The Shortgrass Steppe Long Term Ecological Research (SGS LTER) project occupies an important position among LTER sites. The SGS lies at the western end of the east-west grassland productivity gradient and the northern end of the north-south semi-arid grassland gradient (SGS, Sevilleta, Jornada). This position allows us to evaluate ecosystem properties and processes between the SGS and other sites on these two gradients. In this supplemental proposal, we propose to initiate collaborative efforts across LTER projects and sites by conducting integrated field and laboratory studies that cross precipitation (an east-west transect between SGS and Konza) and temperature gradients (a north-south transect between SGS and Sevilleta). These two transects will allow us to integrate knowledge of ecosystem processes by assessing systematic variations in biotic and abiotic properties across these climatic gradients. The proposed transect studies involve a collaborative project with the Konza LTER group, a collaborative effort with the Sevilleta project, and a pilot study to develop methodologies for study of terrestrial weathering and biogeochemical cycles across the two climatic gradients. In addition to these transect studies, we are requesting funds for a replacement site vehicle.

SGS-Konza Transect

The SGS and Konza sites lie on opposite ends of the central Great Plains precipitation and productivity gradient (Figure 1). The SGS has a mean annual aboveground net primary production of 160 g/m^2. Mean annual aboveground net primary production at Konza is 400 g/m^2. In addition to lying on opposites ends of the productivity gradient, there are large changes in ecosystem structure between the two sites. The SGS site is at the western edge of the shortgrass steppe and Konza is on the western edge of the tallgrass prairie (Fig. 1). Soil biogeochemistry also changes across the gradient (Vinton and Burke 1997). Soil carbon is about 1200 g/m^2 at the SGS and 2300 g/m^2 at Konza (Fig. 2). Similar differences exist for soil nitrogen; the SGS value is 120 g/m^2 and the Konza value is 180 g/m^2. One of the interesting results of the Vinton and Burke (1997) work is associated with what is missing from their characterization of the biogeochemical gradient. Their choice of sites resulted in large differences in soil C and N between CPER and Hays and no differences between Hays and Konza (Figure 2). Hays lies in the southern mixed prairie (mean annual precipitation=588 mm) approximately 200 km west of Konza. The climatic gradient indicates that the key climatic change between Hays and Konza is in precipitation while the differences between SGS and Hays are both in terms of precipitation and temperature (Fig. 1). This suggests that temperature may be an important control on the large differences in soil C and N between SGS and Konza.

The long-term objective of this work is to collaborate with the Konza LTER scientists to develop an understanding of the significance of the gradient that exists between SGS and Konza for long term ecological processes. The immediate objective is to begin building a database that contains information that characterizes the gradient between SGS and Konza focusing specifically on the relationships among climate, vegetation and biogeochemistry. Part of this work will require bringing together existing data from the two LTER. Another part will require that we collect additional data. As a prerequisite to collecting additional data now and in the future we will need to locate a series of sites between SGS and Konza. The Vinton and Burke (1997) work will help us in this effort. It suggests that to complete the characterization of the biogeochemical gradient we should concentrate our efforts on the portion of the transect between SGS and Hays. We plan to locate three sites between Hays and SGS and follow the sampling procedures and analysis protocols of Vinton and Burke (1997). At each site we will characterize the vegetation with respect to density and basal cover by species and collect aboveground plant tissue from 5-6 common species for C and N analysis. We will also sample soils under and between individual plants of these same species. In addition, we will specifically sample plant tissue and soils associated with *Bouteloua gracilis* and *Agropyron smithii* at each site. We are requesting $10,000 to cover travel, personnel, and supplies costs associated with the collection of new data.

SGS-Sevilleta Transect

One of the key challenges facing ecologists over the next century will be to understand how human alteration of the earth’s surface will change the biosphere. In the central and southwestern U.S., the presence of several LTER sites provides a tremendous potential to facilitate that understanding. The ecosystems found at the SGS and Sevilleta LTER sites have a number of striking similarities and differences that are very poorly understood at the present time. Understanding the basis for those differences and how they are related to the environmental and biogeographic gradients that separate the two sites will provide a critical step in the process of understanding the potential responses of ecosystems to human induced environmental changes.

