I. Research Experience For Undergraduates (Funded)

(CSU Participant Support)

Results from Previous REU Supplement

In June, 2003, we received funding for two REU students to conduct research on the Shortgrass Steppe (SGS) LTER. The qualified students whom we had identified earlier in the spring had already committed themselves to other projectes in June so we varied our REU program to accommodate students during the academic year. One student worked with Dr. John Moore during the fall term. A second student will be working with Dr. Bill Lauenroth during the spring term.

Karl Wyant, University of Northern Colorado student

Mr. Wyant worked with Dr. Moore to investigate the effects of pairie dogs on the density of fungal hyphae on the Central Plains Experimental Range (CPER) and the Pawnee National Grassland (PNG) as part of a larger project to assess the entire soil community on the shortgrass steppe. Three prairie dog towns were selected for study on the CPER and three on the PNG. Replicate soil samples were collected from colonized, extinct and 'control' (no prairie dog activity) areas of each town during the spring and fall of 2003. Soil samples were analyzed for hyphal density using epifluorescence microscopy. As expected, hyphal densities were greater in the spring than the fall samples. The density of fungal hyphae appeared to be a function of the specific site rather than the presence or absence of prairie dogs. Further investigations will consider the effects of topography and soil type independently from prairie dog activity.

REU Proposal for the Current Year:

We request funding to support two Research Experience for Undergraduates students during the 2004 summer field season. Students will work directly with PI's and their graduate students from the Shortgrass Steppe Long Term Ecological Research project.

Nature of Student Activities

Philosophy:

Our highest priority for students in this project is not that they learn a large number of facts about the ecology of the shortgrass steppe, nor that they become expert in the field, laboratory, or computer analyses. Rather, our primary goal is that the students learn that science is an exciting process of discovery, and that they become interested in the field of ecology. They will be involved in the everyday process of research, but through this, we hope to infuse them with excitement about both science and ecology. Thus, although we focus below on the technical components of their activities, we will place a great deal of our effort with the students on the overall experience.

There are a number of components to the learning experience for the REU students. We subdivide these components into 1) basic ecology; 2) environmental issues; 3) hypothesis generation in the research process; 4) methods of field and laboratory analysis; 5) data analysis and synthesis; 6) the use of computers in research.

Below, we detail chronologically our plan for how the students will develop this knowledge base.

1. Pre-arrival orientation:

We will send both students a copy of James Michener's "Centennial" before they arrive. This book focuses on the history of European settlement of the northeastern Colorado-southeastern Wyoming region, and provides an excellent introduction to the area, its ecology, and its fascinating history of land use.

2. General Orientation:

The first two days of the summer will be spent with a field orientation. The students will accompany project scientists for two days in the Pawnee National Grasslands and surrounding area. We will discuss the ecology of the shortgrass steppe, and the common land management practices. We will provide an overview of both the natural history and the human cultural context. We will introduce them to the issues that we are interested in, and work to engage the interest of the students in our research.

3. Field, Lab, and Data Analysis Assistance for Research Projects:

During the first six weeks of their time here, the students will assist project scientists in existing research projects. The purpose of this involvement is: 1) to introduce the students to the process of science, including question-generation and design phases; 2) to introduce students to field and laboratory methods in ecosystem ecology, and 3) to allow the students to work as part of a team in the field. We would like the students to get a strong sense of the interdisciplinary and cooperative nature of ecosystem ecology.
Each student will be assigned a professor as a lead mentor from our PI list (either Dr. Burke, Antolin or Lauenroth), and a more proximal graduate student mentor with whom the student will work more closely. The mentors will be responsible for providing continuity among the field, lab, and data-analysis activities, and for helping to assure that the student feels connected to the science being conducted. We have found that this nested mentoring allows the student to get the intellectual challenges that they need, as well as the day to day assistance and guidance. Thus, the students may work on some team projects with all three scientists listed above, but will primarily focus on work by a single PI and graduate student for this phase of their summer.

4. Independent Research Projects:

During week five, we will begin to work with the students to develop their own research projects. The student research projects will necessarily be extremely well-focused and simple. During the seventh week of the summer, students will conduct their fieldwork, and during the subsequent weeks, they will complete their lab work.

5. Data analysis

When the students get close to completing their lab analyses (about week 10), we will begin to involve them in data analysis for an existing project. Each student will work closely with his or her mentor in this process, and will learn how the researcher is analyzing her or his data using simple graphical and statistical analysis. Further, the students will work with their mentor to plan their own data analysis.

6. Research Completion and Presentation

Students will complete their projects during the last weeks of the summer program. They will present their results to our research group in a special end-of-season symposium. We will invite members of our extended research group for the Shortgrass Steppe Long Term Ecological Research Project.

7. Ecological Society of America meetings

If funds permit, we plan to take students to the ESA meetings. In the nine-year history of REU student involvement in the SGS-LTER, this trip has often been described as a program highlight. Past REU students attended the ESA meetings and commented on how these meetings helped to characterize many of the components of the science of ecology. This exposure to the current field of ecology is invaluable in providing the students with a sense of the discipline, as well as giving them the chance to make contacts for graduate school.

The Research Environment:

The students will be associated with a large, well-equipped facility and a large group of interesting ecologists. The undergraduates will have access to some of the most sophisticated field, laboratory, and computer equipment available, as well as human resources: :

- a new wet chemistry laboratory complete with some analytical equipment
- the Natural Resource Ecology Laboratory wet chemistry laboratory with a large number analytical instruments (probably most importantly an autoanalyzer and autotitrator)
- the LTER computer facility supported by the College of Natural Resources
- an extended group of graduate students, faculty, and technical support (about 40 persons) who work closely together on the LTER project

Student Participants:

We will target highly qualified students in the recruitment process for REU students. Our Honors program has had very successful recruitment of under-represented groups, with a current enrollment of 30% - more than twice that of the University at large. However, we will not limit our search to Honors students: we will advertise the REUs campus-wide, and, through an email network and the WWW, we will advertise these positions nationally. During the past nine years, we have had at least one woman or minority student as an REU participant. We feel that this is an important component of our REU program and we plan to continue to recruit under-represented groups. In addition, for almost every year, we have had at least one participant from a small liberal arts college (Denison, Middlebury, Oberlin, Earlham, etc). We feel that we provide a different type of research opportunity to these students, and we and our students certainly gain from the perspectives of these liberal arts scholars.

Ethics Component:

It is both important and appropriate to give the students a strong sense of the process of science as one that is dependent upon integrity at all stages of the process. We propose to introduce students to a collection of topics that relate to an “ethics component,” through group discussions and through interactions with mentors. Our students, postdocs, and investigators regularly discuss issues related to our personal commitment to integrity in a competitive environment, such as quality control in research, and behavioral standards for scientists. We are also very interested in topics related to balancing a sense of professional accomplishment with a well-integrated life, particularly as members of under-represented groups in science. We have identified a number of short readings that elaborate upon these topics.

We will have weekly lunchtime discussions with our research group (postdocs and graduate students), as well as the REU students. Currently, we have such weekly meetings with our group, and we blend informal discussions with more formal ones, sometimes with readings as the focus. The informal atmosphere is very effective for focusing on issues that are philosophical yet have great importance to our daily activities. Past REU students have contributed a great deal to these discussions by introducing discussion topics that may not have otherwise been discussed. Some of the most interesting and provocative topics have dealt with the practicalities of a career in science.

Summary

In summary, we are very excited about the opportunity to continue an REU program. We are extremely enthusiastic about the program and the experiences it affords the students and our research group.

II. Schoolyard LTER Request (Funded)

(Subaward to University of Northern Colorado)

Below is the rationale and budget ($15,000) in request for supplemental funding under the Schoolyard LTER development program. This program is timely and will augment efforts that we currently have in place.

Schools

We will involve 8 schools (one K-6, one 6-12, one middle school and 5 High Schools) from school districts in the northern Front Range and eastern plains of Colorado. The following schools and science teachers have expressed an interest in the program:

School	Science Teacher
Akron High School, Akron, CO	Ms. Deanna Schrock
Frontier Academy, Greeley, CO	Dr. Sean Madden
Greeley West High School, Greeley, CO	Mr. Gary Prewitt
John Evans Middle School, Greeley, CO	Mr. Jason Mclaughlin
Rocky Mountain High School, Ft. Collins, CO	Mr. Dave Swartz
Rough Rock High School, Navajo Nation, AZ	Mr. William Rosenberg
S. Christa McAuliff Elementary School, Greeley, CO	Ms. Rebecca Rimerez
Union Colony Prep School, Greeley CO	Ms. Cathy Hoyt

Plan of Operation

As in past years, science and mathematics teachers from the schools will meet with LTER scientists to visit the SGS LTER site and the demonstration plots at UNC. Meetings and orientations are held in January and May. The May workshop is designed to discuss potential experiment designs, data collection, protocol on maintaining databases, and means by which the projects can be integrated into curricula. All data collected will be maintained as part of the SGS-LTER database and made available to the teachers and students.

<u>Site Visit and Workshop</u>: LTER scientist will host a site visit at the Shortgrass Steppe LTER and the UNC Campus Ecology demonstration plots. The objectives of the visits are to familiarize the teachers with the LTER site and experiments, and provide an example of how a field experiment can be scaled-down to a schoolyard setting.

The agenda for the May workshop includes deciding on the type(s) of experiments to be conducted at the school, guidelines for supplies and equipment, the variables to be sampled, protocol for data collection, guidelines for webpages (format, databases, etc…), and plans to disseminate the materials developed by the group (e.g., data, curricula, lab modules). The January workshop is a mid-year symposium hosted in alternating years by the LTER and the UNC MAST Institute. Progress on research and upcoming events are shared via posters and oral presentations.

<u>Plot Design and Preparation</u>: At the May workshop we decide on one of three scenarios. One scenario would be to replicate the experiment at the UNC demonstration plots (which is

patterned after an LTER experiment) at each of the schools. A second would be to have each teacher decide which LTER experiment (from the SGS or any other LTER site) was best suited for their site and curriculum. The third scenario would have the group develop a unique experiment for the schoolyard that was patterned after the LTER model. The basis for this approach and its value to science-teacher-student partnerships is discussed in Rahm et al. (2003).

UNC Schoolyard Demonstration Plot Maintenance: We propose to use a modest amount of funds for the mantenance and upkeep of the UNC demonstration plots. The plots were established in 1998 through a grant from NSF and matching funds from UNC. The plots have served as a focal point of the SGS-LTER schoolyard program and have been used by K-12 teachers and outreach. The current experiment has run its course and we propose to remove the vegetation and re-initiate a new experiment during the summer of 2005. K-12 teachers and students that participate in our summer outreach program will participate in this effort.

Webpages: All materials developed from the projects, databases and a profile of the projects objects and participants will be incorporated into the webpages for the Shortgrass Steppe – LTER, the Department of Biological Sciences at UNC, and those of the participating schools (if they have one). The data manager for the SGS-LTER will lead this discussion.

Literature Cited and Attributed to the SGS-LTER

Rahm, J., H.C. Miller, L. Hartley and J.C. Moore. The value of an emergent notion of authenticity: examples from two student/teacher-scientist partnership programs. Journal of Research in Science Teaching 40:737-756.

