Activities

The Sevilleta LTER Program addresses ecological concepts and theory through a comprehensive and interdisciplinary research program in desert grassland, shrubland, forest and riparian habitats in central New Mexico. Our focal sites are the 100,000-ha Sevilleta National Wildlife Refuge (SNWR) located about 80 kilometers south of Albuquerque (managed by the US Department of the Interior, Fish and Wildlife Service) and the Middle Rio Grande (MRG) bosque between Cochiti Dam and Elephant Butte Reservoir (Fig 1). Since its inception in 1988, the Sevilleta LTER program has conducted research at multiple ecological levels and a variety of spatial and temporal scales. Our studies are linked by an overarching theme that considers **how abiotic drivers and constraints affect dynamics and stability in aridland populations, communities and ecosystems.**

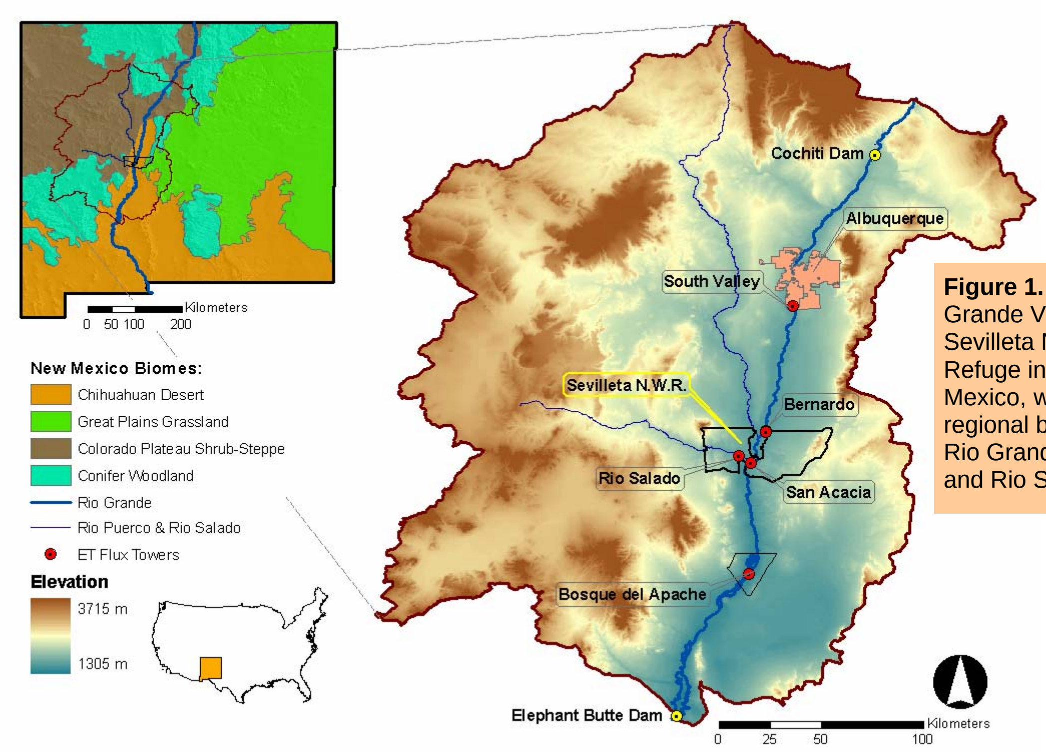


Figure 1. The Middle Rio Grande Valley and Sevilleta National Wildlife Refuge in central New Mexico, with respect to regional biomes and the Rio Grande, Rio Puerco and Rio Salado.

The Sevilleta LTER Program is a long-term, comprehensive, integrated, interdisciplinary research program addressing key hypotheses on pattern and process in aridland ecosystems. Our LTER research in central New Mexico is concentrated on studies in desert grassland and shrubland communities and piñon-juniper and riparian (‘bosque’) woodlands emphasizing transitions in space and time. Each landscape component is governed by key abiotic and biotic drivers, especially climate variability, fire, hydrologic variability, nutrient dynamics, and herbivory. The rates and intensities of these drivers are changing over time. Given the emerging research interest in ecohydrology of aridlands, our focus on the effects of biotic and abiotic drivers on spatial and temporal dynamics of these aridland ecosystems allows us to conduct long-term research that addresses important basic ecological questions and yet has significant relevance to state, regional, national, and international priorities.

The Sevilleta LTER site and its surroundings are positioned at the intersection of several major biotic zones: Chihuahuan Desert grassland and shrubland to the south, Great Plains grassland to

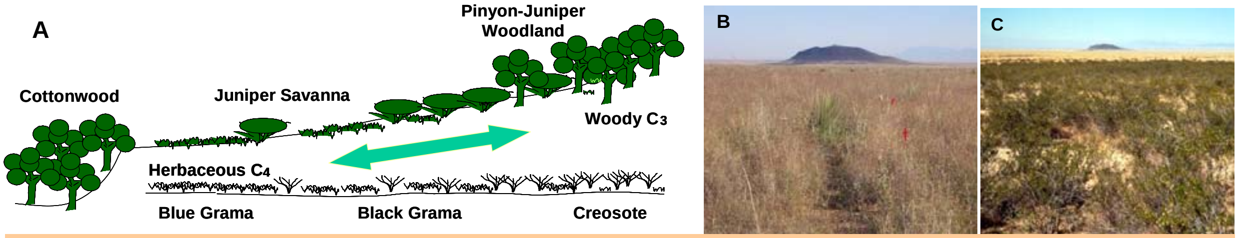


Figure 2. A) Schematic diagram of upland transitions at the Sevilleta National Wildlife Refuge. B) Black and blue grama grassland at Deep Well. C) Creosote dominates 4 km south.

