the award was issued.

### \* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

#### Major Activities:

Major activities focused on decommissioning the SGS-LTER program to curate and make openly available digital data and information, complete and disseminate scientific findings, and develop infrastructure upon which new research studies, and educational and outreach activities can be proposed and/or developed for the future.

#### Specific Objectives:

Scientific objectives related to compiling and analyzing long-term datasets, using long-term datasets in modeling efforts and publishing results.

Information management objectives focused on packaging data and metadata for ingestion into the LTER Network Information System (LTER NIS) Provenance Aware Synthesis and Tracking System (PASTA), and creating an inventory of archived samples for use in the future.

Objectives to have access to an information infrastructure from the SGS-LTER project and maintain partnerships within the local ecological research community were met by researchers and educators.

#### Significant Results:

***Mammal and disease ecology*** - Black-tailed prairie dogs (BTPD) are common on the short and mixed-grass prairie of the western Great Plains, although greatly reduced in abundance because of population control for agriculture, urban/suburban development, and mortality during outbreaks of plague. Plague, caused by the gram-negative bacterium *Yersinia pestis*, was introduced from its native range in Asia to North America in the later 1800's, and spread into the range of BTPD in the 1940's, and is mainly a flea-transmitted pathogen of ground-dwelling rodents. Our main discoveries have been on several mechanisms that promote plague outbreaks via spatial connectivity between BTPD colonies, flea abundance and rates of transmission, and the roles of other rodents also associated with prairie dogs. An important part of the research has been on how plague transmission is affected by climate patterns, and why it is that plague outbreaks are more common in relatively wet years than during periods of drought.

***Grazing and Succession Effects on ANPP Versus BNPP*** - Both grazing and succession have effects on plant community composition of annuals, short-lived perennials, and long-lived perennials, and on tall and short species, which have different above- and below-ground allocation patterns that affect carbon sequestration. We assessed ANPP and BNPP over the seral gradient after additional years of grazing of

the seeded grasslands. A drought year had 32% lower precipitation than an average year during this study. The drought resulted in an average reduction in ANPP of nearly half (58 vs 111 g/m<sup>2</sup>/yr; 48% reduction) (Fig. 1). The drought had a slightly lower across treatment effect on BNPP (77 vs 132 g/m<sup>2</sup>/yr; 42% reduction), resulting in a 9% increase in the BNPP:ANPP. Grazing treatment had few significant effects within year and seral stage. The ungrazed compared to the grazed mid-seral community had greater ANPP in the average year (Fig. 1A) and no significant grazing effects were observed for BNPP (Fig. 1B). Grazing resulted in a small increase in the BNPP:ANPP ratio only in the late seral native community in the drought year (Fig. 1C). Seral stage sometimes had as large of effects on plant productivity as drought versus average precipitation year had (Fig. 1A,B). ANPP generally decreased with increased seral stage, but grazing treatment modified that in the average year of precipitation (Fig. 1A). BNPP between seral stages was mediated more by grazing in the average year of precipitation than in the drought year (Fig. 1B). In the average year, BNPP increased from mid-seral to late seral in the grazed communities but not in the ungrazed. In the average year, BNPP generally increased from early-, to mid-, to late-seral stages (92, 138, 165 g/m<sup>2</sup>/yr, respectively). In the drought year, BNPP was similar in the mid- and late-seral communities and both were slightly greater than in the early-seral. BNPP:ANPP ratios generally increased with increasing seral stage with only one exception in the average year of precipitation (Fig. 1C).

The early-seral versus the late-seral communities represent the greatest difference in species and functional group compositions. The relative effect of drought versus average year of precipitation on ANPP was a -41% reduction for the early-seral communities and a -56% reduction for the late-seral communities (Fig. 1A). Similarly, the relative effect of drought versus average year of precipitation on BNPP was a -31% reduction for the early-seral communities and a -50% reduction for the late-seral communities (Fig. 1B). However, the BNPP:ANPP ratio increased +13% during drought in the early-seral communities compared with only +5% in the late seral communities. Drought had greater negative affect above vs below, but difference between early- and late-seral communities was greater belowground. Seasonally short-lived annuals could grow during short periods of favorable conditions but the long-period of drought impacted even the drought tolerant shortgrass steppe species.

***Modeling influences of precipitation timing on ANPP*** - Growing season net carbon uptake is highly correlated ( $r^2 > .85$ ) to April soil moisture levels. Parton and others investigated whether you could predict growing plant production using the spring soil moisture levels (late April and early May) using the long term NRCS soil water data and the long term SGS-LTER plant production data. Preliminary analysis of the 1997-2012 data show that you can predict the aboveground NPP given the spring soil water levels with an  $r^2$  of .68 (positive correlation). We are continuing this research and using the DayCent model to simulate soil water dynamics from 1982-2012 and then correlating the Daycent simulated spring soil water model results with the 1982-2012 SGS-LTER aboveground plant production data. We have compared the DayCent simulated soil water model results with the observed NRCS soil water data and found that the model does an excellent job of simulating seasonal soil water dynamics.

***Modeling Soil Food Webs using an agent-based approach*** - We developed agent-based models patterned after published equation-based models to explore the influence of microbial-derived extracellular enzymes on carbon (C) dynamics and system persistence under scenarios that emulate the

grass rooting structure inherent in mollisols and the pulsed-pressure moisture and climatic conditions of the Shortgrass Steppe. The models featured spatial arrangements of detritus as either randomly-spaced particles or as root-like structures, detritus input intervals and rates, trophic structures, and extracellular enzymes with different half-lives. We studied how these features affected C dynamics and model persistence (no extinctions), and the concept of perpetual transient dynamics wherein the model system may or may not be stable in the strict mathematical sense (one or more eigenvalue of the Jacobian matrix is greater than zero) yet persists. Our results reinforced the importance of the spatial arrangements and input rates of resources (bottom-up factors) and the movement patterns and consumption rates of predators on prey (top-down factors) in controlling dynamics and persistence. We found that extracellular enzymes control of C dynamics depends on the spatial arrangement of resources, the input rate and input intervals of detritus and trophic structure. Thresholds in dynamic states may result from pushing the system beyond the coping mechanisms of its elements.