Concluding Remarks

The schoolyard ecology program has greatly enhanced our outreach to the community and as a means to influence science education. The funds have supported a phenomenal network and have augmented the supply budgets of our participating schools well beyond what the districts could provide. We thank you in advance for consideration of this proposal. If there are any questions or additional information that you may require, please contact us by phone or e-mail.

III. Research Experience for Teachers (Funded)
(Subaward to University of Northern Colorado)

Below are the rationale and budget ($20,000) in request for supplemental funding under the Research Experience for Teachers (RET) program. We are requesting funds to support two teachers selected from the Greeley-Evans School District 6 and the Poudre R1 School district who are currently participating in NSF funded education programs (NSF GK-12 and NSF CLT) designed to develop teacher leaders.

The RET program will be administered by the Mathematics and Science Teaching (MAST) Institute at the University of Northern Colorado (UNC). MAST has coordinated the K-12 education outreach for the Shortgrass Steppe LTER under the leadership of Dr. John Moore. MAST and the SGS-LTER currently cooperate on an NSF funded GK-12 project, Teacher Enhancement project, and on activities coordinated by the NSF funded Center for Teaching and Learning in the West (CLT-WEST). The RET program offers meaningful teacher professional development tied directly to SGS-LTER research.

Selection Criteria and Process

Applications for Teacher fellows have been solicited through the Northern Colorado High Plains Partnership, which includes the UNC, Colorado State University (CSU), Weld Country School (Greeley) District 6, Poudre R1 School District (PSD, Ft. Collins), Windsor Re-4 School District, and the Northeast (NE) and Centennial (North Central) Boards of Cooperative Educational Services (BOCES) (total of 27 rural school districts). The partnership inlcudes over 80,000 K-12 students and over 6,600 teachers. The districts are contiguous with one another, UNC, CSU, and the SGS-LTER.

In anticipation of the RET program, we have been informing teachers for the past year of the opportunity and expectations at professional development workshops, seminars, school visits, and other programs sponsored by the UNC MAST Institute and its counterparts at CSU. Interested teachers were asked to submit a letter of interest, CV and a list of interests and needs. SGS-LTER scientists were informed of the opportunity and asked to submit a prospectus of potential research activities.

We have identified two teachers for 2004:

Ms. Rebecca Rimerez, 4th Grade	S. Christa McAuliff Elementary School, Greeley, CO
Ms. Karen Koski, K-4	Lab School for Creative Learning, Ft. Collins, CO

Research Experience for Teachers

Ms. Rimerez and Ms. Koski will select one from of the following three areas of research: 1) Research in Prairie Dog Ecology: Changes in Below-ground Allocation and Food Web Stability, 2) Interactions Between Prairie Dogs and the Pollinating Insect Communtiy on the Shortgrass Steppe, and 3) Intesive Grazing on the Shortgrass Steppe. The senior scientists and their graudate students have agreed to work with the teacher and assist in the curriculum development of materials related to the research for transference to the K-12 classroom in an age-appropriate manner. Each of the topics invovles variants of well established research themes at the SGS-LTER (in fact you will recognize the first topic from last year's RAMHSS supplement request).

1) Research in Prairie Dog Ecology: RET Fellows will assist Dr. Moore and his graduate students in their studies of the impacts of prairie dogs on the structure and stability of soil food webs. We have copied the relevant question and portions of our proposal below.

<u>Changes in Below-ground Allocation and Food Web Stability</u>: Colonization and grazing by prairie dogs reduces standing biomass and the amount and quality of plant material entering the soil. At other sites, grazing has been shown to increase the exudation of labile carbon through plant roots, increase N-mineralization and decomposition rates, and induce shifts from the fungal to the bacterial pathway (Figure 1).

Prairie dog activities alter the availability of labile SOM and shift the plant community towards weedy species or accelerates root growth and turn-over (narrows C:N ratios of SOM and plant materials). We predict that extinction of prairie dogs will induce a shift in nutrient cycling and community structure towards the fungal "slow" pathway, while newly colonized will shift toward the bacterial "fast" pathway. We expect that an analysis of the models developed for each site will reveal that sites that retain nitrogen will be more likely to be dynamically stable than sites that retain less nitrogen (Figure 2). A prediction from the hypothesis is that native sites will possess soil food webs that are dynamically more stable than occupied sites, and that after plague epizootics remove prairie dogs, those sites will quickly converge in community composition to the native sites.

Figure 1

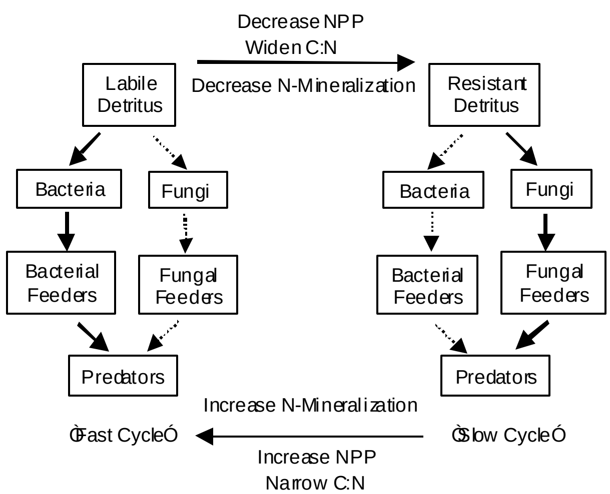


Figure 1. The soil food webs are compartmentalized into three interactive pathways – the root, bacterial and fungal energy channels. Empirical studies at the shortgrass steppe and elsewhere have demonstrated that disturbance can induce changes in the relative flow of nutrients through these pathways and nutrient retention.

Figure

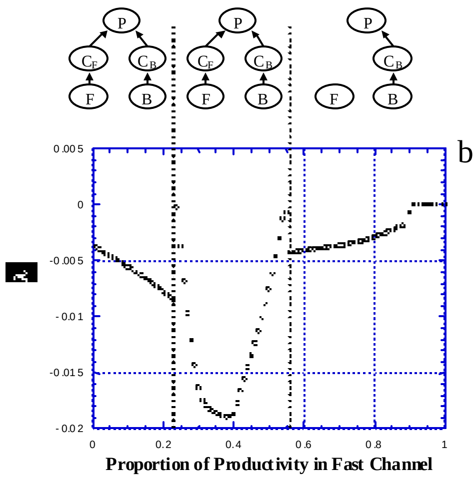


Figure 2. Simulations where the relative proportions of nutrients through the fungal and bacterial channels were altered. Stability is indexed by the most negative eigenvalue, λ. The more stable region occurs when neither the bacterial or fungal energy channel is dominant.

2) **Interactions Between Prairie Dogs and the Pollinating Insect Communtiy on the Shortgrass Steppe**: RET fellows will assist Dr. James Detling and his graduate students with their research on the interactions between prairie dogs and pollinating insects. Previous research into the ways that black-tailed prairie dog (*Cynomys ludovicianus)* colonies affect the vegetation upon which they live have shown that, at least in the mixed-grass prairie, grass cover declines while forb (non-graminoids, such as annual and perennial flowering plants) cover increases. Some studies have also hinted at this trend on the shortgrass steppe, where vegetation changes on prairie dog colonies tend to be less marked, and increase with the age of the town. We hypothesize that more forbs should mean more flowers on the prairie dog towns, especially old towns, but this has never been explicitly tested. It is possible that even if there are more forbs, if prairie dogs consume the flowers and the reproductive buds that produce them, then the increase in flowers that we expect to see may not follow.

The worldwide decline in pollinating faunas has recently become of great conservational and economic concern. Insect pollinators face two main challenges: decimation due to insecticide use, and habitat loss. Rare and/or specialist, native pollinators are more susceptible to these forces than common pollinators, such as the nonnative but naturalized honeybee. Honeybees do not usually exist on the shortgrass steppe because they do not typically ground nest, and suitable nesting trees are in very short supply in this habitat. Instead, native ground nesting bees such as halictids (sweat bees), anthophorids ("flower bees"), and certain types of bumblebees do the job. Also, many types of Lepidoptera (butterflies and moths), as well as native meloid beetles (blister beetles) and bombyliid and syrphid flies (bee flies) are frequent flower visitors in this habitat type.

The research consists of two parts: floral resource determination, and pollinator capture. We first measure floral density by simply counting flowers and inflorescences on randomly chosen plots both on and off- prairie dog towns. We do this in spring and early summer when the shortgrass steppe is in peak flower. We also supplement floral resource estimates by using capillary tubes to measure nectar volumes of flowers and also measure the nectar sugar content of the species that produce enough nectar to do so. Then, we return to the same plots where we have measured floral resources to quantify pollinator community composition and density. This is accomplished by sweep netting insects as they visit flowers and then carefully noting what species of flowers they were visiting. Though some species of Lepidoptera and some blister beetles can be identified on sight and records taken observationally, most insects, especially bees, must be killed and examined by microscope for proper identification. The sweep netting runs at each floral resource plot are timed and carefully matched to on- and off- town sites, since time of day and the weather are often the most important factors in determining which members of, and how many insects are flying and foraging at any given time. Therefore, we catch and note as many insects as possible in the area of a plot in 45 minutes, and then proceed directly to a plot in the opposite treatment (on- or off- town) and sweep net there. Identification can then occur at leisure during the off season.

We hope to show that the pollinator faunas found on prairie dog towns are more diverse and more dense than those found off town, in response to an increase in floral resources. Our preliminary research done in the 2002 field season has provided some evidence for this, with about twice as many flowers on towns and 2-3 times as many bees and butterflies captured on towns. This summer we plan to sample five towns and adjacent off-town areas, in about 8 weeks of field work.

3) **Intesive Grazing on the Shortgrass Steppe**: RET fellows will assist Dr. Ingrid Burke and her students investigating the effects of intensive grazing on plant soil communities at the shortgrass steppe. Past long-term studies of the shortgrass steppe have indicated that grazing by large generalist herbivores was an important part of the evolutionary history of the region. Because of this, much of our research has indicated that there are only minimal effects of grazing on the vegetation and soils of the ecosystem. However, studies of cattle grazing are limited in that they have mostly focused on the most common current management strategy, which is "moderate" grazing.

Currently, our LTER team is beginning a new long-term experiment to begin highly intensive grazing on the shortgrass steppe. We will be studying many aspects of the responses of the system, including vegetation, soils, and wildlife habitat. There are many opportunities for involvement of a teacher in this research this summer, all of which involve both setting up monitoring over the long-term, and data collection. We would welcome participation by a teacher in either collecting data for a specific response variable (for instance, soil erosion effects), or in working with the team for the whole experiment.

Timeline

Recruitment	January 2004
Orientation	May 2004
Research Experience	June 2004-August 2004
Research Symposium	January 2005

Deliverables and Expectations

RET fellows are expected to work a minimum of the equivalent of 3 graduate credit hours of independent studies (75 hours @ 25 hours per credit hour) over the summer period, and an equivalent amount over the academic year. The fellows will conduct research under the supervision of the senior scientists and submit written report of their research and lesson plan(s) developed from their experiences. Fellows are invited to present an oral or poster presentation the SGS-LTER and MAST research symposium held each January.