the north and east, piñon-juniper woodland at upper elevations in the mountains, Colorado Plateau shrub-steppe to the north and west, and riparian vegetation along the middle Rio Grande Valley (Figs 1 and 2). Because of the confluence of these major biotic zones, the SNWR and the Middle Rio Grande Basin present an ideal setting to investigate how environmental change and climate variability interact to affect ecosystem dynamics at the boundaries of major biomes in southwestern North America. Moreover, the rapid growth and southern expansion of the City of Albuquerque and its suburbs increasingly will have an impact on ecosystem processes throughout the Middle Rio Grande Basin, including the SNWR, and these urban forces will interact with climatic variation to catalyze change in this aridland region.

This is the first annual report from our fourth funding cycle. LTER IV (2006-2012) builds on our prior research on patch and boundary dynamics by placing a greater emphasis on interactions among key processes and drivers of change in aridland ecosystems, in particular nitrogen (N) availability and climate dynamics. This new emphasis greatly expands the spatial and temporal scales and conceptual bases of our LTER program. Our new organizing framework is designed to integrate the components of our research program and allow us to test important hypotheses of general ecological interest.

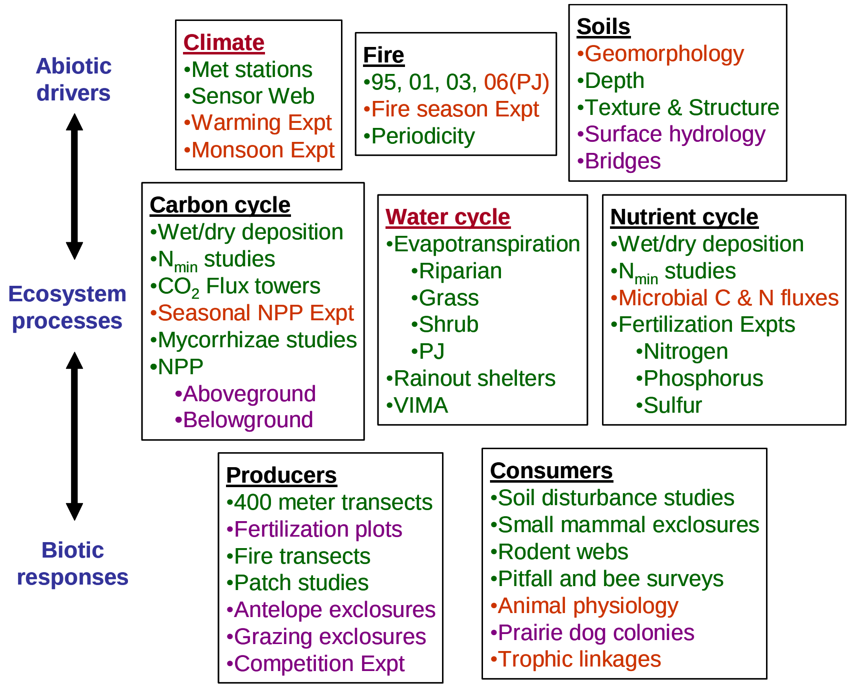


Figure 3. Current (GREEN), **New** (PURPLE) and **Planned** (RED) Sevilleta LTER Research Activities.

More specifically, Sevilleta research is designed to understand the individual and interactive effects of three key system components: abiotic pulses and constraints, ecosystem processes, and biotic responses and feedbacks (Fig 3). The main abiotic *pulses* and *constraints* are (1) seasonal, annual, and decadal variations in climate, (2) geomorphology, soil texture, structure and depth, and surface and riparian hydrology, and (3) season, periodicity, and intensity of fire. These abiotic factors affect *dynamics* of biogeochemical pools and cycles; water input, storage, use and loss; and patterns and controls on primary production. Biotic responses to the coupling of these abiotic factors and ecosystem processes include *dynamics* and *stability* in the distribution, abundance, and diversity of plant and animal populations and communities. Given the fundamental relationship between primary production and community structure in ecological communities, one of our core LTER activities is to link climate dynamics, disturbances, and soil structure with soil nutrient and water fluxes to better understand seasonal and annual variability in NPP and how that variability ultimately affects the dynamics, distribution and abundance of key aridland producers and consumers.

To accomplish these goals, the Sevilleta LTER program is organized into five overlapping thematic areas with designated group leaders: Climate and Abiotic Drivers (Cliff Dahm), Water Fluxes (Will Pockman), Soils and Biogeochemistry (Bob Sinsabaugh), Producer Dynamics (Esteban Muldavin), and Consumer Dynamics (Blair Wolf). These thematic areas are not mutually exclusive, but they serve as an effective mechanism to organize and synthesize our research. New and continuing research includes a variety of activities in each sub-area (Fig. 3).

Figure 4. Photo of piñon-juniper rainout shelters in the Los Piños Mountains at the Sevilleta LTER.