**Data Management** - In addition to satisfying NSF requirements for submission of data packages to the LTER NIS, the local information manager identified a second task: creation of a collection including data, metadata and a diverse set of materials that together represent the SGS-LTER project as a whole. There are close to one hundred datasets produced by SGS-LTER that are diverse, small files with extensive metadata, well described using the EML. These data are largely field-based, geo-located, time-series measurements, which have been integrated longitudinally. Other materials prepared for the collection include over 400 images, 17 GIS layers, species lists, and proposals and reports to NSF.

**Partnerships** - Creation of a SGS-LTER collection in the CSU Institutional Repository (IR) was used as a pilot study for the IR to gain experience with organization, migration, and preservation of a research project collection. The effort required expansion of their basic metadata (i.e. Dublin Core) to incorporate elements important for research data documentation.

NEON scientists have had access to protocols developed by SGS-LTER scientists and adapted these techniques to meet their needs. Data collected by NEON will be of interest to SGS-LTER scientists who will continue to study the shortgrass steppe. Similarly, USDA ARS scientists associated with the CPER LTAR site are interested in information management practices developed by SGS-LTER data managers.

Key outcomes or Other achievements:

The work of the SGS-LTER can serve as an example of how to decommission a long-term site-based ecological field research project in the future.

**\* What opportunities for training and professional development has the project provided?**

Techniques in information management have been adopted for instructional activities and long-term datasets have been used within the SUPER (Skills for Undergraduate Participation in Ecological Research) program run by graduate students and scientists at the Natural Resource Ecology Laboratory (<http://www.nrel.colostate.edu/projects/super/>). SUPER students are typically undergraduates in their

junior or senior year who are interested in experiencing research first-hand. They receive college credit and are teamed up with a mentor for real world experience in research procedures and conduct an independent research project to complete the program and obtain college credit. Professional development activities for teachers interested in soil science have been developed utilizing long-term meteorological data as well as field and lab methods developed by scientists working on the SGS-LTER project for Summer Soil Institute (<http://soilinstitute.nrel.colostate.edu/>) at Colorado State University.

**\* How have the results been disseminated to communities of interest?**

Results have been disseminated through peer-review research publications, presentations at conferences, technical reports, participation on committees, professional development workshops and institutes, and online repositories.

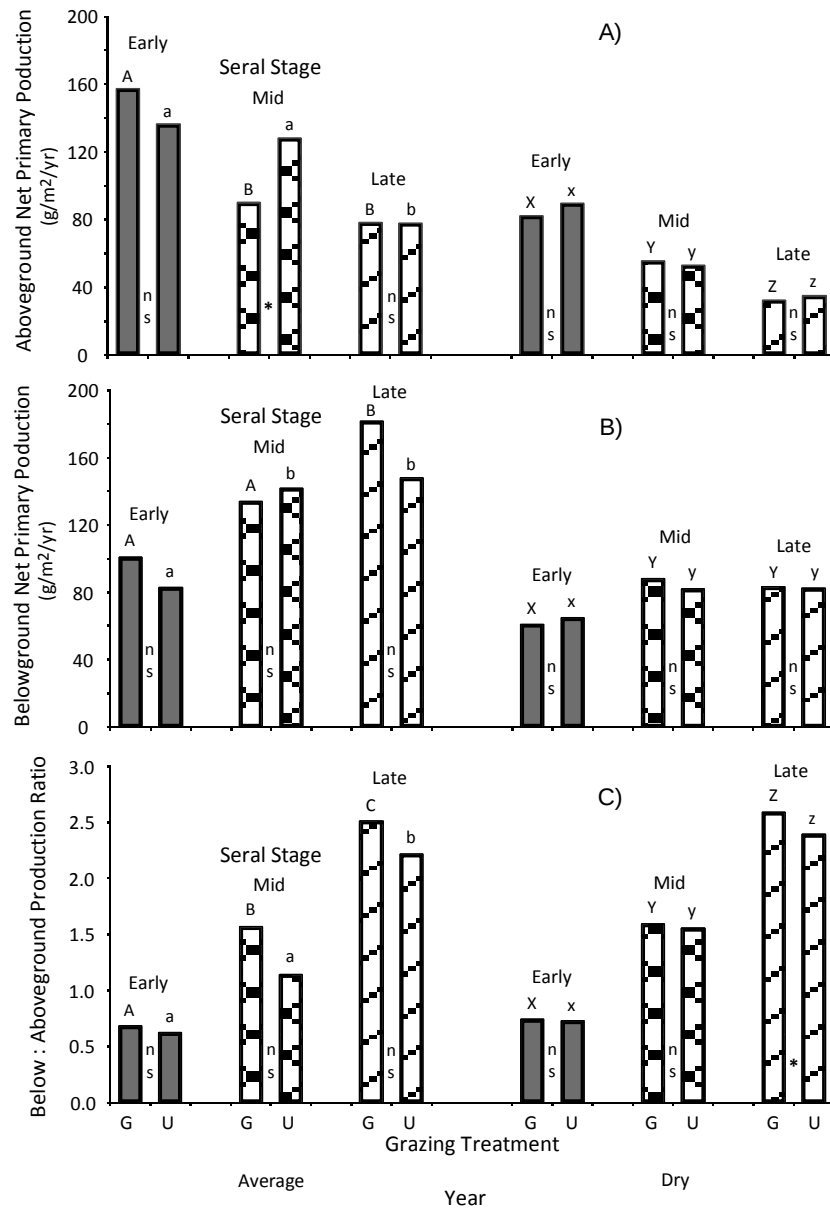


Fig. 1. A) Aboveground net primary production ( $\text{g/m}^2/\text{yr}$ ), B) belowground net primary production ( $\text{g/m}^2/\text{yr}$ ), and C) Belowground to aboveground production ratios in early-seral, mid-seral, and late-seral native shortgrass steppe plant communities, moderately grazed (G) or ungrazed (U), during an average year of precipitation or a dry year with a long seasonal drought. Bars not sharing the same upper-case letters are significantly different with respect to seral stage within grazed treatment and year, and bars not sharing the same lower-case letters are significantly different with respect to seral stage within ungrazed treatment and year. A ns between bars indicates no significant grazing effect between the two, and a \* indicates a significant grazing effect.