IV. Environmental Education (Funded)
(Subaward to University of Northern Colorado)

Environmental Education and Outreach Program for Educators of Native American Students

Introduction

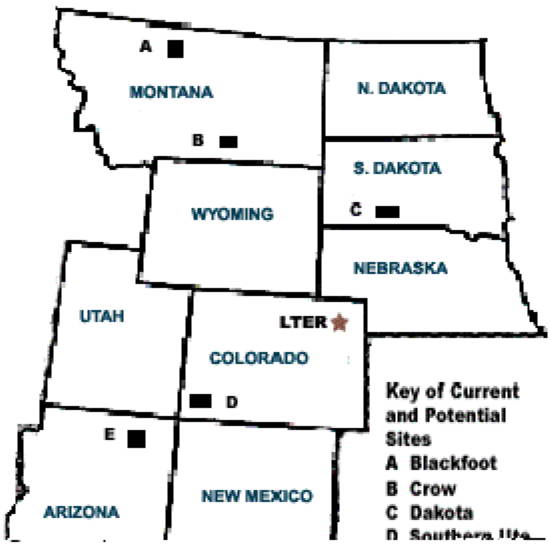
In support of the Shortgrass Steppe (SGS) Long Term Ecological Research (LTER) goal to investigate and learn about the changes in the environment due to natural and anthropogenic impacts, this proposal's education goals are to provide K-post secondary educators and students with field research, content and pedagogical professional development, and challenge education to close the gap in achievement. Specifically, we are requesting funds for a project that will provide educators of a Native American secondary school and Tribal Community College (TCC) an opportunity to learn how to guide Native American high school students to better understand, investigate, analyze and communicate environmental topics in their community. The proposed project will combine the experience of land use and ecological processes of researchers and educators at the SGS-LTER project, and the experience of challenge education and technological applications of researchers and educators at the Mathematics and Science (MAST) Institute at the University of Northern Colorado (UNC). This collective expertise is integral in the delivery of an environmental education program that improves the teaching and learning of science in Native American schools.

The SGS-LTER and MAST have a long history of serving students and educators from groups under-represented in Science, Technology, Engineering, and Mathematics (STEM) disciplines. Current projects aligned with the SGS-LTER include the DOE funded Mathematics and Science Upward Bound, the Corporate and Foundation funded Frontiers of Science Institute, the NSF funded GK-12 project, and the annual Research for Minority High School Student (RAMHSS) and Schoolyard Ecology supplements. The majority of students in these programs are Hispanic, African American, and Southeast Asian. Conspicuously absent from these efforts are ones directed at Native Americans, in large part to the relatively small Native American population in the immediate area surrounding the SGS-LTER, CSU and UNC due to relocation in the 19th century to reservations. MAST does have working relationships with several Native American tribes and reservations in the region (Figure 1) through its involvement in the NSF funded Center for Learning and Teaching in the West (CLTW). The proposed project will help to expand our outreach efforts to include Native Americans.

Native American educators and students have been selected because their communities on the reservations face disproportionately high rates of poverty compared to non-reservation schools. Their education system faces many of the same issues that inner city schools face: lack of innovative instruction in science, lack of cultural sensitivity to science, low self esteem and self confidence of students, insufficient financial resources, a curriculum not aligned with STEM standards, high drop out rates, and low graduation rates. Native American reservations face many of the same pressures in terms of their natural resources that are currently under investigation at the SGS-LTER, e.g., grazing, agriculture, and development.

These issues lead to under-representation of Native Americans in STEM careers which in turn causes insufficient expertise for land use decisions on the reservation.

We propose to bring secondary teachers and students from Rough Rock Community School and science faculty from Dine College to a two week program that allows them to work with science researchers and science education faculty and staff from the UNC, Colorado State University (CSU) and the SGS LTER project Both tribal schools are located in the Four Corner Region and serve students of the Navajo reservation. Teachers would bring Navajo high school students who show leadership and academic potential.



The Rough Rock population was selected because it faces poverty. Their land experiences extensive soil erosion due to wind, rain, and grazing. Their high school is not successfully graduating students with success in mathematics and science courses. This project will provide them with skills on how to investigate and understand their soil erosion problems, find solutions, manage their land, and communicate the findings to the Rough Rock community. This in turn should develop methods to improve effective land use in Rough Rock, and encourage Dine College and Rough Rock School students to focus on land management careers.

This project is viewed as a pilot for a model that can be used with other education systems in Native American communities. Based on the success and assessment of this project, our long term goal is to expand the project to include schools in communities noted in Figure 1. The SGS LTER and UNC's MAST Institute have established partnerships with five different Native American reservations. Current activities include faculty professional development on science and mathematics content and pedagogical topics for both tribal colleges and the reservation schools, K-12 student challenge education outreach, and on line graduate course development and delivery for the educators on these reservations.

Activities

The program will consist of a 2-week summer session that will be divided into three distinct phases. Even though each phase is distinct, lessons learned from one phase will be used to facilitate success in subsequent phases. In addition, there will be a series of follow-up on-site workshops throughout the academic year.

The first phase will include all participants (students, teachers and TCC faculty) in hands-on challenge education and environmental science activities designed to promote leadership, teamwork, and cohort building. Similar activities in other projects have helped participants to develop intrinsic motivation to further investigate areas of interest. The cohort bonding aspect of the first phase experience is designed to build trust among participants. This phase is included because it will improve the participants' self confidence and motivation to succeed. The activities planned for phase one are consistent with those offered at Outward Bound and the National Outdoor Leadership School (NOLS). The phase will be conducted at a field location such as Vedauwoo, Wyoming which has a rich foundation with regard to the cultural history of the landscape. This area is a relatively short distance from SGS-LTER and provides a diversity of ecological settings from prairie to rock formations that can be used for environmental and challenge education activities.

The second phase of the program will be held at UNC, CSU, and the SGS LTER site. This phase will include group and breakout sessions where students, teachers, and tribal faculty will pursue different areas of interests (i.e., content science, techniques in field research, academic tutoring, professional development). Students will be introduced to the collegiate environment through interactions with UNC, CSU, SGS LTER, science researchers, faculty and students. Students will also be given assistance in academic planning and tutoring as dictated by their individual needs. Students will have an opportunity to investigate careers in land use and management. Tribal faculty members and teachers will have an opportunity to participate in professional development workshops that are offered by faculty and researchers in areas of science content (i.e., soil ecology, land use, and grazing), grant writing, use of GIS/GPS technology for site mapping and inventory, use of graphical presentation and Web editing software for communication of the project, and educational leadership. Faculty will also be asked to participate in a workshop addressing major issues in Native American education and how to integrate field research into their high school and college curricula. Project researchers and science education faculty will work with the tribal teachers and faculty to insure that research investigations and curriculum development are culturally relevant to the Navajo culture.

The third and final phase will be held at Rough Rock Community School and Dine College. With the support of project staff, the teachers and tribal faculty will develop and implement a model for integrating field research on land composition, use, and management into their science curriculum. Navajo high school and community college students will work with this model to investigate a specific environmental issue important to their community. The participants will be asked to approach this issue as an applied research project from both a scientific and social perspective as it relates to the Navajo culture. Students will be asked to investigate, synthesize, communicate, provide recommendations for resolution, and address the role of research in determining solutions to preventing future issues in their environment. The final deliverable for this phase will be oral and written presentations to the entire community. Adult participants will learn how to facilitate the research project development and assist students in their investigation and gathering of information for their presentations.

Additionally, all participants will enter into on line discussions, through a Web based system, with the project staff throughout the Fall and Spring semester of 2004-2005. The discussion will focus on the topics and workshops covered during the summer. There will also be an on line technical tool for participants to share their applied research project progress and their written and oral presentations to their community.

The secondary teachers and tribal faculty members will be invited to continue to build their content and educational leadership knowledge by taking on line graduate courses that are jointly offered by both participating universities. These courses are offered through an NSF funded program, Center for Learning and Teaching in the West (CLTW).

The project staff will visit the participants during the Fall and Spring semester. The staff will provide support to the faculty and teachers on the progress of curriculum integration. The staff will be able to see first hand the progress and completion of the integration of the environmental research project. The staff also will visit with other students and community leaders to encourage support of the participants' work and to seek continued involvement in the program by their community members.

Evaluation

The program will use Dr. Rose Shaw of Metrica, Inc., as an external evaluator to review the program's success. Specifically, the following are targeted outcomes for this program.

- Science classes at the high school and college level will complete their research projects and provide reports by May 2005.
- 80% of the adult participants will complete one CLTW course by May 2005.
- Based on measurement of attitudes of participants, it is expected that the majority of the participants will have positive attitudes towards the environmental education experience providing them a method to understand and make informed decisions on land use This attitude change will be determined by focus group discussions, review of journals of participants, and surveys.
- Increases in enrollments will be observed by high school and community college students in advance mathematics, science, technology and communication courses after the summer 2004 experience as well as after Fall and Spring participation in field research.
- Full explanation and outcomes of Field research projects conducted by the participants will be posted on the project Web site by May 2005.

Timeline

February 1, - May 1, 2004 – Recruit participants and communicate process for participating in Phase One - Summer Activities. Provide a pre survey to participants to determine attitudes toward field research and land use management.

June1, – June 15, 2004 – Participants arrive onto UNC campus, and work with faculty and researchers at SGS-LTER, CSU, and UNC on Phase One (Challenge Education) and Phase Two - activities include leaning content science, techniques in field research, technology use and integration into teaching of Web development and GIS technology, academic skills, and professional development.

July 1 - September 1, 2004 - Educators and faculty work together through on line Web interface to begin adding field research to high school and Tribal College science curricula. Educators begin to establish research plots. Enroll educators in CLTW courses.

September 1, 2004 – Begin Phase Three of project - Educators begin to engage their students in field research through the science courses.

September 1, 2004 – December 15, 2004 – Continue Phase Three of Project – Through e-mail and on line Web interface, educators, students, and project staff communicate progress of integrating field research into course, and provide technical support of field research techniques and curriculum integration support.

October 1, 2004 – Project staff travels to Rough Rock to view field research activities in the high school and Tribal College, provides feedback on activities, continues evaluating project by reviewing journal entries, and meets community members and leaders.

January 1 – April 30, 2005 - Through e-mail and on line Web interface, educators, students, and project staff continue to communicate progress of integrating field research into course, current outcomes of field research by students, and provide technical support and curriculum integration support

March 20, 2005 – Project staff travels to Rough Rock to view field research activities in the high school and Tribal College, provides feedback on activities, continues evaluating project by reviewing journal entries, and communicates progress of project to Rough Rock Community members and leaders. Students provide oral and written presentations of their field work, results, and recommendations for improved land use to the Rough Rock community.

April 30, 2005 – Educators will provide a final written report on the implementation and outcomes of using field research as a vehicle to study soil erosion in their science programs. Students will provide a final written report on their research, results, and recommendations on how to better manage their land. The final attitudinal survey will be given to all participants. Data will be collected on educator completion of CLTW courses, and student participation in higher level science and mathematics courses in high school and in the Tribal College.

V. International Collaborative Research
(Part A received partial funding)
(CSU budget page)

We are requesting funds for three international LTER cooperative projects: A) Cross-site research on North American grasslands and South African savannas; B) I-LTER workshop in India, and C) Comparative study of long-term grassland dynamics between SGS LTER and Ordos Long-term Grassland Research site in China.