In 2007 we continued all long-term data collection efforts described in our renewal proposal (LTER IV). New activities begun since our last report include (1) a multiple factor global change experiment that manipulates nighttime temperature, N-deposition, and winter rainfall frequency, (2) a summer monsoon rainfall manipulation experiment, (3) a new rainfall manipulation experiment in piñon-juniper woodlands (Fig 4), (4) a new Gunnison’s prairie dog restoration experiment, (5) use of stable isotopes to understand food web dynamics, and (6) installation of two new CO_2-ET flux towers, one in piñon-juniper woodland and one in juniper savanna. In addition, a number of Sevilleta LTER graduate students and REU’s have conducted important short-term measurements and experiments on climate, biogeochemistry and soils, water and nutrient cycling, producer, and consumer communities. Highlights of results from a subset of these activities are provided in “Findings.”

In addition, to research activities, important and exciting developments have occurred at the Sevilleta Field Research Station. Our wireless backbone, funded by an FSML award, now covers

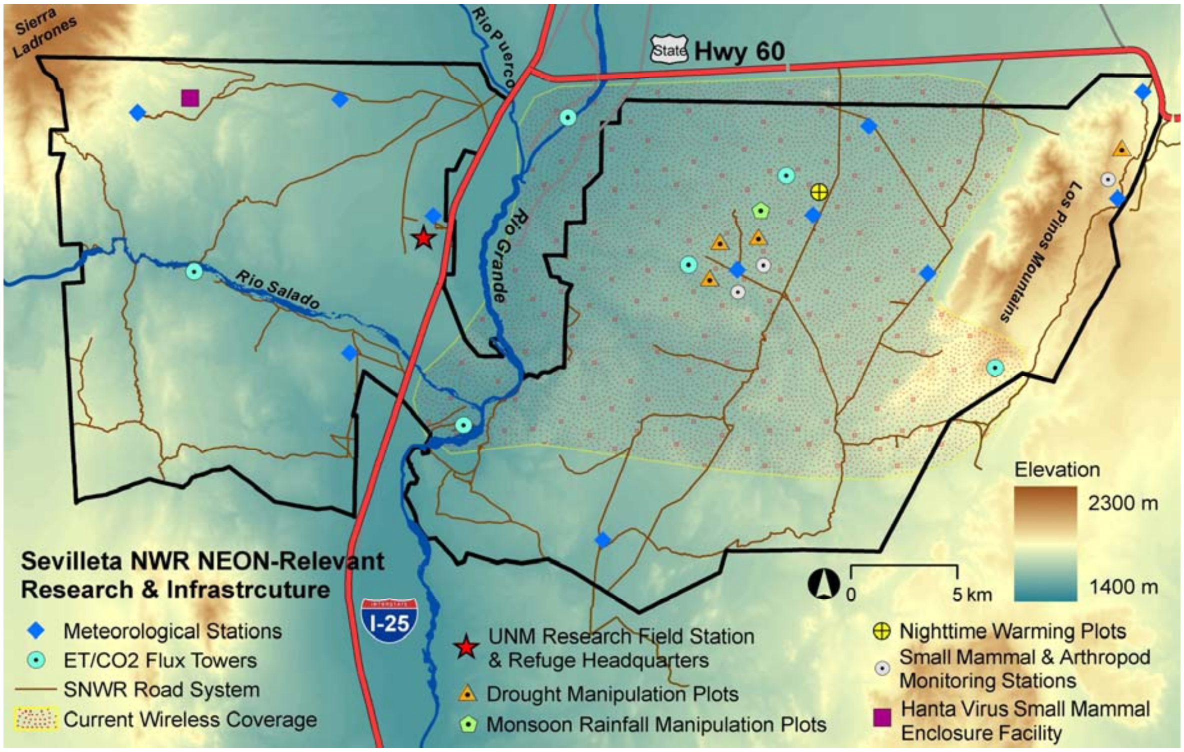


Figure 5. Map of the SNWR showing the current distribution of wireless access on the Reguge.

Figure 6. The University of New Mexico Field Research Station. A) View looking east showing houses (foreground) and the landscape in the distance. B) View looking northwest showing the carport, main drylab building and office building with patio and conference room. C) Phase I of the Sevilleta Education and Research Facility (SERF).

much of the eastern half of the refuge and continues to expand to provide wireless data transmission at most of our key field sites (Fig 5). Phase I of the Sevilleta Education and Research Facility (SERF) was completed in 2007 (Fig 6) and Phase II is scheduled to begin later this year. The completed facility will include state-of the-art research laboratories designed for work in animal and plant physiology, molecular biology, infectious diseases, environmental sensing, and plant, water and soil chemistry. The facility will include a teaching lab for wet chemistry and a computer and information management training lab including software usability testing facilities. It will also contain an institutional kitchen, an 80-100 capacity conference room, and space for plant and animal voucher collections, in addition to support rooms and equipment (growth chambers, autoclaves, high-purity water, etc.). Phase I contains research laboratories and collection facilities and will be available for users in 2007. Along with existing facilities, SERF will permit development of new educational and outreach programs that will compliment current K-12 programs run by FWS, thereby providing extraordinary opportunities for interfacing teaching, outreach and research initiatives. Many functions at the current UNM Field Station will move to SERF. As a consequence, we successfully competed for FSML funds ($250K) to convert our old conference room, dry labs and computer room into dormitory space that will increase our housing capacity from 48 to 90. Doing so will complete our Field Station infrastructure and allow the facility to be used for 2-3 week long classes.

Education, Outreach, Cross-site and Network Level Activities.