## Products

### Books

- Fang, Q.X., L.R. Ahuja, A. A. Andales, and J. D. Derner (2014). *Using a model and forecasted weather to predict forage and livestock production for making stocking decisions in the coming growing season*. American Society of Agronomy, Inc., Crop Science S. Madison, WI. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.2134/advagricsystmodel5.c7

### Book Chapters

- Moore, J.C. (2015). Soil ecology, environmental literacy, and educational access and engagement: Lessons from networked lives.. *Long-term environmental research: Changing the nature of scientists* M.R. Willig and L.R. Walker. Oxford. UK. . Status = AWAITING\_PUBLICATION; Acknowledgement of Federal Support = Yes
- Shaver, G.R., J.A. Laundre, M.S. Bret-Harte, F. Stuart Chapin, III, A.E. Giblin, L. Gough, S.E. Hobbie, G.W. Kling, M.C. Mack, J.C. Moore, K.J. Nadelhoffer, E.B. Rastetter, and J.P. Schimel. (2014). Terrestrial Ecosystems at Toolik Lake, Alaska. *The Arctic LTER Syntheses* J. Hobbie, and G.W. Kling. Oxford University Press. Oxford. 90. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes

### Conference Papers and Presentations

- Brewer, P.E., and J.C. von Fischer (2014). *Activity and anoxia: Methanogenesis follows high rates of decomposition in an unsaturated litter patch experiment*. Ecological Society of America. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Alster, C.J., A. Kpyama, N.G. Johnson, and J.C. von Fischer (2014). *Assessing the relative importance of microbial versus abiotic factors for an ecosystem function: An evaluation of soil respiration rates from three grassland soils reciprocally transplanted with microbial communities*. Ecological Society of America. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Knapp, A.K., D.L. Hoover, K.R. Wilcox, M.L. Avolio, S.E. Koerner, K.J. La Pierre, M.E. Loik, Y. Luo, O.E. Sala, and M.D. Smith (2014). *Characterizing precipitation regimes of extreme wet and dry years: Implications for regional to global scale experiments*. Ecological Society of America. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Kaplan, N., D.C. Draper, D. Bastian Pascal, J.C. Moore, K.S. Baker, and S. Swauger (2014). *Data curation issues in transitioning a field science collection of long-term research data and artefacts from a local repository to an institutional repository*. International Digital Curation Conference. San Francisco, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

- Shi, Zheng, M.L. Thomey, W. Mowll, M.E. Litvak, N. Brunsell, S.L. Collins, W.T. Pockman, M.L. Smith, A.K. Knapp, and Y. Luo (2014). *Differential effects of extreme drought on production and respiration: Synthesis and modeling analysis*. Ecological Society of America. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Moran, M.S., G.E. Ponce-Campos, A. Huete, M.P. McClaran, Y. Zhang, E.P. Hamerlynck, D.J. Augustine, S.A. Gunter, S.G. Kitchen, D. Peters, P.J. Starks, M. Hernandez, J.D. Hottenstein, and M.L. Ross (2014). *Grassland resilience during the warm drought of the early 21st century*. Ecological Society of America. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Flores, K., and P. Stapp (2014). *Landscape Genetics of Northern Grasshopper Mice in Relation to Prairie Dog Colonies in Shortgrass Steppe*. American Society of Mammalogists. Oklahoma City, OK. Status = OTHER; Acknowledgement of Federal Support = Yes
- Byrne, K.M, W.K. Lauenroth, I.C. Burke, and S. Evans (2014). *Lasting effects of long-term climate disturbance on grassland community structure under two levels of drought*. Ecological Society of America. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- King, E.G., M.V. Johnson, and D.J. Augustine (2014). *Rangeland Ecology: Cowboys and steaks??*. Ecological Society of America. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes
- Augustine, D.J., J.D. Derner, and J.K. Detling (2014). *Testing for thresholds in a semiarid grassland: the influence of prairie dogs and plague on vegetation dynamics*. Ecological Society of America. Sacramento, CA. Status = OTHER; Acknowledgement of Federal Support = Yes

## Journals

- Augustine D. J. and J. D. Derner (2015). Patch burn grazing management in a semiarid grassland: {Consequences} for pronghorn, plains pricklypear, and wind erosion. *Rangeland Ecology & Management*. 68 40--47. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Augustine, D. J., J. D. Derner and D. P. Smith (2014). Characteristics of burns conducted under modified prescriptions to mitigate limited fuels in a semi-arid grassland. *Fire Ecology*. 10 36--47. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.4996/fireecology.1002036
- Augustine, D. J., J. D. Derner and J. K. Detling (2014). Testing for Thresholds in a Semiarid Grassland: The Influence of Prairie Dogs and Plague. *Rangeland Ecology & Management*. 67 701--709. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