A) LTER International Cross-Site Research on Grassland and Savanna Ecosystems in North America and South Africa – 2004

US LTER Sites/Collaborators	South African Site/Collaborators
Konza Prairie (John Blair)	Kruger National Park (Harry Biggs,
Sevilleta (Scott Collins)	Nick Zambatis, Mike Peel, Judith Kruger)
Shortgrass Steppe (Alan Knapp)	

Introduction, Background and Justification.
The current strategic vision for the future of the LTER Network, as articulated in the 20-year review, is based on the premise that the third decade of LTER science should be one of synthesis and cross-site research. These two activities can and should be linked such that the synthesis of existing knowledge informs and guides the initiation of new cross-site research. In this way, the scale of inference of LTER results can be extended beyond the borders of individual sites, leading to a better understanding of complex environmental problems and resulting in knowledge that better serves science and society.

As global change issues confront society, ecology is now at the forefront of research addressing questions at regional and global scales. However, an implicit assumption made when working at larger scales is that the ecological processes identified as important in intensively studied sites operate consistently, or at least change predictability, across similar ecosystems within and between regions. Several LTER scientists, including those identified in this supplement request, have been actively synthesizing results from grassland LTER sites through LTER and NCEAS workshop activities. As a result of these efforts, a series of grassland ecological "rules" have been derived to predict community and ecosystem responses to key drivers (fire, grazing, climatic extremes) of these biomes (Collins et al. 1998). But to test the generality of these ecological rules (defined by Lawton (1999) as "general principles that underpin and create patterns") and thus our ability to generalize more broadly (globally), we need to conduct parallel research in partnership with LTER and ILTER scientists and take advantage of comparable long-term studies in other ecosystems. This will allow us to probe the limits of these rules and potentially identify key contingent factors that may alter their manifestation (Thompson et al. 2001). We believe that there is a pressing need to identify the extent to which we can extrapolate beyond individual study sites and model systems (the current domain of our understanding), and to identify those ecological processes that are predictive rather than descriptive (Lawton 1999).

This supplement will support international cross-site research focused on grassland and savanna ecosystems in North America and South Africa, respectively. We propose to explicitly test a suite of fundamental ecological rules, using experimental manipulations of key drivers (fire and grazing) in intensively studied N. American grassland LTER sites and in structurally similar South African savanna sites (in Kruger National Park (KNP), an ILTER site in the Republic of South Africa). Ongoing experiments in KNP offer unprecedented opportunities to conduct this research. In KNP there are a series of 7 ha Experimental Burn Plots (EPB's) that have had fire frequency and timing experimentally manipulated for over 50 years. These span a 400 mm precipitation gradient within a portion of KNP. There are also two very large (> 100 ha) herbivore exclosures (spanning this mesic to semi-arid gradient) established within the park in which the impact of grazers can be assessed. Finally, KNP provides a precipitation gradient from south to north (500 mm, Fig. 1) that is equivalent to the gradient from the SEV and SGS sites to KNZ. Excellent fire and grazing history records have been kept through annual game censuses and fire surveys throughout the history of the park. Thus, although our proposed data collection to test rules will be short-term, we have access to sites with long-term manipulations and monitoring records across a significant rainfall gradient, which is essential for comparative analysis with our North American LTER sites.

Temperate grasslands in North America and sub-tropical savannas of Southern Africa are ideal systems for assessing the generality of grassland rules and identifying contingent factors. These systems share many similarities in that both are gramminoid-dominated with woody species being rare, sub-dominant or co-dominant. Moreover fire, large grazers and climatic extremes (droughts) were historically important, and today remain key drivers of ecological pattern and process that vary in significance along precipitation/productivity gradients. But these systems also have important differences. First, the "dormant" period of these biomes are set by different climatic factors; cold temperatures in temperate grasslands and the dry season in sub-tropical savannas. But there are two other critically important areas

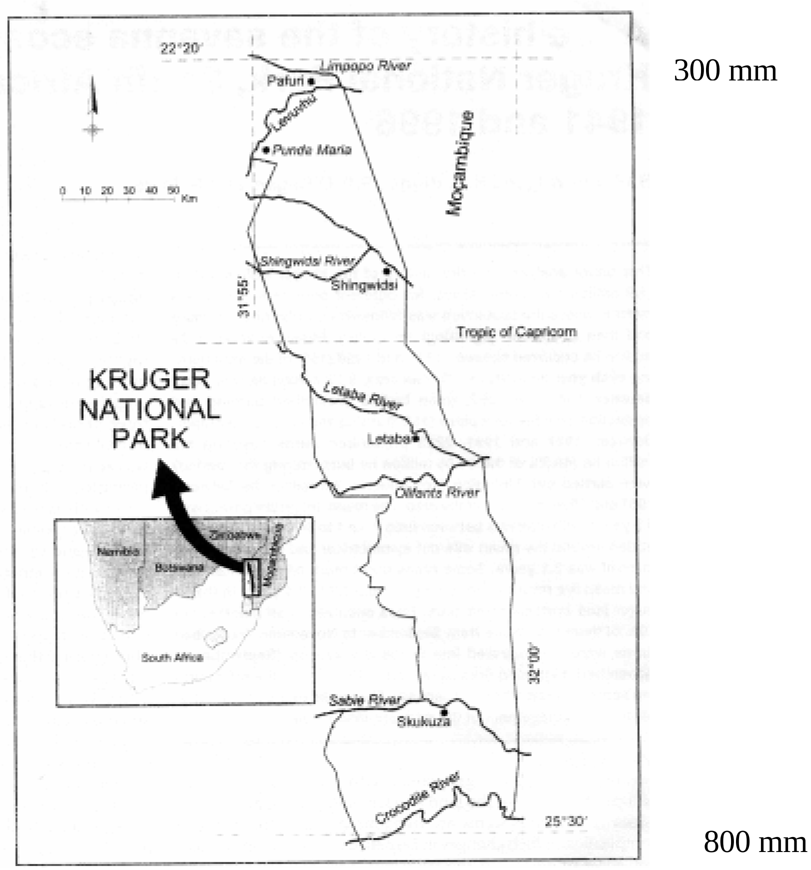


Figure 1. Location of Kruger Park in South Africa with the N-S rainfall shown.

where these biomes differ: in age (their historical and evolutionary legacies) and the richness and functional breadth of the megaherbivore guild currently present. Grasslands of North America are relatively young systems first arising 5-7 million yrs ago, with many of the present vegetation associations arising less than 10,000 yrs ago (Wright 1970; Stebbins 1981; Axelrod 1985; Coughenour 1985). In contrast, the savannas of southern Africa arose > 40 million yrs ago with extant communities present throughout the last 4-6 million years. Thus, southern African savannas have a much longer evolutionary history and represent highly co-evolved systems relative to North American grasslands (Coughenour 1985; Scott et al. 1997). In addition, African savannas still contain a majority of the megaherbivores that evolved with this system, whereas the richness and functional diversity of megaherbivores in North America has decreased dramatically, with the loss of > 70% of the megafauna (Stebbins 1981; Martin 1984; Coughenour 1985). Today, a single ungulate grazer dominates most North American grasslands (native bison or introduced cattle; Knapp et al. 1999) with white-tailed deer (*Odocoileus virginianus)* in tallgrass prairie or other browsers such as pronged-horn antelope of secondary importance. Bison were very recent arrivals (late Pleistocene) to North America (Stebbins 1981; Coughenour 1985) whereas in Africa, 46 ungulate species (22 Bovidae in KNP) are extant and have been present for millions of years (Owen-Smith and Cumming 1993). Differences in historical legacies (short and long-term) and degrees of species loss are not unique to grasslands and savannas -- indeed, these factors vary within most biomes. At issue is the degree to which these differences alter processes and relationships (i.e., change the rules) that define the system. Distinguishing those processes and interactions that are dependent on historical legacies and/or megaherbivore guild richness (contingencies in Lawton's (1999) terminology) from those that are more robust is critical for refining our predictive understanding of grassland ecosystems worldwide.

Proposed Research

Over the past 4-yrs, several LTER scientists from the three LTER sites collaborating in this cross-site proposal have visited Kruger National Park and their experimental plots, and limited preliminary data have been collected. During the same time period, > 20 South African scientists and students have visited the North American LTER grassland sites. Most recently, scientists from KNP and KNZ, SEV and SGS participated in an NCEAS working group (May 2003) during which long-term data were synthesized from NA and SA experiments and comparative analyses were attempted. During these interactions, we discovered that differences in methodology between studies within North America and between NA and SA experiments precluded definitive comparative analysis. For example, even relatively simple comparisons of plant species richness responses to fire or grazing could not be made because, although experimental treatments were comparable, KNP scientists only identified a subset of "important species" in their surveys rather than all species. Thus, we mutually agreed on plans for collaborative studies in which the methods used are identical and we have already "registered" such projects with KNP. Indeed, a graduate student of A. Knapp's (Mr. Tony Swemmer, a South African resident) is conducting his PhD research in both KNP and LTER sites with funding from a Mellon Fellowship. These preliminary interactions have been invaluable, as the logistical hurdles involved with working internationally in two hemispheres can be daunting. We have successfully dealt with most of these in the past few years. With funds from this special LTER supplement for international cross-site research, we propose to expand these initial efforts significantly and collect data of sufficient quality and extent to test NA grassland rules in South African savanna.

First, some brief rationale for rules. The biome rules we outline are based on 20+ years of LTER grassland research that have identified 3 defining characteristics of temperate grasslands.

1. Although the grasses in these systems are responsible for most of the energy flow (and hence make up most of the biomass), it is the forbs (broad-leaved dicots) that contribute most to plant community diversity (Knapp et al. 1998). Hence, a focus on these two functional groups is informative as they provide links between community characteristics and ecosystem processes.

2. As a group, the grasses tend to be more resource-use-efficient than the forbs. This is partially related to their C_4 ecophysiology (although even the C_3 grasses are also comparatively more efficient) resulting in high water, light and N use efficiency relative to the C_3 forbs (Knapp et al. 1998). Resource augmentation (water, N) has repeatedly been shown to lead to shifts towards greater forb abundance, whereas reductions in resources are associated with greater graminoid dominance (Lauenroth et al. 1978, Knapp 1998). Moreover, resource patterns (spatial heterogeneity) have also been shown to influence community patterns (Bakker et al. 2003). Thus, understanding how drivers affect resource amounts and spatial patterns is key to explaining responses in these two functional groups.

3. Across broad climatic and productivity gradients (i.e., shortgrass steppe to tallgrass prairie) productivity is strongly related to precipitation (Sala et al. 1988). But both fire (which is most important and frequent in productive grasslands and uncommon in shortgrass sites), and chronic droughts (which display the opposite pattern) are “non-selective” drivers. In other words, they impact all biota directly to some degree. In contrast, although large herbivores can be important drivers across all grasslands (despite differences in grazing intensity), megaherbivores are “selective” in that grasses are grazed non-randomly relative to the forbs (Knapp et al. 1999). Megaherbivores also increase resource heterogeneity and availability by speeding the cycling of N (Johnson and Matchett 2001), and increasing light penetration through the plant canopy and soil moisture levels, whereas fire more uniformly decreases availability of N and water (Blair 1997), and drought, of course, uniformly decreases water availability. Again, mechanistic links among these key drivers, resources (patterns and amounts) and functional groups are well established. This allows us to articulate rules that focus on easily measured patterns of basic resources and plant functional groups that are impacted by the key drivers of the systems and yet provide information about emergent properties such as diversity and productivity.

Effects of frequent fire and large herbivores on the vegetative structure.