The SEV LTER is involved in education and outreach through BEMP (our Schoolyard LTER), the SNWR, E-MRGE (our GK-12 program), a summer REU program, ESA SEEDS, and our everyday classroom teaching activities. SEV scientists are also active in numerous cross-site and synthesis projects, and provide service to the LTER Network.

Figure 7. BEMP staff members explain field biology to students throughout New Mexico. As part of BEMP activities, sixth-graders in New Mexico measure groundwater depths in riparian areas up and down the Middle Rio Grande.

Schoolyard LTER. The SEV schoolyard LTER/Bosque Ecosystem Monitoring Program (BEMP) is dedicated to science, education, and stewardship, bringing together each year over 2,000 K-12 students, their teachers, and UNM researchers to monitor and understand the Rio Grande and its riverside “bosque” forest (Fig 7). BEMP is coordinated by Drs. Cliff Crawford (Professor Emeritus, UNM Biology) and Kim Eichhorst (BEMP Science Education and Information Specialist), and Jen Schuetz, Program Administrator. Currently, BEMP organizes field and classroom activities at a variety of sites along the Middle Rio Grande in collaboration with more than 16 school systems, including the Albuquerque Public Schools, local private schools, one home school, several rural schools and two Pueblo schools. Each month, students use 22 research sites spanning 250 km of the Rio Grande to gather key indicators of structural and functional change within this complex ecosystem. These data are published in reports and used by local, state, tribal, and federal governmental agencies. Most BEMP students are from traditionally underrepresented groups in environmental education including large numbers of Hispanics and Native Americans. BEMP sponsors an upper level undergraduate/graduate biology class at UNM in which students from the sciences, education, communication, and other departments learn about the bosque ecosystem while serving as interns within the program. The interns act as liaisons between researchers and K-12 students, take on quality control duties, assist in field data collection, lab analyses, and are mentors to the K-12 students. BEMP activities meet national and state education standards for K-12 science, math, social studies, and also include lessons in art and language, as well.

In 2005 and 2006, BEMP received Educational Enhancement supplements to develop additional resources for teachers to improve learning activities that build on data collecting trips. BEMP staff are creating a lending library of lesson plans and activity kits that BEMP interns and teachers can readily use with K-12 students. In addition, a professional educator works with BEMP staff to develop and present classroom activities in the context of ongoing bosque science (Fig 6). All activities are translated into Spanish and placed on the BEMP website (http://www.bosqueschool.org/BEMP/bemp.htm) as both a service to existing BEMP classrooms and as a recruitment and expansion tool.

Undergraduate education. UNM is a certified Hispanic serving institution, and the Department of Biology has over 1200 undergraduate majors of which 48% are Caucasian, 33% Hispanic, 10% Native American, 7% Asian and 2% Black. Thus, through our day-to-day activities UNM faculty regularly work with, encourage, mentor, and train a large number of minority students. In that regard, we serve the broader goal of recruiting minority students into ecological research.

In 1996, ESA established SEEDS (Strategies for Ecology Education, Development and Sustainability) to diversify and advance the profession of ecology. A key goal is to stimulate and nurture the interest of underrepresented students in ecological research. In 2005, UNM Biology established a local SEEDS Chapter (Collins is faculty rep). Sevilleta LTER will host the next SEEDS Leadership Conference in spring 2008.

Fig 8. Left: Summer institute middle school student holding a Kangaroo Rat after a small mammal trapping experience at the Sevilleta. Right: Summer institute middle school students collecting lizards at the Sevilleta with LTER Graduate student and GK12 Fellow Robin Warne.

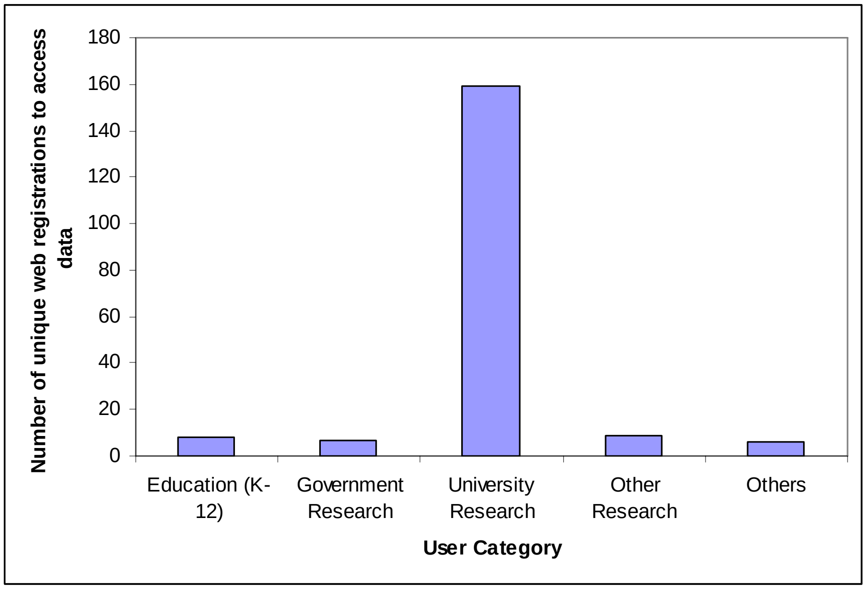
Graduate and undergraduate training. In 2006 we started E-MRGE, our GK-12 program in Ecohydrogeology in the Middle Rio Grande Environment (PI Collins, Co-PI Laura Crossey (Dept. Earth and Planetary Sciences)). E-MRGE Fellows work in partnership with middle school teachers in three rural New Mexico communities (Belen, Socorro and Laguna Pueblo) and the SNWR outreach program. Fellows and teachers develop activities to learn about long-term research and then develop related inquiry-based projects that provide hands-on science experiences for middle school students. These active learning projects are designed to meet New

Mexico science standards. Several of our GK12 Fellows are also conducting part or all of their dissertation research at the Sevilleta.