- Augustine, D. J., P. Brewer, D. M. Blumenthal, J. D. Derner and J. C. von Fischer (2014). Prescribed fire, soil inorganic nitrogen dynamics, and plant responses in a semiarid grassland. *Journal of Arid Environments*. 104 59--66. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Cleveland, C. C., B. Z. Houlton, W. K. Smith, A. R. Marklein, S. C. Reed, W. Parton, S. Del Grosso and S. W. Running (2013). Patterns of new versus recycled primary production in the terrestrial biosphere. *PNAS*. 110 (31), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Del Grosso S., P. Smith, M. Galdos , A. Hastings and W. Parton (2014). Sustainable energy crop production. *Current Opinion in Environmental Sustainability*. 9 20--25. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.cosust.2014.07.007
- DeLucia, E. H., N. Gomez-Casanovas, J. A. Greenberg, T. W. Hudiburg, I. B. Kantola, S. P. Long, A. D. Miller, D. R. Ort and W. J. Parton (2014). The theoretical limit to plant productivity. *Environmental Science & Technology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1021/es502348e
- Eads, D. A., D. E. Biggins, M. F. Antolin, D. Long, K. P. Huyvaert and K. L. Gage (2015). Prevalence of the generalist flea *Pulex simulans* on black-tailed prairie dogs in New Mexico: the importance of considering imperfect detection. *Journal of Wildlife Diseases*. . Status = AWAITING\_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Eads, D. A., D. E. Biggins, P. F. Doherty, K. L. Gage, K. P. Huyvaert, D. H. Long and M. F. Antolin (2013). Using occupancy models to investigate the prevalence of ectoparasitic vectors on hosts: {An} example with fleas on prairie dogs. *International Journal for Parasitology: Parasites and Wildlife*. 2 246-256. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Evans, S. E. and I. C. Burke (2013). Carbon and nitrogen decoupling under an 11-year drought in the shortgrass steppe. *Ecosystems*. 16 20-33. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Evans, S. E., M. D. Wallenstein, and I. C. Burke (2014). Is bacterial moisture niche a good predictor of shifts in community composition under long-term drought?. *Ecology*. 95 (1), 110. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Fetcher N., S. J. Agosta, J. C. Moore, J. A. Stratford and M. A. Steele (2015). Evidence of compartmentalization of energy flow based on C3 and C4 pathways in a reclaimed ecosystem. *Restoration Ecology*. . Status = AWAITING\_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

- George, D. B., C. T. Webb, K. M. Pepin, L. T. Savage and M. F. Antolin (2013). Persistence of black-tailed prairie-dog populations affected by plague in northern Colorado, USA. *Ecology*. 94 1572-1583. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Giuliani, A. L., E. F. Kelly and A. K. Knapp (2014). Geographic variation in growth and phenology of two dominant Central US grasses: Consequences for climate change. *Journal of Plant Ecology*. 7 211-221. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Kachergis, E., J. D. Derner, B. B. Cutts, L. M. Roche, V. T. Eviner, M. N. Lubell and K. W. Tate (2014). Increasing flexibility in rangeland management during drought. *Ecosphere*. 5 1-14. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Knapp, A. K., C. J. W. Carroll, E. M. Denton, K. J. La Pierre, S. L. Collins and M. D. Smith (2015). Differential sensitivity to regional-scale drought in six central US grasslands. *Oecologia*. 177 949-957. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Koch, A., A. McBratney, M. Adams, D. Field, R. Hill, J. Crawford, B. Minasny, R. Lal, L. Abbott, A. O'Donnell and D. Angers and J. Baldock and E. Barbier and D. Binkley and W. Parton and D. H. Wall and M. Bird and J. Bouma and C. Chenu and C. B. Flora and K. Goulding and S. Grunwald and J. Hempel and J. Jastrow and J. Lehmann and K. Lorenz and C. L. Morgan and C. W. Rice and D. Whitehead and I Young and M. Zimmermann (2013). Soil Security: Solving the Global Soil Crisis. *Global Policy*. 4 (4), 434-441. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/1758-5899.12096.
- Koyama, A., M. D. Wallenstein, R. T. Simpson and J. C. Moore (2014). Soil microbial community compositions altered by increased nutrient availability in {Arctic} tundra soils. *Frontiers in Microbiology*. 5 (516), 1-16. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.3389/fmicb.2014.00516
- La Pierre, K.J., D.M. Blumenthal, C.S. Brown, J.A. Klein and M.D. Smith (2013). Drivers of variation in ANPP differ across a broad precipitation gradient. *Oecologia*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Milchunas, D. G. and M. W. Vandever (2014). Grazing effects on plant community succession of early- and mid-seral seeded grassland compared to shortgrass steppe. *Journal of Vegetation Science*. 25 22-35. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Mobley, M. L., M. J. Cleary and I. C. Burke (2014). Inorganic nitrogen supply and dissolved organic nitrogen abundance across the US Great Plains. *PLoS ONE*. 9 (9), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

- Mobley, M. L., R. L. McCulley, I. C. Burke, G. Peterson, D. S. Schimel, C. V. Cole, E. T. Elliott and D. G. Westfall (2014). Grazing and no-till cropping impacts on N retention in dryland agroecosystems. *Journal of Environmental Quality*. 43 1963-1971. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Moore, J. C., R. Boone, A. Koyama, and K. Holfelder (2014). Enzymatic and detrital influences on the structure, function, and dynamics of spatially-explicit model ecosystems. *Biogeochemistry*. 117 205-227. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Mowll, W., D. M. Blumenthal, K. Cherwin, A. Smith, A. J. Symstad, L. T. Vermeire, S. L. Collins, M. D. Smith and A. K. Knapp (2015). Climatic controls of aboveground net primary production in semi-arid grasslands along a latitudinal gradient portend low sensitivity to warming. *Oecologia*. 177 959-969. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Newbold, T. A. S., P. Stapp, K. E. Levensailor, J. D. Derner and W. K. Lauenroth (2014). Community Responses of arthropods to a range of traditional and manipulated grazing in shortgrass steppe. *Environmental Entomology*. 43 556-568. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <http://dx.doi.org/10.1603/EN12333>
- Rahm, J., and J.C. Moore (2012). A Look at Four Youths' Hybrid Identity Work Within and Beyond a Math and Science Upward Bound Program. *Science Education*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Robinson T. M. P., K. J. La Pierre, M. A. Vadeboncoeur, K. M. Byrne, M. L. Thomey and S. E. Colby (2013). Seasonal, not annual precipitation drives community productivity across ecosystems.. *Oikos*. 122 727-738. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Ryals, R., M. D. Hartman, W. J. Parton, M. S. DeLonge and W. L. Silver (2015). Long-term climate change mitigation potential with organic matter management on grasslands. *Ecological Applications*. . Status = AWAITING\_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Scheer, C., S. J. Del Grosso, W. J. Parton, D. W. Rowlings and P. R. Grace (2014). Modeling nitrous oxide emissions from irrigated agriculture: Testing DAYCENT with high frequency measurements. *Ecological Applications*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Seabloom, E. E.T. Bore, Y. Buckley, W.E. Cleland, K. Davies, J. Firn, S. Harpole, Y. Hautier, E. Lind, A. MacDougall, J.L. Orrock, S.M. Prober, P.B. Adler, T.M. Anderson, J.D. Bakker, L.A. Biederman, D.M. Blumenthal, C.S. Brown, L.A. Brudvig, M. Cadotte, C. Chu, K. L. Cottingham, M.J. Crawley,