Rule 1. In more mesic grassland/savanna, frequent fire increases graminoid dominance and reduces plant species richness. The presence of megaherbivores reduces, but does not eliminate this response to fire (Collins et al. 1998). Sites for data collection: Long-term annually burned and unburned watersheds, and grazed and ungrazed watersheds at KNZ; Long-term annually burned and unburned Experimental Burn Plots and large herbivore exclosures at KNP.

Effect of rainfall gradients on vegetation structure.

Rule 2. Across a precipitation/productivity gradient, broad-leaf, dicot forbs increase in abundance and cover relative to grasses as rainfall increases, and thus plant species richness and diversity increases. Sites for data collection: long-term plots at KNP, KNZ, SGS, SEV (the Ft. Hays Experimental Station in Western Kansas will also be used for this study)

Effect of herbivores on resource abundance and distribution.

Rule 3. Megaherbivores increase N availability, cycling and energy (light) to the soil surface, but decrease soil C cycling in grasslands/savanna (Knapp et al. 1999, Johnson and Matchett 2001). Megaherbivores also increase the spatial heterogeneity of these resources (Bakker et al. 2003). When fire is present, availability and heterogeneity of resources is decreased and soil C cycling is increased (Blair 1997, Knapp et al. 1998b). Sites for data collection: long-term plots and exclosures in KNP, KNZ, SGS, SEV.

Methods

The key to successful comparative research is to use common, standard methods at all sites. The primary data collection for rules 1 & 2 will entail plant community composition measurements using standardized quadrat-cover data collection techniques (Collins 1992). Aboveground biomass and productivity measurements will also be made in grazing exclosures or ungrazed plots at each site. Standardized quadrat harvest methods with biomass sorting by growth form will be used (Briggs and Knapp 1995). Methods for measuring patterns of resources (light and soil N, rule 3) will also be standardized. Equivalent sampling grids will be laid out in all sites, and light (photon flux density) will be measured with a quantum ceptometer above and below the herbaceous canopy, whereas 2 cm diam. x 10 cm deep soil cores will be collected for determinations of KCL-extractable NO_3 and NH_4 levels, as well as total soil C and N and percent soil water content. Standard spatial statistics and metrics can then be used to assess heterogeneity of resources and link these to plant community structure and fire and grazing treatments.

We anticipate data collection will require two intensive field campaigns in the KNP sites in South Africa, early and mid-summer for plant community composition estimates (to capture spring and summer flora and be consistent with NA grassland sampling), and mid-season and end of season for biomass and resource abundance/pattern sampling.

Responsibilities of US and International collaborators.

The three US LTER scientists will be responsible for study design and data collection with graduate students. We prefer to use graduate students rather than technicians to provide international experience to the future generation of ecologists. Knapp, Blair and Collins will provide the on-site logistical support and access for students to collect data from their respective LTER sites. Moreover, they will facilitate access to data collected as part of their LTER programs to provide context for interpretation.

The South African Scientists will provide local expertise in plant identification (Zambatis and Peel), logistical support (Biggs) and local data access (Kruger). Both NA and SA groups will collaborate for data analysis and interpretation, with graduate students providing the lead on manuscripts and co-authorship shared among all involved as appropriate. All data will be archived and available through the three LTER sites and data will also be provided to the KNP data manager (Judith Kruger).

Expected Products and Broader Implications

The three students that gain experience in conducting research internationally in South African savannas, as well as across North American LTER sites, will benefit substantially from both a scientific and cultural perspective. Continued and expanded ILTER collaborations with South African National Parks scientists will enhance future opportunities to build linkages among LTER and ILTER sites and researchers. Finally, we envision at least one high-profile manuscript resulting from the explicit testing of each of these rules. These will help launch the "decade of synthesis" of LTER research and serve as a model for testing the predictive limits of our ecological knowledge in other systems.

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B) I-LTER Initiative: Workshop on LTER in India

The Shortgrass Steppe LTER has long had an important interaction with scientists from Banaras Hindu University in India. This interaction was begun during the International Biological Program, and has extended to visits in both directions, and many peer-reviewed journal articles. Most recently, Dr. Jai Singh visited the US on an LTER supplemental grant several years ago, and worked up and published two long term data sets.

Although there are several long-term monitoring programs in ecology and botany in India, at this time there is not a country-wide network of long term ecological research sites. Since last July, SGS-LTER co-PI's Lauenroth and Burke have been invited to visit India and run a workshop on LTER for scientists there. Until this point, we have been unable to find funding.

We propose to prepare an I-LTER workshop based on those that the LTER network has previously offered (and which we have participated in, in Taiwan and Argentina). The major goals of the workshop would be: a) to introduce the ideas, concepts, and implementation of an LTER network to potential I-ILTER scientists; b) to hear from scientists about the current activities that could become a national LTER network, (such as the current Indian network of tropical forest sites); and c) to provide an external viewpoint to national funding agencies regarding the value of LTER research and participation in the ILTER network.

We propose that Lauenroth and Burke, as well as a member of the LTER data management community (such as our own data manager), organize a workshop for Indian scientists in late 2004 or early 2005. We would plan to spend at least 4 days in business meetings, and additional time visiting long-term research sites. The specific location of the workshop will be chosen by Indian scientists.

We are currently working with three individuals on the organization of such a workshop:

Dr. Jai Singh, Professor, Department of Botany, Banaras Hindu University
Sharda R. Gupta, Professor of Botany, Kurukshetra University, Kurukshetra, India
Dr. Uppeandra Dhar, Director In charge, G.B. Pant Institute of Himalayan Environment and Development Kosi-Katarmal, Almora, India

C) Comparative Study of Long-term Grassland Dynamics between SGS-LTER and Ordos Long-term Grassland Research Site, China

US host institution	China host institution
Colorado State University	Inner Mongolia University
	Ordos Rangeland Monitoring Station

INTRODUCTION TO ORDOS PLATEAU AND THE GRASSLAND SITES

The State and Function of the Ordos Rangeland

Located at the northern part of China, the Ordos Plateau is surrounded by the Yellow River in the west and north, and then stretches to the Loess Plateau in the south. The plateau can be divided into four parts according to landform and landscape; they are the Jungle Loess Hills in the east, the Kubuqi & Maowushu Sandy Land stretching from north to south, the Wusheng Basin in the center, and a desert and semi-desert plateau in the west. These four landform units are covered by typical steppe (*Stipa bungeana*), sandy shrubs (*Artemisia ordosica*), salt meadows and marshes, and desert steppe (*Stipa breviflora*) respectively. The great variation of landform gives the plateau higher ecosystem diversity than the surrounding areas in the region.

The climate in the Ordos Plateau is characterized by an alternation of cold dry and hot wet seasons. The average precipitation of 130-450 mm is mostly distributed from June to September. The fluctuation of annual rainfall is another main feature in the region. In approximately 30% of the years on record, annual rainfall drops to 100-150 mm or lower. The high temperatures in the hot season are responsible for high rates of potential evapotranspiration in relation to rainfall. The aridity ratio (precipitation/potential evapotranspiration) in the Ordos region ranges from 1.5-3.4.

Humans have influenced the structure of Ordos vegetation through grazing, conversion to cropland, and industrial activities and the introduction of planted woodland. The growing population, both as a result of high birth rate and population redistribution, has often been accompanied by an increase of grazing pressure on the regional vegetation. The rise of urbanization and industrialization during the last four decades has further intensified these activities. In particular, the surface coal mining and Chinese traditional medical industry have caused serious problems. The present landuse pattern in Ordos rangeland is a reflection of these human pressures.

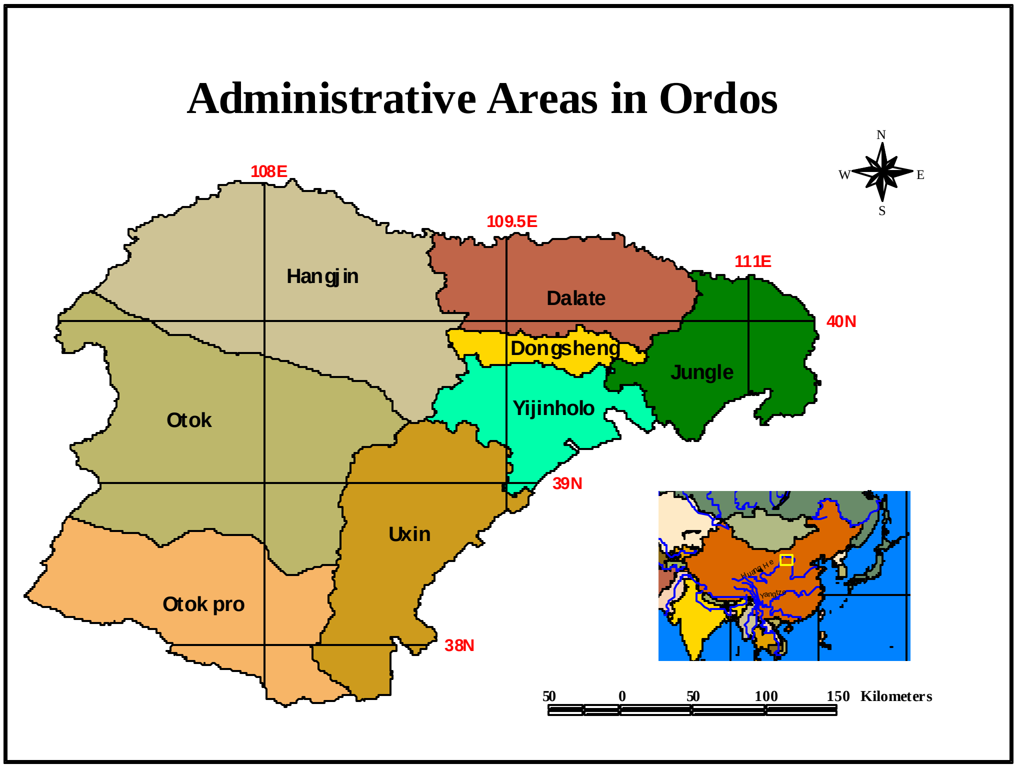

Figure 1 Location and geographical units of Ordos (Jia, 1999)