In July of 2007 nine middle school students attended a week long summer internship at the Sevilleta National Wildlife Refuge. These students were selected from 7th grade classes at Belen Middle School, where Sevilleta LTER graduate student Juliana Medeiros participated as a GK12 fellow working with life science teacher Kenda Meathenia. Students participated in data collection and instruction in four ongoing research projects at the refuge, as well as interacted with several researchers currently working on the refuge. Research projects included, replication of David Lightfoot's long term study of grasshopper populations, assisting UNM PhD candidate Robin Warne in collection of lizards for his laboratory research (Fig 8), assisting in sensor installation at the Pinon-Juniper study headed by Dr. Will Pockman and mammal trapping with UNM graduate student Jason Thomas (Fig 8). Students also received a variety of instruction at the FWS laboratory using their teaching collections of both plants and mammals. The program was a great success, and student interviews indicated that the program greatly increased their knowledge and interest in the field of biology.

In 2006 and 2007, we pieced together funds to create a summer REU program at the Sevilleta to foster interactions between our summer graduate fellows, SEV scientists, undergraduate interns and REU students. There were seven REU students in 2006 and eight in 2007. Students live at the Sevilleta during the summer and interact frequently with their mentors. This program includes a weekly journal club, a seminar series, and informal events to foster interactions among the various researchers and staff working at the SNWR. Our program is coordination by Jennifer Johnson, a Research Scientist with the SEV LTER.

In response to requests from the user community, this year the Sevilleta Information Management Team made all Sevilleta legacy climate data and the provisional current year's climate data available from a queryable web interface. All the legacy meteorological data were migrated into the Sevilleta MySQL database and a system for harvesting daily data from datalogger files and inserting it into the database was developed. Queries for monthly or daily Sevilleta climate data can be made from http://sev.lternet.edu/project_details.php?id=SEV001.



Information management

During the period August 2006 – July 2007, there were 189 unique registrations to access the Sevilleta LTER database. Most users were from the university research community.

Network-level interactions. At the Network level and beyond, SEV LTER scientists are involved in a variety of cross-site and international projects. IM Vanderbilt serves on the ILTER committee, NISAC, and is currently spearheading the effort to prepare a Critical Site and Network Functionality Document to serve as a planning tool for developing LTER cyberinfrastructure. She also serves as the chair of the International LTER Information Management Committee and frequently lectures in IM national and international training sessions organized by the LTER Network Office (LNO). PI Collins represents the SEV on the LTER SC, and just completed a torturous three year term on the LTER Executive Committee. Collins serves as PI on the NSF-funded LTER Planning Grant that is developing an ambitious funding initiative and research agenda to increase network-level coordination, cooperation, collaboration and capability. Finally, SEV researchers are involved in synthesis efforts such as ecoTrends, PDTNet (Suding et al. 2005, Pennings et al. 2005, Clark et al. 2007) and other cross site projects on compensatory dynamics (Houlahan et al. 2007), and shrub encroachment (Knapp et al. in review), Nutrient Network (NutNet) to name a few.

Sevilleta LTER is engaged in research in support of the National Phenology Network. In collaboration with Bethany Bradley (Princeton) and Geoff Henebry (South Dakota State University), a protocol was developed for collecting ground truth data as both digital photographs and quadrat estimates of vegetation “greenness” at the Blue Grama and Black Grama core research sites. Ground measurements are taken by Kristin Vanderbilt (IM) and Karen Wetherill (Field Crew Leader) every two weeks from June to October on days that coincide with collection of ASTER imagery. Geoff Henebry has identified algorithms for measuring greenness from the digital photographs, and these data will be related to both the quadrat measurements and indices calculated from the ASTER imagery.

Together these activities illustrate how the SEV LTER and its scientist are committed to the goals of the LTER Network, as well as education, outreach and training at K-12, undergraduate, graduate, postgraduate, and informal levels.

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Findings

As noted above, our research program is based on the concept of pulse dynamics in which pulses of rainfall, primarily at the event scale, stimulate biological processes from microbial metabolism through plant production and consumer population dynamics. The main components of our research are climate drivers, water in the environment, biogeochemistry and soils, producer dynamics, and consumer dynamics. Below we present highlights of some of the key results from our research in 2006-2007.

Climate variability (Doug Moore, Scott Collins)

General circulation models predict that our climate will continue to become more variable. Precipitation is already highly variable in desert environments, yet it is unknown how greater climate variability will affect aridland ecosystems. We can show, however, that climate variability has been increasing at the Sevilleta. Currently approximately 60% of our annual rainfall (250 mm on average) comes during the summer monsoon (July through September). A simple analysis of mean daily rainfall during the monsoon shows that, in general, the average amount of daily rainfall has not changed much from 1989-2005 (Fig 1). However, the *variability* in the size of average daily rainfall events has increased significantly over this same time period (Fig 1). Thus, it appears that the key driver of biotic processes, precipitation, is indeed becoming more variable over time. We are now using this type of information to drive several of our new long-term experiments (see below), including experiments that manipulate winter, summer, and annual rainfall.