E.I. Damschen, C. M. Dantonio, N.M. DeCrappeo, G. Du, P.A. Fay, P. Frater, D.S. Bruner, N. Hagenah, A. Hector, H. Hillebrand, K.S. Hofmockel, H.C. Humphries, V.L. Jin, A. Kay, K.P. Kirkman, J.A. Klein, J.M.H. Knops, K.J. La Pierre, L. Ladwig, J.G. Lambrinos, A.D.B. Leakey, Q. Li, W. Li, R. Marushia, R. McCulley, B. Melbourne, C.E. Mithcell, J.L. Moore, J. Morgan, B. Mortensen, L.R. O'Halloran, D.A. Pyke, A.C. Risch, M. Sankaran, M. Schuetz, A. Simonsen, M. Smith, C. Stevens, L. Sullivan, E. Wolkovich, P.D. Wragg, J. Wright and L. Yang (2013). Predicting invasion in grassland ecosystems: Is exotic dominance the real embarrassment of richness?. *Global Change Biology*. 19 (12), 3677. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/gcb.12370

- St. Romain, K., D.W. Tripp, D.J. Salkeld, and M.F. Antolin (2013). Duration of plague (*Yersinia pestis*) outbreaks in Black-tailed prairie dog (*Cynomys ludovicianus*) colonies of northern Colorado. *EcoHealth*. 10 241-245. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Toledo D., M. Sanderson, H. Johnson, J. L. Reeves, J. D. Derner, L. Vermeire, J. Hendrickson (2014). Evaluating plant biodiversity measurements and exotic species detection in {National} {Resources} {Inventory} {Sampling} protocols using examples from the {Northern} {Great} {Plains} of the {USA}. *Ecological Indicators*. 46 149--155. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Walker, A. P., S. Zaehle, B. E. Medlyn, M. G. De Kauwe, S. Asao, T. Hickler, W. Parton, D. Ricciuto, Y. Wang, D. Warlind and R. J. Norby (). Predicting long-term carbon sequestration in response to {CO}2 enrichment: How and why do current ecosystem models differ?. *Global Biogeochemical Cycles*. . Status = AWAITING\_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Wang, L., Y. Qian, J. E. Brummer, J. Zheng, S. Wilhelm and W. J. Parton (2015). Simulated biomass, environmental impacts and best management practices for long-term switchgrass systems on marginal land in a semi-arid region. *Biomass & Bioenergy*. 75 254-266. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Wilcox, K. R., J. C. von Fischer, J. M. Muscha, M. K. Petersen and A. K. Knapp (2015). Contrasting above- and belowground sensitivity of three Great Plains grasslands to altered rainfall regimes. *Global Change Biology*. 21 335-344. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Wolkovich, E. M., S. Allesina, K. L. Cottingham, J. C. Moore, S. A. Sandin and C. de Mazancourt (2014). Linking the green and brown worlds: The prevalence and effect of multi-channel omnivory in food webs. *Ecology*. 12 3376-3386. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

## Other Publications

- Derner, J. D. and D. J. Augustine and E. Kachergis (2014). *Cattle as ecosystem engineers: New grazing management enhances rangeland biodiversity*. Western Confluence, Winter Issue, pages 10-13. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Conway, K., & P. Stapp. (2014). *Determinants of prevalence of botfly infestation in thirteen-lined ground squirrels in Colorado shortgrass steppe..* Dimensions 16:7-12 (CSUF Undergraduate Research Journal). Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Kaplan, N.E., K. Baker, D.C. Draper, and S. Swauger (2014). *Packaging, transforming and migrating data from a scientific research project to an institutional repository : the SGS LTER Collection*. This report describes the process of preserving a collection of project-related scientific research materials - data, metadata, and artifacts - produced over 32 years at the Shortgrass Steppe Long Term Ecological Research (SGS LTER) site.. Status = OTHER; Acknowledgement of Federal Support = Yes

## Thesis/Dissertations

- Eads, D. A.. *Factors affecting flea densities in prairie dog colonies : implications for the maintenance and spread of plague..* (2014). Colorado State University. Acknowledgement of Federal Support = Yes
- Mowll, W. M.. *Temperature sensitivity in aboveground net primary productivity in semi-arid grasslands..* (2014). Colorado State University. Acknowledgement of Federal Support = Yes

## Websites

- *SGS LTER Project Website*  
<http://sgslter.colostate.edu/>

This website summarizes the history of the SGS LTER project and delivers open access to data and information. Webpages include inventories of products with links to objects preserved and curated within an extensive collection available online.

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## Participants/Organizations

### What individuals have worked on the project?

| Name                        | Most Senior Project Role | Nearest Person Month Worked |
|-----------------------------|--------------------------|-----------------------------|
| <a href="#">Moore, John</a> | PD/PI                    | 2                           |