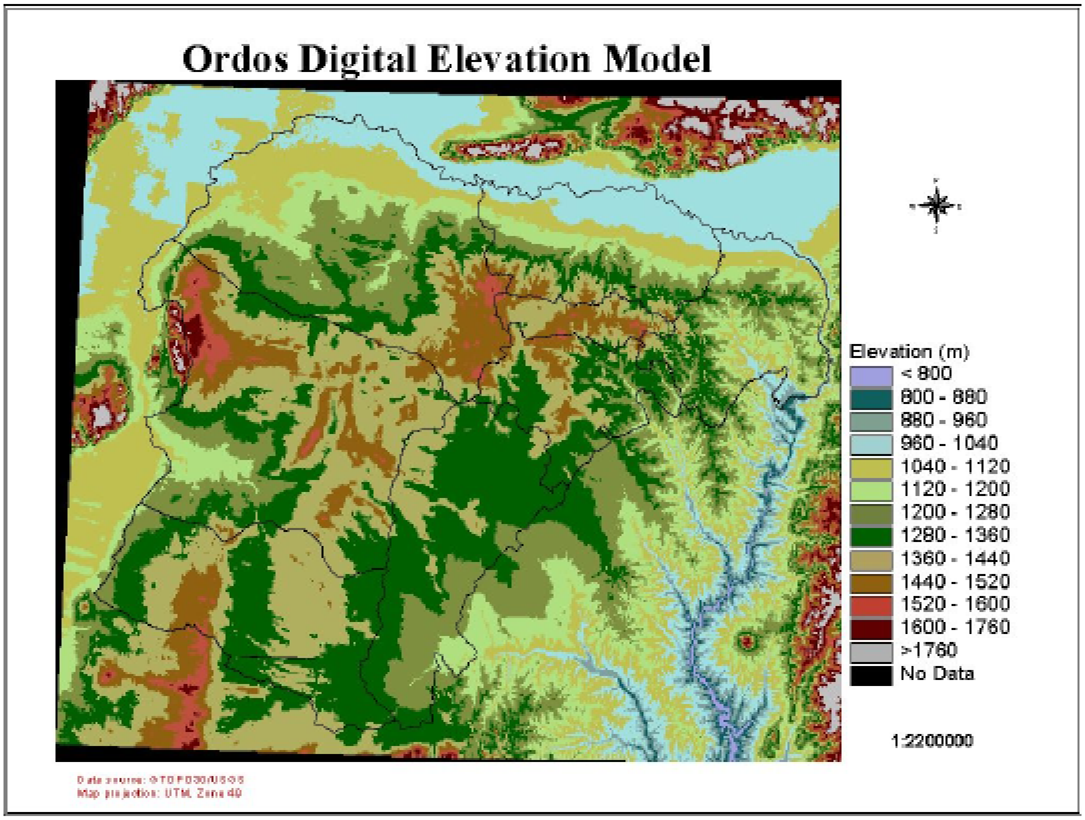

Figure 2 Digital elevation model of Ordos (Jia, 1999)

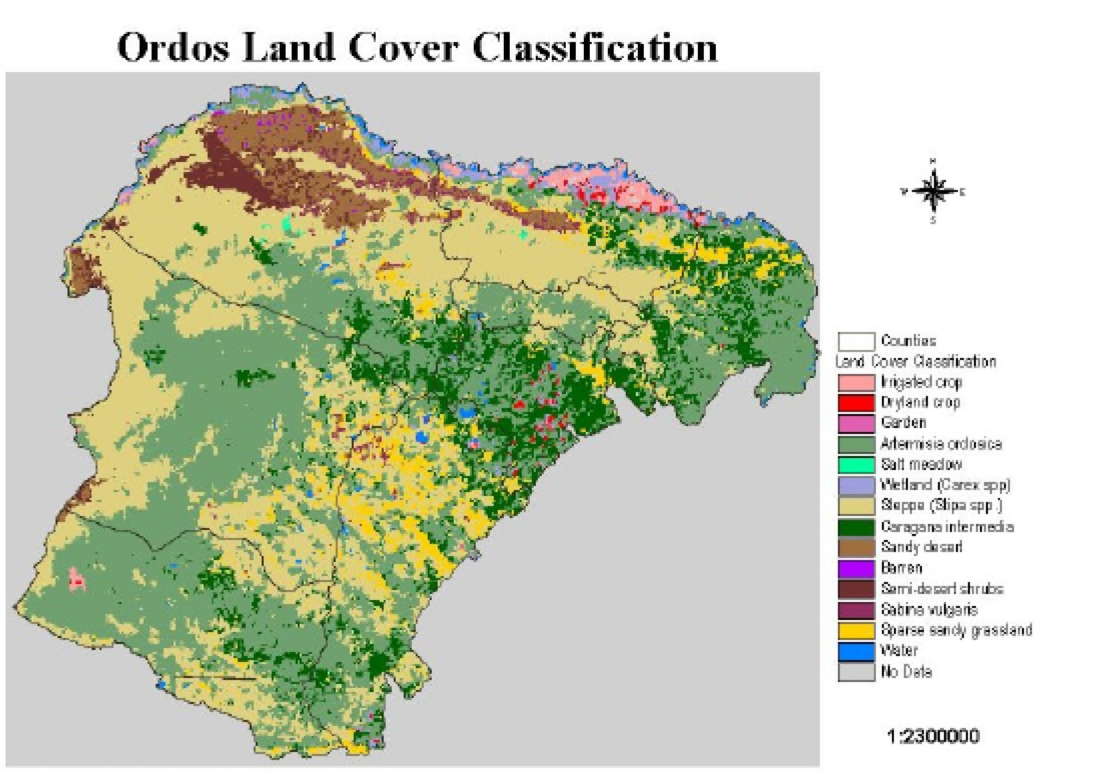

Figure 3 Land cover classification of Ordos (Jia, 1999)

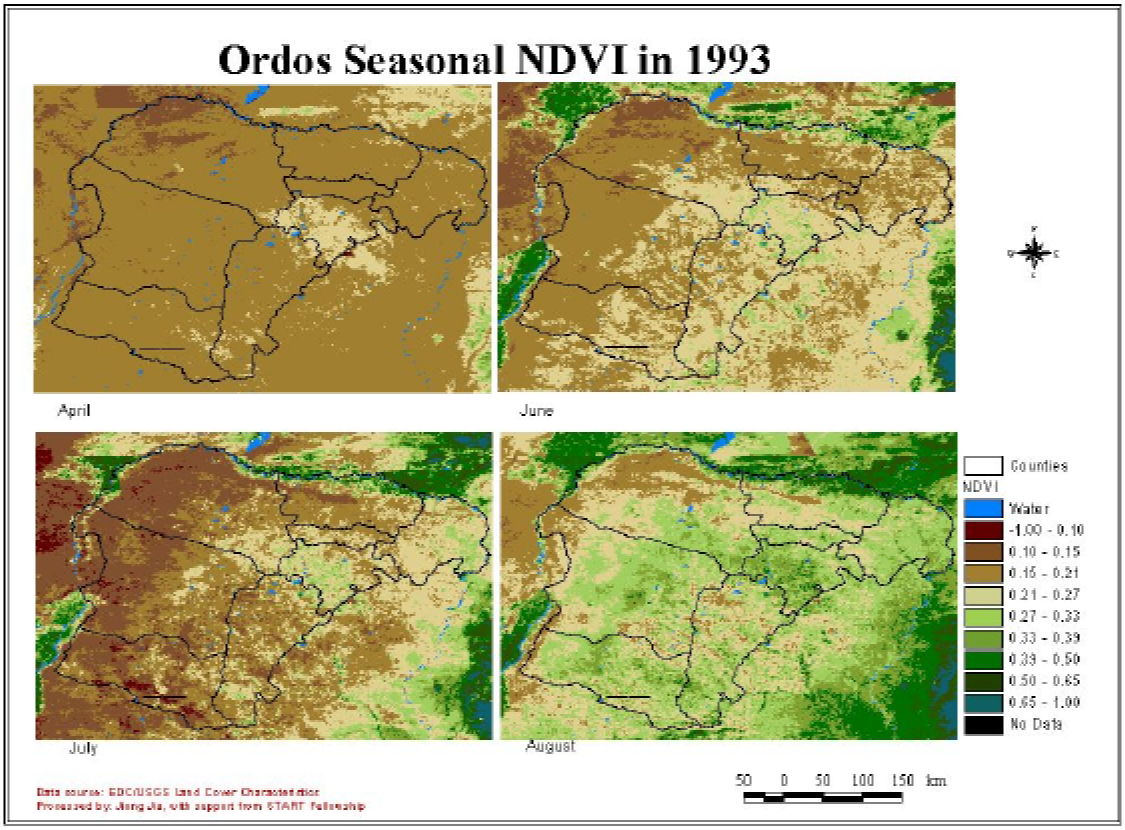

Figure 4 Summer AVHRR-NDVI of Ordos (Jia, 1999)

<u>Permanent Ecological Research in the Ordos Rangeland</u>

The permanent ecological research in the Ordos Plateau was started in 1983, and consists of several long-term ecological research sites and programs on grassland ecosystem dynamics and rangeland productivity widely distributed in various climate and vegetation units throughout the plateau. Currently, there are at least a regional grassland productivity monitoring program and two independent long-term ecological research sites (stations) operated in Ordos. They are the Ordos Grassland Productivity Monitoring Program of the Ministry of Agriculture, the Dalate Grassland Ecology Research Site of Inner Mongolia University and the Ordos Sandland Ecological Research Station of Chinese Academy of Sciences.

1. The Ordos Grassland Productivity Monitoring Program

The program was established in 1983 as part of the grassland/cropland productivity monitoring network sponsored by the Ministry of Agriculture. In 1983 and 1985, four series of permanent sites were set up at typical steppe, desert steppe, sandy vegetation and salt meadow separately. The sites are sampled seven times a year during the growing season by

Ordos Rangeland Monitoring Station and from 1992-1997 jointly by Jiong Jia's group of Beijing Normal University. The measurements include:

Community features: aboveground biomass, under-ground biomass, root distribution, coverage, height, species composition, leaf area index, plant distribution pattern, etc.

Soil features: physical and chemical features

Grazing density, selected consumption, etc.

The scientific aspects of the program are divided into six areas: 1) evaluation of vegetation production and composition; 2) analysis of stocking rate and diversity; 3) effect of climate fluctuation on forage supply and stocking rate; 4) development of index and indicators; 5) regional rangeland production and degradation analysis using remote sensing; 6) integrated impact factors- degradation models.

2. The Dalate Grassland Ecology Research Site

The site is located in northern Ordos and is about 48 km south of the Yellow River. It was established in 1992 jointly by Inner Mongolia University and the Institute of Grasslands. In the past decade, research has been focused on eco-physiology of dominant perennial and shrub species and their adaptation mechanism in sandy and salty environment. The research has been eliminated since 2001, however, the 40-ha permanent site is still maintained by a local partner.

3. Ordos Sandland Ecological Research Station

The site is located in the center of the Ordos Plateau. The permanent site was established in 1993 and consists of several permanent plots of typical steppe and sandy grassland, and a small greenhouse.

The research focus is on the structure, function and dynamics of sandy grassland ecosystems in semi-arid regions, restoration ecology, biodiversity conservation, and ecological adaptability of plants.

This site is affiliated with the Institute of Botany, Chinese Academy of Sciences

Our comparative studies will assist both the Ordos Plateau sites and the SGS LTER site to better understand the seasonal and annual dynamics of vegetation production, long-term vegetation changes under different natural and human impacts, and to determine the mechanism of rangeland degradation at ecosystem and landscape scale. The result of the research will contribute to national and local rangeland restoration and usage.

<u>Scientific questions</u>:

1) How does grassland vegetation fluctuate and change in response to climate dynamics and human disturbance under different climate regimes and in different vegetation types? What are the differences and similarities between North American short-grass steppe and East Asian desert steppe?
2) Is there a common decadal trend in grassland productivity and carbon budget in temperate short-grass steppe amd desert steppe?
3) How do grazing intensity and land use type influence vegetation productivity and carbon balance in temperate short-grass steppe and desert steppe?

FUNDAMENTAL GRASSLAND ECOLOGY RESEARCH

Based on current ecological research at both locations, we proposed the following comparative studies:

1) Comparing seasonal and inter-annual vegetation dynamics of short-grass steppe and desert steppe under different climate regime and in different vegetation types between the SGS LTER and Ordos. The variables willinclude plant species dominance, dominant population density, aboveground biomass, leaf area index and vegetation spectral reflectance. There are 10-20 years of long-term measurement data available from both study sites, and we will integrate the field methods from both sides and perform similar measurements at both Ordos and CPER in summer during the course of the project.
2) Comparing carbon budget and temporal dynamics of carbon balance between the two ecosystems. The carbon budget studies will also be performed along a climatic transect (east-west) and a degradation severity gradient to examine the impact of climate regime and disturbance on carbon sinks and sources.