We are proposing to establish a transect that links the SGS and Sevilleta sites with the long term objective of providing a critical tool to help us understand the environmental and biogeographic controls on the similarities and differences between the sites. The immediate objective of this supplement request is to convene the planning efforts that will be attended by participants at both sites to establish a set of long-term objectives for the transect and a work plan for the most important steps to be taken over the next 5 years. At this time, we envision the two sites both as critical points along the Shortgrass Prairie gradient between SGS and SEV, and as a segment of the larger gradient extending southward into Mexico (including the Jornada LTER and the Mapimi Research Site). Transect analyses, modeling of environmental drivers and ecological processes responding to environmental fluctuations and validation of model projections with satellite studies between these LTER sites are initial expectations.

These sites have a number of studies and measurements that can serve as the basis for comparisons. Standardized protocols are used for rodent and rabbit sampling, and all sites are conducting studies utilizing rodent/rabbit exclosures to examine the effects of rodents on plant communities and soil characteristics. In addition, both sites are initiating studies on the role(s) of keystone species (e.g., prairie dogs, kangaroo rats), and there are long term studies on the dominant perennial grass species in common for the sites (recent comparison of SGS and Sevilleta, Lauenroth et al. 1997). Both sites are also evaluating the role of cattle grazing with exclosure studies. A current research project is funded to compare ant communities at SGS and Sevilleta (Wiens et al). At the SGS and Sevilleta sites, a number of graduate students have performed comparative studies for both sites. These efforts will be key in the analyses of results from previous studies as well as the development of the next proposals for these two sites. The first planning effort will be convened in the fall of 1998-99 at a location to be determined (likely the Sevilleta). We are requesting $2,000 in travel and meeting support funds for the appropriate personnel from the SGS LTER, with matching funds from the Sevilleta LTER site for their personnel.

Soil Weathering Studies

We propose to conduct several new cross-site field studies and laboratory studies on the SGS, the Sevilleta, and the Konza to develop the necessary methods to further quantify the relationship between terrestrial weathering processes and global biogeochemical cycles. This work is appropriately conducted under supplemental funding because it represents pilot work on methodological development that we would like to use to develop a much larger collaborative cross-site effort with other LTER projects. Specifically, we will develop data on the relationships between the stable silicon (Si) isotope ratios of environmental waters and biogenically produced soil minerals across the precipitation and temperature gradients. To accomplish this overall objective, we will conduct an integrated set of greenhouse, laboratory, and field experiments to assess the utility of stable Si isotopes for biogeochemical research across the grassland gradients. Dr. Gene Kelly will take the lead on this project.

Scientists from many disciplines are now seeking quantitative information about key ecosystem processes that augment regional and global biogeochemical cycles. Geological, ecological and pedological investigations, utilizing different approaches and methods, have all demonstrated that the relative importance of plants in regulating weathering processes is dependent on climate (Jackson and Keller 1970a,b; Berner 1992; Drever 1994; Kelly et al. 1998).

The biogeochemical cycling of silica may significantly influence the path of soil formation by maintaining soil silica levels higher than those expected if silica could leach freely from the soil system. Once silica is solubilized and enters the biological cycle it may be removed from the soil by leaching, be involved in supergene mineral formation (i.e. kaolinite), form pedogenic opaline minerals (commonly called laminar opaline silica) or reside as biogenic opaline silica (plant opal or phytoliths). The biogenic opaline silica is easily distinguished from other forms of opaline material according to their morphological properties. Plants take up silica passively from the soil solution through the transpiration stream as monosilicic acid and deposit it in cell walls, cell luminas, and intercellular spaces near evaporating surfaces (Jones et al. 1963). Once the plant dies, this silicate material is returned to the soil upon decomposition of the plant material. These microscopic opaline particles are found in a variety of ecosystems and their abundance is related to the degree of chemical weathering (Alexandre et al. 1997), soil mineralogical composition (Dahlgren et al. 1993), plant type, and climate (Kelly 1989).

The stable isotopes of Si consist of ^{28}Si (92.27%), ^{29}Si (4.68%), and ^{30}Si (3.05%). The ^{30}Si/^{28}Si ratio is typically examined, as ^{29}Si has not shown significant fractionation with terrestrial samples (Douthitt, 1982). The theoretical foundation of stable isotope studies is based upon the differential physical and chemical behavior of isotopes due to their difference in mass (O'Neil, 1986). This differential behavior results in isotopic fractionation (one isotope being "favored" over the other) during the mineral formation, phase change (solid-liquid), or diffusion of a substance. The ratio of rare to common isotopes in a substance is compared to international standards where the deviation of the
sample from the standard is referred to as the delta (δ) value.