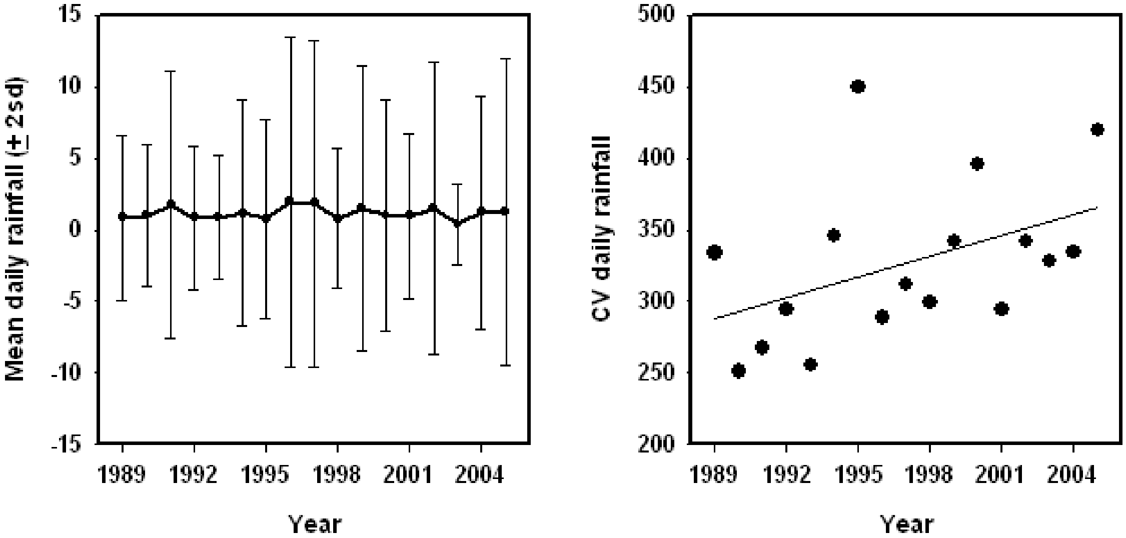


Figure 1. Left: mean daily rainfall during the summer monsoon season (July through September) at the Sevilleta LTER site. Right: Coefficient of variation (CV) of mean daily rainfall during the summer monsoon season. Although average daily rainfall has not changed much from 1989 to 2005, the variability of mean daily rainfall has increased significantly during this time period.

Evapotranspiration, water table fluctuations and riparian ecosystem dynamics (Cliff Dahm, James R. Cleverly, Kristin Vanderbilt, James R. Thibault, Maceo Carrillo Martinet and Chelsea Crenshaw)

Figure 2. Aerial view of the South Valley of Albuquerque ET measurement site looking south down the Rio Grande. The tower is located in the wider portion of the bosque in the foreground. The bridge in the background is the Interstate 25 Bridge over the Rio Grande near Isleta. This photo was taken in the early summer of 2000 before the June 2006 fire.

Restoration efforts that remove non-native understory vegetation or dense monotypic stands of non-native vegetation from riparian zones (or "bosque") are designed to reduce consumption of water. Quantification of the response of evapotranspiration (ET) and water table depths to non-native understory removal or to eradication of dense stands of non-native species like salt cedar or Russian olive is needed to provide defensible estimates of potential water-savings from restoration activities. In addition to restoration assessment, it is also important to monitor the effects the increasing roles of fire and post-burn management have on ET and water tables. LTER scientists monitor ET and water table responses at several sites along the Middle Rio Grande. Here we report results from one site in the Albuquerque South Valley at which the non-native understory vegetation was removed (Fig 2). Scaling the information on ET at this and other sites along the Albuquerque reach of the Rio Grande is an on-going challenge.

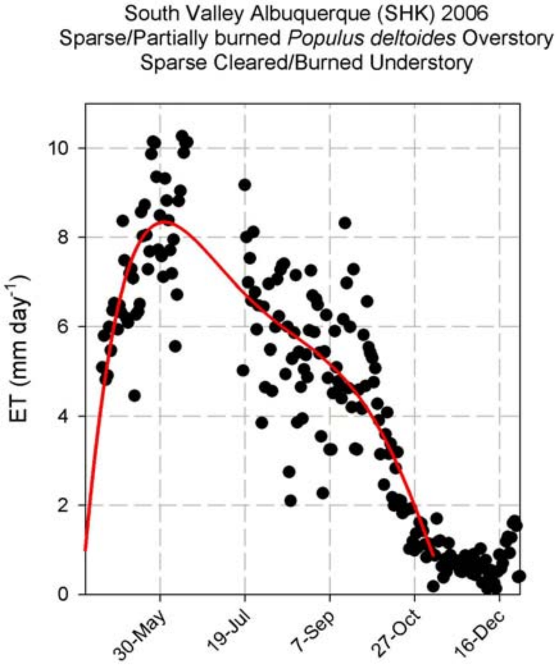


Figure 3. Rates of evapotranspiration (ET) at the Albuquerque South Valley tower site for the growing season of 2006.