| <b>Name</b>                         | <b>Most Senior Project Role</b> | <b>Nearest Person Month Worked</b> |
|-------------------------------------|---------------------------------|------------------------------------|
| <a href="#">Antolin, Michael</a>    | Co PD/PI                        | 1                                  |
| <a href="#">Derner, Justin</a>      | Co PD/PI                        | 1                                  |
| <a href="#">Kaplan, Nicole</a>      | Co PD/PI                        | 6                                  |
| <a href="#">Kelly, Eugene</a>       | Co PD/PI                        | 1                                  |
| <a href="#">Augustine, David</a>    | Co-Investigator                 | 1                                  |
| <a href="#">Blumenthal, Dana</a>    | Co-Investigator                 | 1                                  |
| <a href="#">Burke, Ingrid</a>       | Co-Investigator                 | 1                                  |
| <a href="#">Knapp, Alan</a>         | Co-Investigator                 | 1                                  |
| <a href="#">Lauenroth, William</a>  | Co-Investigator                 | 1                                  |
| <a href="#">Milchunas, Daniel</a>   | Co-Investigator                 | 1                                  |
| <a href="#">Morgan, Jack</a>        | Co-Investigator                 | 1                                  |
| <a href="#">Parton, William</a>     | Co-Investigator                 | 1                                  |
| <a href="#">Stapp, Paul</a>         | Co-Investigator                 | 1                                  |
| <a href="#">von Fischer, Joseph</a> | Co-Investigator                 | 1                                  |
| <a href="#">Brown, Cynthia</a>      | Faculty                         | 1                                  |
| <a href="#">Klein, Julia</a>        | Faculty                         | 1                                  |
| <a href="#">Smith, Melinda</a>      | Faculty                         | 1                                  |
| <a href="#">Wallenstein, Matt</a>   | Faculty                         | 1                                  |
| <a href="#">Flynn, Bob</a>          | Other Professional              | 4                                  |
| <a href="#">Lindquist, Mark</a>     | Other Professional              | 1                                  |
| <a href="#">Sprague, Sallie</a>     | Other Professional              | 5                                  |

| Name                           | Most Senior Project Role              | Nearest Person Month Worked |
|--------------------------------|---------------------------------------|-----------------------------|
| <a href="#">Brewer, Paul</a>   | Graduate Student (research assistant) | 3                           |
| <a href="#">Eads, David</a>    | Graduate Student (research assistant) | 1                           |
| <a href="#">Moore, Lynne</a>   | Graduate Student (research assistant) | 3                           |
| <a href="#">Mowll, Whitney</a> | Graduate Student (research assistant) | 1                           |
| <a href="#">Salley, Shawn</a>  | Graduate Student (research assistant) | 3                           |

**Full details of individuals who have worked on the project:**

**John C Moore**

**Email:** jcmoore@nrel.colostate.edu

**Most Senior Project Role:** PD/PI

**Nearest Person Month Worked:** 2

**Contribution to the Project:** Principal investigator, serves as graduate student adviser, leads project management, and correspondence with the Network. Writes reports and presents research at meetings.

**Funding Support:** These funds support graduate work in the summer months and some salary.

**International Collaboration:** Yes, netherlands

**International Travel:** No

**Michael F Antolin**

**Email:** michael.antolin@colostate.edu

**Most Senior Project Role:** Co PD/PI

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Co-Principal Investigator supervising and advising graduate students and participates in project management as a member of the SGS-LTER Executive Committee. Writes reports and presents research at meetings.

**Funding Support:** These funds support graduate work in the summer months and some salary.

**International Collaboration:** No

**International Travel:** No

**Justin D Derner**

**Email:** justin.derner@ars.usda.gov

**Most Senior Project Role:** Co PD/PI

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Co-Principal investigator within partner organization, USDA-ARS. Serves to coordinate research on the ARS managed CPER site and participates in project management as a member of the SGS-LTER Executive Committee. Writes reports and presents research at meetings.

**Funding Support:** Subcontract to ARS supports summer field crew and supplies but not salary.

**International Collaboration:** No

**International Travel:** No

**Nicole E Kaplan**

**Email:** Nicole.Kaplan@colostate.edu

**Most Senior Project Role:** Co PD/PI

**Nearest Person Month Worked:** 6

**Contribution to the Project:** Professional information manager. She decommissioned the SGS-LTER project data management system to ensure a collection of data sets continued to be available through open access within the institutional repository at Colorado State University and machine accessible as valid Ecological Metadata Language packages for harvesting into the LTER Network Information System automatically. Writes reports and presents research at meetings. Participants in project management as a member of the SGS-LTER Executive Committee.

**Funding Support:** This project

**International Collaboration:** Yes, finland

**International Travel:** No

**Eugene F Kelly**

**Email:** pedoiso@lamar.colostate.edu

**Most Senior Project Role:** Co PD/PI

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Co-Principal Investigator supervising and advising graduate students and participates in project management as a member of the SGS-LTER Executive Committee. Writes reports and presents research at meetings.

**Funding Support:** These funds support graduate work in the summer months and some salary.

**International Collaboration:** No

**International Travel:** No

**David Augustine**

**Email:** David.Augustine@ars.usda.gov

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist. Conducts research, supervises staff at the field site. Writes reports and presents research at meetings.

**Funding Support:** Subcontract to ARS supports summer field crew and supplies but not salary for Augustine.

**International Collaboration:** No

**International Travel:** No

**Dana Blumenthal**

**Email:** Dana.Blumenthal@ars.usda.gov

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist. Works with Julia Klein and Cini Brown on the NutNet research project.

**Funding Support:** Funding for NutNet work supported one graduate student. No other project funding supported Blumenthal's involvement.

**International Collaboration:** No

**International Travel:** No

**Ingrid Burke**

**Email:** Indy.Burke@uwyo.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist. Directs graduate students, writes research reports.

**Funding Support:** This project supported past graduate students and page charges for publications. No salary support.

**International Collaboration:** No

**International Travel:** No

**Alan Knapp**

**Email:** Alan.Knapp@colostate.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist. Conducts research, directs graduate students, writes up results.

**Funding Support:** Project funds supported supplies and field construction for his research.

**International Collaboration:** No

**International Travel:** No

**William K Lauenroth**

**Email:** wlauenro@ulyo.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist. Oversees graduate student research, writes reports.

**Funding Support:** Subcontract to UWyoming supports one of his graduate students and some supplies for research on the SGS.

**International Collaboration:** No

**International Travel:** No

**Daniel Milchunas**

**Email:** Daniel.Milchunas@colostate.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior researcher. Conducts research. Writes research reports. Assists students and staff in the field. Collaborates with Spanish grasslands researcher.