Materials of interest in terrestrial ecosystems have a δ^{30}Si range of -1.4 o/oo to 2.8 o/oo for phytoliths and a range of -2.3 o/oo to 1.8 o/oo for a variety of authigenic clay minerals. The limited number of samples reported thus far leans toward the possibility of Si isotope fractionation; however, development of a larger body of data is needed to clarify both the direction (increase or decrease ratios) and mechanisms behind the fractionation.

Field Studies

In the proposed study, Si isotopes will be used in an attempt to better define the climatic and mineralogic controls on Si cycling and solubility in semiarid soil-vegetation systems. Specifically, does biogenic Si cycling in the form of phytoliths provide a sufficient level of Si activity to slow the dissolution of other Si-bearing minerals? The following study site components (rain water, plant phytoliths, and Si- bearing material collected from dust traps), and soil horizon components (sand, silt, and clay sized fractions along with their respective Si-bearing minerals, and parent material and bedrock where applicable) will be analyzed with respect to δ^{30}Si. When compared to previously determined solubility's for these same constituents, it is thought that the δ^{30}Si signature of these constituents may increase the resolution of the mineral species responsible for Si control. Further resolution may be obtained through examination of equilibrium fractionation relationships.

Greenhouse Experiments

A series of greenhouse experiments will be established to obtain more baseline data in an effort to clarify the mechanisms responsible for Si fractionation. The fractionation in question involves the uptake of H_4SIO_4 and subsequent phytolith formation. The goals of the greenhouse study are as follows: 1) to verify the existence of a biological Si fractionation component as reported earlier (Douthitt, 1982); 2) to attempt to identify and refine the direction of this fractionation with respect to a particular family of vegetation (gramineae); and 3) to attempt to decipher the responsible mechanisms.

In one experiment, a variety of C_3 and C_4 grasses of native species from the semiarid and tallgrass systems at SGS, Konza, and the Sevilleta will be grown in subsamples of the same soil at constant moisture (field capacity) and temperature. Grasses have been chosen for their fast growth rate and propensity to form relatively large amounts of phytoliths compared to other families. The initial δ^{30}Si signature of the irrigation water and the
water that pass through the soil will be measured periodically as a baseline value against possible Si fractionation. The leaves will be harvested and phytoliths separated (Kelly , 1990) for Si isotopic analysis.

In a second experiment, the same suite of grasses will be grown hydroponically in a solution where the δ^{30}Si has been previously determined. Once again, the δ^{30}Si will be monitored periodically for any potential changes in δ^{30}Si of the solution Si over time. This particular variation will ensure that the Si taken up into the plant is coming from only one known Si source, thus ruling out any potential competing Si sources that could contribute different δ^{30}Si signals. Depending on the results of these greenhouse study, variations in environmental stresses such as moisture, temperature and nutrient levels may be introduced to asses their impact on Si fractionation. Regardless, these results will be compared against previously published phytolith values (Douthitt, 1982) to either support or refute the use of δ^{30}Si as a means of refining the study of Si biogeochemistry in soils.

Data Generated

The data generated from the three studies (greenhouse, laboratory, field) will yield information with regard to the amount and direction of biological fractionation. We will construct a simple model to assess the role of plants in the soil silica cycle which will be used as the basis for a large scale interdisciplinary research project with collaborators at other biologically diverse LTER sites. We are requesting $6,500 to cover costs of personnel, analyses, and travel.

Transportation

Finally, we are requesting funds to purchase one vehicle for the field station: a four-wheel drive, extended cab, 3/4 ton pick-up truck for use by the site manager. The four-wheel drive truck will replace the site manager's current vehicle, a 1983 Dodge pickup truck that has nearly 150,000 miles and has been repaired over one hundred times in the last three years at a cost of over $4,500. This vehicle is the only permanent vehicle at the SGS LTER field station and as such, it is relied upon for nearly every facet of field station management. The uses include the daily duties of the site manager: recording meteorological data, maintaining site facilities, shuttling field crew members and equipment to remote research locations, and maintenance of research sites; and the special needs required by research projects: monitoring routes, mammal and invertebrate trapping protocols, and assisting with specific research projects as needed. In short, this vehicle makes our site run smoothly and each time this truck is in the repair shop it affects our ability to conduct our research. The current vehicle has a very high probability of breakdowns in remote locations, and it seems more than prudent to replace it.

We are requesting funds in the amount of $26,000 to purchase a new vehicle through the Colorado State Motor Pool. Purchasing this vehicle through this state agency allows us to get a much better price for the type of heavy duty vehicle we need and it allows us to utilize the repair shop of Colorado State University at no charge. We feel that this is an extremely important investment in equipment that is long overdue.

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