Evapotranspiration (ET) and water table measurements along the Rio Grande south of Albuquerque. An aerial view of the South Valley site where ET measurements are made is shown in Figure 2. The ET tower is located in the broader swath of bosque in the foreground of the figure. A fire on June 15, 2006 burned the vegetation to the south of the tower. Soil temperatures exceeded 100°C at 10 cm depth during the fire and soil heat flux values reached almost 500 W m^{-2}. In 2006, early growing season values for ET ramped up quickly in the late spring after leaf out (Fig 3). Maximum rates near 10 mm d^{-1} occurred on a number of days in late May and early June. These values approach the theoretical maximum rate of ET for a clear sunny day at this time of year. The high ET rates indicate a very high rate of primary production from the riparian forest during this period. The rates of ET were generally much lower after July 18 following the fire. Occasional higher rates show a stronger contribution from the unburned forest north of the tower. Average values ramped downward from < 7 mm d^{-1} in late July to around 4 mm d^{-1} in mid-September. Senescence occurred in September and October with ET rates falling to background levels by late October after the first hard freezes. The growing season of 2006 represents the seventh year of ET measurements at this site.

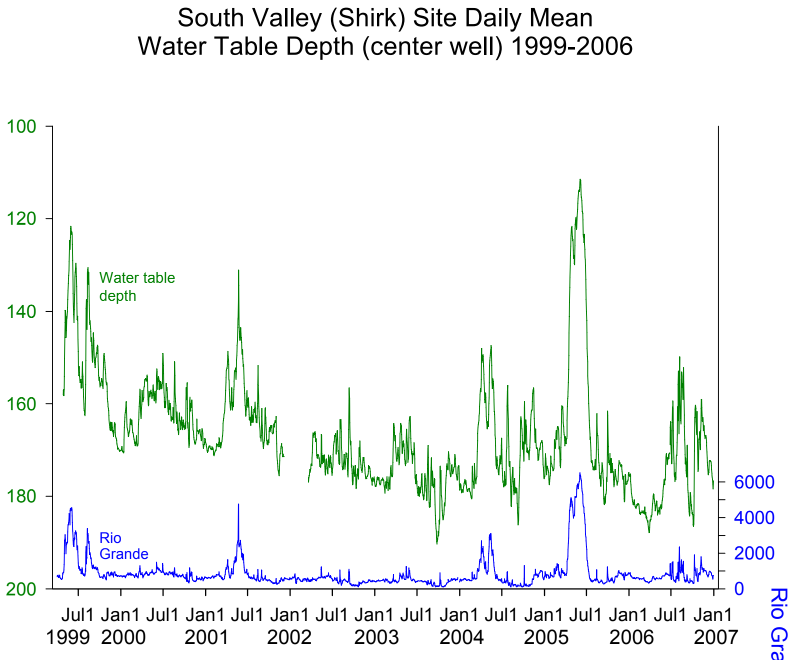


Figure 4. Long-term record of water table depth at the Albuquerque South Valley site beginning in spring 1999. The discharge (Q) of the Rio Grande at the Central Bridge USGS gauging station is shown for comparison.

A long-term record of water table depths is available for this site (Fig 4). Water table measurements began in the spring of 1999. The long-term record shows the responsiveness of the site to discharge in the Rio Grande. Snowmelt peak flows in the river in 1999, 2001, 2004, and 2005 are clearly seen in the rising water table depth at the Albuquerque South Valley site. The highest water table at the site occurred in May and June of 2005 when peak flows in the Rio Grande reached about 6500 cubic feet per second (cfs). The bosque at this site is disconnected from the river and overbank flooding has not occurred at the site since the completion of Cochiti Reservoir in 1975. The unusually strong summer monsoon in 2006 is seen in both river discharge (Q) and the strong water table fluctuations in the summer of 2006. The strong drought years of 2002 and 2003 also are seen in the long-term record with maximum water table depth at the site occurring in the late summer of 2003.

A graduate student on this project, Maceo Carrillo Martinet, is exploring the relationship between tower-based estimates of ET and the diurnal pattern of groundwater elevations. Chapter 1 of his thesis that he is presently preparing is titled “Applying diurnal fluctuations of shallow alluvial ground water to estimate plant uptake of groundwater and water salvage through non-native vegetation removal." Data from Maceo's dissertation research will allow a rigorous analysis of the possibility that diurnal fluctuations in groundwater elevations can be used to estimate riparian zone ET rates. The ability to compare estimated ET rates calculated from daily fluctuations in groundwater elevations with independently-derived tower-based ET measurements is a distinct aspect of the research that has not been reported in the literature to date.

Scaling up the estimates of evapotranspiration to an estimate of water use throughout the Urban Flood Demonstration Project area of interest is underway using remote sensing and geographical information systems (GIS). In addition, multispectral remote sensing provides a tool to classify the riparian vegetation along the Rio Grande and to look for changes in vegetation or vegetative cover through time. Multispectral images from 2002 and 2006 along the reach show large changes in vegetation density due to fire, human construction activity, understory removal, and restoration.

Remote sensing analyses using multispectral SPOT imagery will allow comparison of the vegetation within the bosque in the Albuquerque reach in 2006 to an earlier assessment from LANDSAT imagery from 2002. Major changes in the vegetation within the reach are linked to fires, construction activity, and understorey thinning operations. Vegetation classification can ultimately be coupled with estimates of vegetation density and the tower-based measurements of ET rates in various vegetation types to generate spatially explicit estimates of ET rates along the riverine corridor of the Rio Grande.