APPLICATION RESEARCH ON RANGELAND RESTORATION

The priority objective of Ordos grassland ecological research program is to directly apply long-term research findings to the management of its fragmented rangelands, to enhance vegetation productivity and to combat rangeland degradation. After decades of intensive ecological research, SGS LTER scientists have substantial knowledge about the vegetation structure and function and plant-herbivore interactions in short-grass steppe. This knowledge could greatly help our Chinese counterparts in their rangeland enhancement and ecological restoration efforts. We propose that applications be focused on two aspects:

1) Use best available knowledge on grassland nutrient cycling in ecological restoration practice. Dr. Burke's and Dr. Lauenroth's studies on grassland biogeochemistry have led to an in-depth understanding of carbon and nitrogen cycling under various conditions. This is essential knowledge for restoring the severely degraded rangeland in Ordos. We will work with Chinese colleagues to examine current restoration practices and select the ones that greatly improve soil fertility and ecosystem functions.
2) Most Ordos rangelands are under heavy grazing pressure and to some extent degraded. However, there are still arguments among scientists and managers about whether or not current stocking rates are too high, and practically how many livestock per hectare is optimum for rangeland management. There have been experimental studies on the response of grassland vegetation to various grazing intensities at the SGS LTER site over the past 6 decades. The findings from this work could help answer the questions.

ORDOS TRAVEL PLAN IN SUMMER 2004

Time: Late June to early July, about three weeks
Personnel: William Lauenroth, Ingrid Burke, and Gensuo Jia
Purpose: Field work in Ordos and workshop with Chinese colleagues
Schedule:

Day 1	Fly from DEN to PEK (Beijing Capital Airport), stay in Beijing
Day 3	Visit CERN headquarter and Institute of Botany in Beijing
Day 4	Meeting and data exchange with Chinese colleagues in Beijing
Day 5	Drive to Huhhot (6-7 hours), and meeting in Inner Mongolia University
Day 6	Drive to Ordos (3 hours), and talk with local partners
Day 7	Workshop with Chinese scientists and local officers
Day 8	Field work in Ordos long-term research sites: - Otok desert steppe plot - Wushen sandy grassland plot - Dalate typical/sandy grassland plot
Day 11	Drive back to Beijing
Day 12	Flexible
Day 13	Workshop with colleagues from Inner Mongolia University, Institute of Botany and CERN
Day 14	Flexible
Day 15	Fly from PEK to DEN

VI. Collaborative Social Science (Not funded)
(Subaward to UNC)

Determining public perceptions of LTER's, with special emphasis on the SGS-LTER, to enable development of effective outreach programs about these resources.

Richard R. Jurin[1,2] and John C. Moore[2]

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Introduction

The SGS-LTER is committed to K-12 education and public outreach. Currently the SGS-LTER supports a number of programs in both formal and informal education, with a strong emphasis on serving first generation and low income, and rural school students. In Colorado, the majority of these students are students of color, and groups under-represented in science, technology, engineering and mathematics (STEM) disciplines. The programs include but are not limited to the following:

1) **Schoolyard LTER**: supports 9 schools in 6 cities, visits the station and mirrors some of our experiments at their own schools;

2) **Research Assistance for Minority High School Students**: has supported over 35 students from groups under-represented in ecology to conduct projects at the station;

3) **NSF-GK-12-Graduate Fellowship Program**: connects teachers, K-12 students, and graduate students who work at the station;

4) **NSF-TE-Teacher Enhancement**, establishes a summer research internship program and professional development workshops for K-12 teachers.

In addition to the education programs, the SGS-LTER serves a diverse array of public stakeholders that includes local residents, ranchers, and visitors. To serve these groups the SGS-LTER leadership is developing plans to expand and modernize the facilities at the site "…to increase the quality and number of undergraduate and graduate students that we reach, to improve our capability for state of the art ecological research, to expand our outreach and interpretation capacity for the state, and to better serve the public."

Each of the programs listed above and the desire to modernize the facilities is clearly aligned with our educational focus and mission, and is or will be evaluated for effectiveness. What is less clear is how the suite of programs and plans operate collectively to serve our diverse stakeholders. The public's perception of science is often different from that of the science community. For example, research at the SGS-LTER on mentoring programs involving the K-12 community and the establishment of schoolyard ecology plots on school grounds revealed that teachers and students have different understandings of what constituted science than do scientists (Rahm et al. 2003). The study involved surveys, focus groups and an ethnographic analysis of videos of students and scientists conducting research and vetting data. Rahm et al (2003) concluded that what emerged from the partnership was of value, but different nonetheless from what we as scientists had anticipated. The finding of this work has changed how we interact with teachers and students, strengthened our partnership with K-12 and has forced us to confront how our perceptions of modernized facilities may or may not align with the public's. It is public perceptions and beliefs about science and the SGS-LTER that we intend to study using ideas developed by the field (Jurin, et. al, 2000; Jurin & Fortner, 2002).

At present, very little is known about the LTER work outside of the "inner circle" of users, and few constituents that could use the SGS-LTER even understand just what is ecology. For example, our analysis of over 250 interviews of high school students over attitudes and understanding of ecology reveal that most students have a positive attitude about ecology, but have confused ecology as a discipline with environmental studies (Miller et al. 1999). Hence, the objective of this proposal is to gain a better understanding of how K-12 education (students and teachers) and how the public perceive, understand and ultimately utilize the facilities, experiences, materials, and information generated by the SGS-LTER program. The project will involve analyses of a series of focus groups and questionnaires of different stakeholders. Focus groups will help develop a profile of public sentiment and knowledge about SGS-LTER site. A mailed fact sheet and questionnaire will help develop a baseline of public needs for understanding stewardship of these sites and also generate an interested body of people to volunteer time and effort to being stewards of these sites. Many people profess to be environmentally minded (Jurin & Hutchinson, in review) so it behooves us to bring them into this resource to strengthen their resolve. This work will assist in our development of the facilities, that might include the building of an innovative visitor/interpretive environmental learning center (ELC) to increase outreach efforts in the SGS-LTER and also sustainability concepts for better living and environmental management. The results obtained through this study at this SGS-LTER would serve as a springboard for developing such capacity building at other LTER sites in the country.

Collaborative Social Science Research at the SGS-LTER

LTER sites are unique plots of land set aside for research. The foci of research at the sites are different but all share a common theme of understanding how the local terrain and biota react to changing conditions be they natural or anthropogenic. When it comes to different groups apart from the scientific community using and understanding the research that occurs at the SGS-LTER site, these can be crudely broken down into two main categories, 1) Formal education groups (K-12 and beyond), and 2) the Public-at-Large. The general breakdown of the audience analysis for these two categories from the scientists' perspectives at the SGS-LTER can be generalized as follows: The first category groups already use the sites to a limited extent and more studies could be done to increase their use of the SGS-LTER, the second may interact with the SGS-LTER, given their proximity to the site, but has little understanding of the research at the site. This second group needs to be studied to understand what they know about the SGS-LTER and how they perceive it to be of benefit, or otherwise, to themselves and their community. Once these perceptions are known, capacity building and outreach efforts will be more successful. The public audience needs to find a reason to be involved, and through a well-defined communications plan based on formative evaluation from this study, we expect that the public will find this focus for involvement (Jurin, et. al, 2000).

There are two phases to the research. The first phase is designed to identify and formally define our stakeholders beyond the broad K-12 and the Public-at-Large designations. Potential audiences include ranchers, farmers, teachers, local community leaders, business leaders, scientists, news media, governmental, non-governmental organization representatives, and the residents of local communities. Questionnaires, open forums, and mailing will be used to collect information on demographics and needs. This would encompass doing audience analysis to define what are our numerous unique audiences and then identifying a manageable number of stakeholders from those groups. Surveys accompanied by fact sheets would be mailed to determine how much is known in the surrounding and nearby communities about LTER work. The respondents to the survey would also be asked to indicate if they were interested in being involved in further study. This latter smaller group would be contacted by telephone and asked more in-depth questions and given more information about the LTER before being asked to participate in field visits.

The second phase will use focus groups to identify and create ways that the SGS-LTER can build capacity and outreach to the different audiences, tailoring it all to the specific needs of the community, e.g., help in creating outreach to minorities within the area to improve the cultural relevancy of science in communities. These focus groups would be day-long sessions at the site, that include field trips, brainstorming sessions, surveys, questionnaires and short interviews. Examples include, a day for scientists and K-12 teachers to determine how the they might interact to work on research, to transfer research to the classroom, and to design on-site experiences at the proposed visitor center geared towards students at different grade levels.

Outcomes

The following are specific examples of how this research would enhance the mission of the SGS-LTER:

- Surrounding and nearby communities would have positive attitudes to the LTER site and be willing to assist in their stewardship. The surrounding communities would also have positive knowledge of the role of LTER's and how this helps their communities. The role of community communications and outreach would also involve not only education but also psychological/social research to determine attitudes, beliefs and values about the LTER's and many facets of the land and biota connected to the LTER work. For instance, what are public attitudes to these areas as wild lands, habitats for wild prairie animals, and loss of "original" prairie?
- Groups of adults from surrounding communities willing and trained to assist in data collection in collaboration with the researchers. This would also serve as a form of

non-formal science education for the adults involved and as ambassadors for future visitors.

- A clearer understanding of how the SGS-LTER can serve K-12 educational needs from the transference of LTER science to the classroom to how the SGS-LTER could better serve teacher professional development.
- Data collected from this initial study would support a proposal for the building of an innovative visitor center/ELC for use by all groups. Following construction of this visitor center/ELC, informal interpretive programs would be developed to enhance the outreach/educational efforts of the users and supporters of the LTER not only to support the work of the LTER, but also to increase outreach efforts about sustainability concepts for better living and environmental management. This center, because of its isolated nature, would be a model of how sustainable thinking and building can be environmentally sensitive, economically sound and inexpensive, and also beneficial in displaying how sustainability is a reality achievable now. The impact from such a center would be national in scope.

Institutional Review Board (IRB) for Human Subjects

Since the work to be done is confidential, and all reported responses grouped, no harm will come to the subjects. UNC currently has IRB approval to work with high school students and teachers through the projects listed above. The current IRB will be updated and modified (in progress) to include the questionnaires and additional stakeholders prior to initiating the research.

Literature Cited

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VII. "Other" General Research Support (Funded)

(3) Equipment Request (CSU budget page)

A) Land-Atmosphere Investigations

At present, about half of the shortgrass steppe remains as relatively intact native grassland, managed for livestock grazing. However it is becoming increasingly fragmented, primarily due to farming, and secondarily to urbanization. A major focus of the Shortgrass Steppe LTER Project is to evaluate feedbacks between this ecoregion and land-atmosphere dynamics, and to determine the impact of land-use change on energy, water and carbon balances. The project currently has nine operating micrometeorological flux towers for monitoring CO_2 and water fluxes (five Bowen ratio Energy Balance Systems; four eddy covariance systems) in shortgrass steppe (3 grazing practices), CRP (Conservation Reserve Program) land (grazed; ungrazed; and converted to cropping), and in winter wheat/fallow and irrigated corn. However, the project does not have automated capability to track plant canopy development, nor to obtain full radiation balances involving critical spectral components for each location. This information is needed to understand how the different land uses and management schemes affect plant canopy development and the consequences for land-atmosphere energy, CO_2 and water exchanges. Further, there is an increased awareness among those who utilize flux towers that night-time micrometeorological flux measurements need to be supplemented with automated soil CO_2 measurements to arrive at independent measures of CO_2 fluxes. The Shortgrass Steppe LTER Project has no such soil CO_2 monitoring devices. In order to enhance on-going research in the study of land-atmosphere interactions, we request supplemental funding to purchase the following canopy, radiation, and CO_2 measurement equipment to address the above-mentioned equipment limitations of the project.