**Funding Support:** This project.

**International Collaboration:** Yes, spain

**International Travel:** No

**Jack Morgan**

**Email:** Jack.Morgan@ars.usda.gov

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior research scientist with the USDA ARS in Fort Collins and on the Central Plains Experimental Range, now semi-retired. He oversees research and staff activities on the CPER and is currently writing up the results of his long-term work with us.

**Funding Support:** Funds from this project supported technical assistance in data analysis.

**International Collaboration:** No

**International Travel:** No

**William Parton**

**Email:** william.parton@colostate.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist. Conducts research and models results. Collaborates with many scientists around the world. We are checking 'no' in the international collaborations section because the list is extensive and we are not funding those collaborations.

**Funding Support:** This project supports students working with him, travel to local research areas. Other funds support his international efforts.

**International Collaboration:** No

**International Travel:** No

**Paul Stapp**

**Email:** pstapp@exchange.fullerton.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist, located at California State University - Fullerton. Conducts research, directs graduate and undergraduate students. Writes research reports.

**Funding Support:** No direct salary support from this project. Project supports travel and housing to the Colorado SGS LTER site for his work.

**International Collaboration:** No

**International Travel:** No

**Joseph von Fischer**

**Email:** Joe.von\_Fischer@colostate.edu

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist and faculty member. Directs graduate student research, writes reports and presents results at meetings.

**Funding Support:** Project funds supported his graduate students and construction of field experiments.

**International Collaboration:** No

**International Travel:** No

**Cynthia S Brown**

**Email:** Cynthia.S.Brown@colostate.edu

**Most Senior Project Role:** Faculty

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist. Directs students working on the Nut Net project. Writes reports and presents results at meetings.

**Funding Support:** No direct support for Brown from this project. We supported a graduate student in past years.

**International Collaboration:** No

**International Travel:** No

**Julia Klein**

**Email:** Julia.Klein@colostate.edu

**Most Senior Project Role:** Faculty

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientists. Directs undergraduate and graduate students working on the Nut Net project.

**Funding Support:** No funding from this project this year.

**International Collaboration:** Yes, mongolia

**International Travel:** No

**Melinda Smith**

**Email:** Melinda.Smith@colostate.edu

**Most Senior Project Role:** Faculty

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist. Conducts research, directs graduate students and technicians in field research.

**Funding Support:** Project funds supported supplies and field construction for her research.

**International Collaboration:** No

**International Travel:** No

**Matt Wallenstein**

**Email:** Matthew.Wallenstein@colostate.edu

**Most Senior Project Role:** Faculty

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Senior scientist. Oversees graduate research assistants, writes reports and presents research at meetings.

**Funding Support:** No direct funding from this project. His grad students have been supported in the

past.

**International Collaboration:** No

**International Travel:** No

**Bob Flynn**

**Email:** Robert.Flynn@colostate.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 4

**Contribution to the Project:** Maintains GIS files, creates maps and layer for researchers. Assists data manager with data handling through SGS LTER web site.

**Funding Support:** This project.

**International Collaboration:** No

**International Travel:** No

**Mark Lindquist**

**Email:** Mark.Lindquist@colostate.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Site Manager for buildings, vehicles and experiments at the SGS LTER field station 30 miles NE of campus.

**Funding Support:** This project.

**International Collaboration:** No

**International Travel:** No

**Sallie Sprague**

**Email:** Sallie.Sprague@colostate.edu

**Most Senior Project Role:** Other Professional

**Nearest Person Month Worked:** 5

**Contribution to the Project:** Project manager responsible for day-to-day operations, budget tracking, purchasing.

**Funding Support:** This project.

**International Collaboration:** No

**International Travel:** No

**Paul Brewer**

**Email:** Paul.Brewer@colostate.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Graduate research assistant under Joe von Fischer. Conducts doctoral research, helps summer undergraduate students, presents results at scientific meetings.

**Funding Support:** Project funds supported summer stipends for his field work.

**International Collaboration:** No

**International Travel:** No

**David Eads**

**Email:** David.Eads@colostate.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Grad research assistant under the direction of Mike Antolin. Conducts research on the shortgrass steppe, presents results at meetings. Currently completing PhD work.

**Funding Support:** This award support summer stipend.

**International Collaboration:** No

**International Travel:** No

**Lynne Moore**

**Email:** lmoore7@uwyo.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Graduate research assistant under direction of Bill Lauenroth at U Wyoming. Conducts research, writes reports and presents results at scientific meetings.

**Funding Support:** Subcontract on this project supports her research and stipend.

**International Collaboration:** No

**International Travel:** No

**Whitney Mowll**

**Email:** Whitneymowll@gmail.com

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Graduate assistant under the direction of Alan Knapp.

**Funding Support:** Summer research support from this project.

**International Collaboration:** No

**International Travel:** No

**Shawn Salley**

**Email:** Shawn.Salley@colostate.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Graduate assistant under the direction of Co-PI Gene Kelly. Conducts PhD research.

**Funding Support:** This project.

**International Collaboration:** No

**International Travel:** No

**What other organizations have been involved as partners?**

| Name                                                              | Type of Partner Organization              | Location                  |
|-------------------------------------------------------------------|-------------------------------------------|---------------------------|
| <a href="#">California State University - Fullerton</a>           | Academic Institution                      | Fullerton, CA             |
| <a href="#">Colorado State University - Ag Experiment Station</a> | Academic Institution                      | Fort Collins, CO          |
| <a href="#">Pawnee National Grassland</a>                         | Other Organizations (foreign or domestic) | Nunn, CO                  |
| <a href="#">USDA-ARS</a>                                          | Other Organizations (foreign or domestic) | Nunn and Fort Collins, CO |
| <a href="#">University of Illinois</a>                            | Academic Institution                      | Champaign, IL             |
| <a href="#">University of Wyoming</a>                             | Academic Institution                      | Laramie, WY               |

**Full details of organizations that have been involved as partners:**

**California State University - Fullerton**

**Organization Type:** Academic Institution

**Organization Location:** Fullerton, CA

**Partner's Contribution to the Project:**

In-Kind Support  
Collaborative Research  
Personnel Exchanges

**More Detail on Partner and Contribution:** Dr. Paul Stapp is a faculty member in Biology at Cal State Fullerton. He trains students, helps train the Colorado summer field crew, contributes intellectually to mammalian areas of research on the project.