1) <u>Albedo measurement at CRP, SGS, and cropping system sites</u>

CRP: Already have measurement capability for all treatments (Eddy covariance towers)
SGS: Moderate grazed (location of BREB and Eddy Covariance towers): have CNR1 4-sensor net radiometer, which will handle all incoming radiation for three SGS sites, plus reflected radiation for this particular site.
Heavily grazed (BREB tower): will use CM3 radiometer of Peter Blanken for measuring reflected radiation.
Spring grazed (BREB tower): will purchase **1 CM3 radiometer** for measuring reflected radiation.
Cropping systems:
Corn field (BREB tower): need incoming and outgoing radiation for albedo (purchase **2 CM3 radiometers**)
Wheat field (BREB tower); need incoming and outgoing radiation for albedo (purchase **2 CM3 radiometers**)
Additional equipment need: 5 CM3 radiometers ($650 ea) **$3,250**

2) Canopy leaf area monitoring at CRP, SGS and cropping system sites
Equipment need (**2 Skye SKR 2 channel sensor** at $1,227 ea):

CRP: 3 sensor(s) needed	$3,681
SGS: 3 sensor(s) needed	$3,681
Cropping systems: 2 sensor(s) needed	$2,454
TOTAL	**$9,816**

3) Soil CO_2 Measurements

Equipment needed: I recommend we buy three of **Vaisala GMP343 CO_2 probes**. They will not be available until March. Considering the uncertainty of our micromet flux data and the possibility that nighttime fluxes are a big part of the problem, this seems like a high priority item. Three probes @ $2200 each for a total of **$6,660**.

B) Field Station Upgrades

1) Standard Weather Instrument Shelter
We have been collecting weather data daily for over 30 years from the SGS LTER meteorological station as part of one of our longest term data sets. Our equipment has been housed in a Standard Weather Shelter that was built in the early 1970's. It has been repaired often over the past 30 years, but has recently become structurally unsound and cannot be repaired. It is unsafe for our data collectors as well as inadequate in protecting our instrumentation and needs to be replaced at this time. We are requesting funds for a Novalynx large instrument shelter model 380-605 with metal legs.

Mower/Brush hog
We must routinely mow around experimental plots to control noxious weeds, and around headquarters, research, storage and dormitory buildings at our field site for fire protection, to minimize habitat for poisonous snakes in taller vegetation, and to provide easy access to our facilities. In the past we have borrowed a tractor mower from the USDA-ARS-CPER headquarters located about seven miles from our field station. Due to new federal regulations we are no longer able to drive their vehicles, including the tractor. We are currently using a push mower that very time consuming. We do have a tractor at our field site to which a mower/brush hog could be mounted. We feel that this would be a more efficient way to keep the vegetation under control, and free up staff time for other tasks. We are requesting funds for a 6 ft. Rhino Mower that will work with our tractor.

Binoculars
We are experiencing a steady increase in the number of mammalian and ornithological studies at the SGS LTER site. These studies depend upon visual estimates of populations and our current supply of binoculars is not meeting the needs of our researchers. We are requesting funds for 1 additional pair of binoculars (Kahles 10x 42@ $649.00 each).

Digital Camera

Demand for digital images from our research, education and outreach projects has been increasing dramatically in the last years. We have found that digital equipment is now being used for training new researchers at all levels on our methods and techniques; for education and outreach regarding the SGS LTER program; for capturing visual changes in the landscape as part of various experiments; for analyzing data from experiments measuring production and changes in vegetation over time; for documenting faunal species and aiding in identification; and generally for recording many of our experiments. We anticipate that this use will only increase as more researchers become familiar with the options available from digital images of their experiments. One of the vary intesive projects at this time is an effort by Dr. Lauenroth, one of our co-PI's, to use digital images of vegetation plots as the basis for determining net primary production. If his group is able to find a way to make this kind of calculation we would be able to phase out the extremely labor intesive vegetation clipping tasks. We are requesting funds for a.Canon G5 Digital Camera, extra memory cards, and a carrying case to facilitate image capture.

(4) Opportunistic Projects/New Collaborations

(CSU and subaward to UNC)

A) **Assessment of cattle grazing to create habitat for threatened Mountain Plover**

We are requesting Supplemental Funds to support data collection on a new research project on the SGS site to determine the effects of grazing on fauna of shortgrass steppe. This work is part of a larger project that will be submitted for funding by Paul Stapp, (SGS-LTER co-PI, California State University-Fullerton), Bill Lauenroth (SGS-LTER co-PI, CSU) and Justin Derner (USDA-ARS to the USDA) NRI Competitive Grants Program in March, 2004. In this project, we propose to assess the effectiveness of cattle grazing as a tool for creating habitat for the Mountain Plover, a threatened shorebird that prefers heavily disturbed shortgrass prairie for breeding. Existing grazing practices will be modified to create two treatments that may benefit plovers: intensive early-season (spring) grazing to remove cool-season grasses, and extreme season-long (summer) grazing. Moderately grazed summer pastures will serve as controls. Drs. Lauenroth and Derner will examine responses of plant communities, cattle production and other ecosystem properties; Dr. Stapp and his graduate students will study responses of native consumers (mammals, birds, arthropods) to these treatments, as well as in long-term grazing exclosures and in areas with combined effects of cattle and prairie dogs. In addition to providing the opportunity to evaluate the utility of grazing as a habitat management tool, we will be able to investigate, for the first time, the effects of intensive, prolonged grazing on the shortgrass steppe ecosystem. A key result from past SGS-LTER research is that, compared to other western ecosystems, shortgrass steppe is relatively resistant to negative effects of cattle grazing; however, none of these past studies used grazing of this extreme intensity, which should push the system to its limits. Our proposed research therefore fits well within the framework of past, ongoing and future SGS-LTER research.

Dr. Stapp is requesting supplemental funding for this project for several reasons. First, this is a new project, initiated since the last site proposal was submitted and awarded, and no funds are currently available to support sampling in 2004. The RFP for the USDA NRI program was delayed, which extended the deadline from November, 2003, to March, 2004. Even if their March, 2004, submission were successful, funding would not be available for the coming field season. Second, implementation of the grazing treatments has already begun. Dr. Stapp's graduate student was able to collect pre-treatment data on her study sites in 2003, work that was supported by his summer salary from SGS-LTER. Cattle will be moved to the heavy spring-grazing pastures in early March, and then to the intensive summer pastures in late May. It is imperative that we sample all of the sites in 2004, the first post-treatment year, to detect any immediate responses.

B) **Winter activity and the use of torpor in silky pocket mice (*Perognathus flavus*)**

We have the opportunity to begin a new collaboration with Marilyn R. Banta at the University of Northern Colorado, because of the identification of silky pocket mice on the shortgrass steppe. Her CV (document 1) and the UNC animal protocol (documents 2 and 3 for approval and protocol, respectively) are included in the 'supplementary documents' area of our request.

Rodents in the family Heteromyidae (specifically kangaroo rats in the genus *Dipodomys* and pocket mice in the genera *Perognathus* and *Chaetodipus*) are well known for their behavioral and physiological adaptations to a desert lifestyle. All species are nocturnal, allowing them to avoid activity during the heat of the day. Compared to other mammals of similar mass, heteromyid rodents have metabolic rates that are 60-80 % of the predicted value. Low metabolic rates require less energy to fuel and produce less heat, also advantages in the desert.

While many species of *Dipodomys*, *Perognathus* and *Chaetodipus* have ranges that are entirely encompassed within desert and semi-desert habitats in the southwestern United States, there are a few species that have ranges that extend northward through the grasslands as far as Canada. Individuals living in these northern climates experience very different climatic patterns and challenges than individuals living in the warmer southern regions. Long, very cold winters provide a number of unique challenges to these individuals, and yet adaptations in heteromyid rodents to cold environments have been largely ignored by scientists.

We are interested in examining patterns of activity and the use of torpor and/or seasonal dormancy in one of the smallest members of the heteromyid family, the silky pocket mouse (*Perognathus flavus*). Adult animals weigh about 9 g, and the few studies of this species that have examined torpor have done been conducted in Arizona. This species has been captured on the shortgrass steppe LTER site, but virtually nothing is known about its winter activity patterns or use of torpor or seasonal dormancy there.

Much of the work will be done by James Dye, a graduate student at the University of Northern Colorado (UNC). Primarily during winter months, and periodically during the rest of the year, James will use Sherman live traps to capture and ear tag pocket mice. He will use fluorescent powder tracking (seeds on a tray coated with fluorescent powder) to monitor nightly activity and locate their home burrows. Once a home burrow has been located, the resident will be live trapped and a small temperature datalogger (I-button, Maxim Corp.) will be tied to the animal's foot with a thread. The animal will be released and should return to its home burrow pulling the datalogger (attached to a wire) into the burrow with it. The animal will be able to easily chew through the thread to release itself from the datalogger, which will remain in the burrow. The datalogger will be programmed to read and store ambient temperature periodically over the course of several weeks. Then the datalogger will be recovered by pulling it out of the burrow with the wire, and the time/temperature data will be downloaded.

Some individual pocket mice will be temporarily removed from the LTER site and held in the animal care facility at UNC. In the laboratory at UNC, individual pocket mice will be held at various temperatures and their behavior (entry and exit to/from torpor) and their metabolic rates will be monitored and measured.

From this combination of field and laboratory data, a clear picture of winter activity and metabolic demands on the shortgrass steppe LTER population of this species will be elucidated. This project will be part of a larger project to conduct comparative studies of this type on several populations of *P. flavus* ranging from the very northern portion of their range (Wyoming) to the very southern portion of their range (northern Mexico).

Facilities currently available at UNC:

Dr. Banta's lab is already equipped with 100 Sherman traps, 100 I-button dataloggers (plus software and hardware for downloading data from dataloggers), pin flags, fluorescent powder and UV lights. She has space and cages in the animal care facility for housing heteromyid rodents, and an animal care protocol to cover housing the animals and all laboratory procedures. Her laboratory at UNC also contains temperature cabinets for controlling ambient temperature, and oxygen analysis equipment for measuring metabolic rate.

(5) Information Management (CSU)

Our long-term goals for data management continue to be: 1) increasing our web delivery of metadata and data for long-term experiments; 2) increasing our interactions with federal partners/hosts of the SGS LTER site, the Agricultural Research Service and the USFS Pawnee national Grassland by developing a joint spatial data management/experiment management system; 3) leading the way in the network for metadata and data management of simulation models, an area in which we have a major scientific investment; and 4) developing data management interactions for our Schoolyard LTER and Outreach programs. We have made progress in each of these areas and would like to continue moving forward with each.