#### **Colorado State University - Ag Experiment Station**

**Organization Type:** Academic Institution  
**Organization Location:** Fort Collins, CO

**Partner's Contribution to the Project:**

In-Kind Support  
Facilities  
Collaborative Research  
Personnel Exchanges

**More Detail on Partner and Contribution:** We share a variety of facilities and services with the Ag Experiment Station, including soil pits, educational exchanges, researchers for joint projects.

#### **Pawnee National Grassland**

**Organization Type:** Other Organizations (foreign or domestic)  
**Organization Location:** Nunn, CO

**Partner's Contribution to the Project:**

Facilities

**More Detail on Partner and Contribution:** PNG makes available large areas on the grassland for our researchers to situate experiments.

#### **USDA-ARS**

**Organization Type:** Other Organizations (foreign or domestic)  
**Organization Location:** Nunn and Fort Collins, CO

**Partner's Contribution to the Project:**

In-Kind Support  
Facilities  
Collaborative Research  
Personnel Exchanges

**More Detail on Partner and Contribution:** Dr. Justin Derner is a Co PI on the project. His staff routinely

help the SGS LTER field crew during the summer field season, as our crew helps them, when more hands are needed for a specific task. Most of our research is conducted on federal land made available by the ARS Central Plains Experimental Range.

#### **University of Illinois**

**Organization Type:** Academic Institution

**Organization Location:** Champaign, IL

**Partner's Contribution to the Project:**

Collaborative Research

**More Detail on Partner and Contribution:**

#### **University of Wyoming**

**Organization Type:** Academic Institution

**Organization Location:** Laramie, WY

**Partner's Contribution to the Project:**

Collaborative Research

Personnel Exchanges

**More Detail on Partner and Contribution:** Drs. Indy Burke and Bill Lauenroth are now at U Wyoming. They collaborate with the project and share their graduate students for some projects.

**What other collaborators or contacts have been involved?**

Nothing to report

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#### **Impacts**

**What is the impact on the development of the principal discipline(s) of the project?**

Over 45 years, the IBP and LTER scientists produced almost 1200 journal publications, almost 400 book chapters, over 200 theses, and more than 100 core, long-term datasets with open access. Scientists continue to use the field research site and the rich legacy of SGS-LTER for new projects including [the Summer Soil Institute](#), [the Semi-Arid Grasslands Research Center](#) and [the USDA Long-Term AgroEcosystem Research Network](#).

**What is the impact on other disciplines?**

The SGS LTER pilot study for curating a research data collection was also of interest to Library Science students at the University of Illinois, Champaign. Karen Baker, PhD candidate, has used this collaborative project as a case study for her research comparing and contrasting site-based and center-based information management approaches.

**What is the impact on the development of human resources?**

Nothing to report

**What is the impact on physical resources that form infrastructure?**

Some research field equipment will remain available for use by other projects in the future (e.g. archived finely ground soil and plant matter samples, storage space in buildings, meteorological sensors, tractor, truck, and various hand tools).

**What is the impact on institutional resources that form infrastructure?**

Nothing to report

**What is the impact on information resources that form infrastructure?**

The pilot project in curating research data expanded institutional capacity and know-how for working with field-based ecological research data. The pilot project focused on all three elements identified by the ARL Report (2009) as central to digital repository service – access, context, and content. Access will be provided by two repositories: the LTER Network Information System and the CSU Digital Repository, referred to as The Digital Collections of Colorado. These represent two different contexts: the LTER arena with a recognized metadata standard and validation checker; the CSU Institutional Repository arena with Digitool's structure for content and standards support. This enhances the opportunity for discovery and preservation. The dual focus contributes to data and system interoperability as well as the vision for a robust knowledge infrastructure of the future (Edwards et al. 2013). The migration to two repositories provides an example of what it means to envision remote repository requirements supporting a web-of-repositories (Baker and Yarmey 2009).

ARL, A. R. L. (2009). The Research Library's Role in Digital Repository Services. In A. D. R. I. T. Force (Ed.).

Baker, K. S. and Yarmey, L. (2009). Data stewardship: Environmental data curation and a web-of-repositories. *International Journal of Digital Curation*, 4(2), 12-27.

Edwards, P. N., Jackson, S. J., Chalmers, M. K., Bowker, G. C., Borgman, C. L., Ribes, D., Burton, M., Calvert, S. (2013). Knowledge Infrastructures: Intellectual Frameworks and Research Challenges. Ann Arbor: Report of a workshop sponsored by the National Science Foundation and the Sloan Foundation, Deep Blue.

**What is the impact on technology transfer?**

Metadata standards, documentation tools and mapping tools have been shared with and adapted by other projects interested documenting metadata, such as Citizen Science projects managed within CitSci.org and the Math and Science Partnership.

### **What is the impact on society beyond science and technology?**

The reliable infrastructure and collaborative framework associated with this long-term project has afforded researchers and educators use of the site, human resources, and digital information for designing and establishing professional development activities for teachers from surrounding school districts. The project has also provided opportunities for local producers to participant as Citizen Scientists in shaping research studies by engaging with scientists while forming research questions, designing and applying field protocols and assessing research results as related to agricultural production practices within their own operations as well as public lands grazed by cattle owned by the Crow Valley Grazing Co-op.

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### **Changes/Problems**

#### **Changes in approach and reason for change**

Nothing to report.

#### **Actual or Anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

#### **Changes that have a significant impact on expenditures**

Nothing to report.

#### **Significant changes in use or care of human subjects**

Nothing to report.

#### **Significant changes in use or care of vertebrate animals**

Nothing to report.

#### **Significant changes in use or care of biohazards**

Nothing to report.

The National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230, USA Tel: (703) 292-5111, FIRS: (800) 877-8339 | TDD: (800) 281-8749