Ecohydrology and the dynamics of islands of fertility (Paolo D'Odorico, Sujith Ravi, Ted Zoback, Greg Okin, Carl White, Scott Collins)

Figure 5. Water repellent soils around a burned shrub at Sevilleta

Hydrological and aeolian processes control the redistribution of soil particles and nutrients in arid environments thereby contributing to the formation of heterogeneous landscapes with nutrient-rich "resource islands" surrounded by patches of unfertile bare soil. Recently, fire has been observed to alter this pattern of resource heterogeneity through the redistribution of nutrients from the fertile islands of burnt shrubs to the surrounding bare soil areas. Even though, the role played by soil erosion processes (by wind and water) in dryland ecosystems has been well documented, very few studies have addressed how fires interact with these processes to affect the dynamics of the "resource island". We investigated how fires may affect wind and water erosion in a shrub-encroached heterogeneous landscape at the grassland-shrubland boundary at the Sevilleta LTER site. This study tested the hypothesis that fires can alter the pattern of resource heterogeneity through the redistribution of nutrients from the fertile islands of burnt shrubs to the surrounding bare soil areas. Wind erosion activity (dust flux and saltation activity), and infiltration rates in replicated burned plots were compared with observations both from plots denuded of their vegetation cover, and from unmanipulated control plots. Differences in microtopography and nutrient distribution between vegetated islands and bare interspaces following a fire were measured. We quantified the water repellency induced by fires using water drop penetration time and Molar Ethanol Drop tests (Fig 5). Our results indicate that fires increase wind erosion, reduce microtopographic variation, and enhance overall soil erodibility in shrub-dominated islands of fertility (Fig 6). We interpret this effect as a result of the weakening of interparticle bonding forces caused by fire-induced soil water repellency. This interpretation is consistent with the results from wind tunnel experiments on soil erosion following experimental burning (*Ravi et al*. 2006).

The results from these laboratory experiments were also field validated at Sevilleta both at the field and patch scales in heterogeneous arid landscapes. Higher water repellency was observed in conjunction with a stronger decrease in wind erosion threshold velocity around the shrubs than in grass-dominated patches affected by fire; while neither water repellency nor changes in threshold velocity were noticed in the bare soil interspaces (*Ravi et al.* 2007).

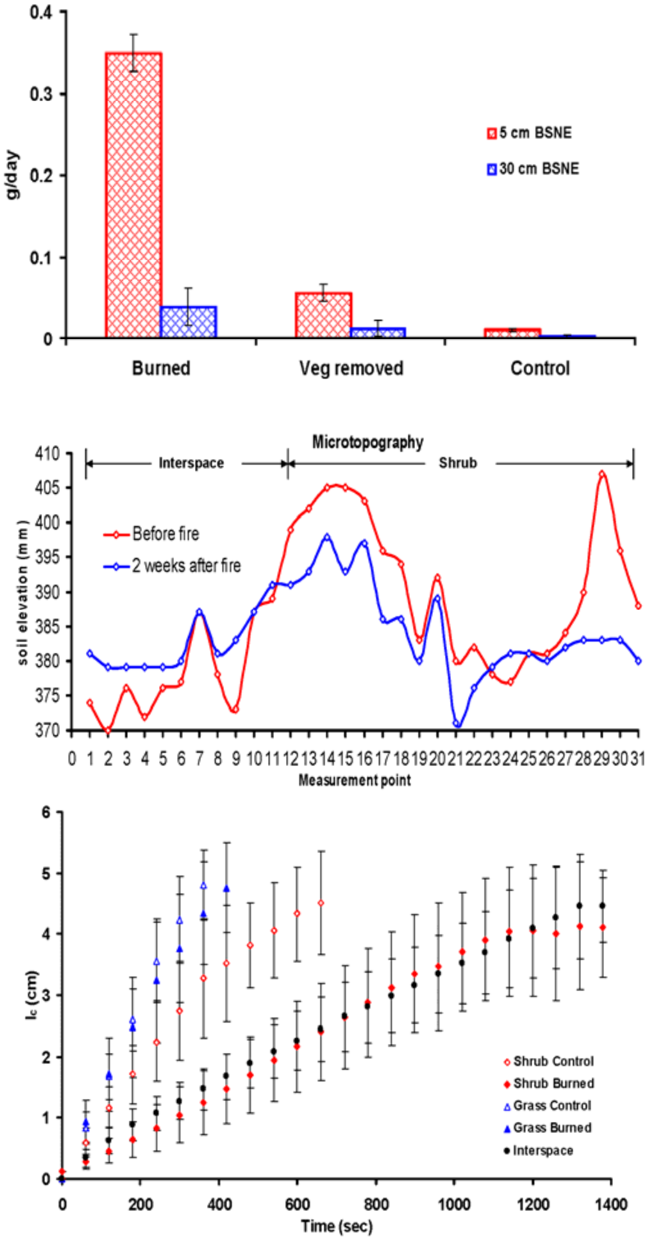


Figure 6. Top: Dust flux measurements from BSNE dust sediment collectors. Middle: Post-fire changes in microtopography. The areas under the burned shrubs lose soil (erosion), while the bare soil interspaces gain (deposition). Bottom: Cumulative infiltration as a function of time in burned and unburned soil patches with bare soil, shrub and grass cover.

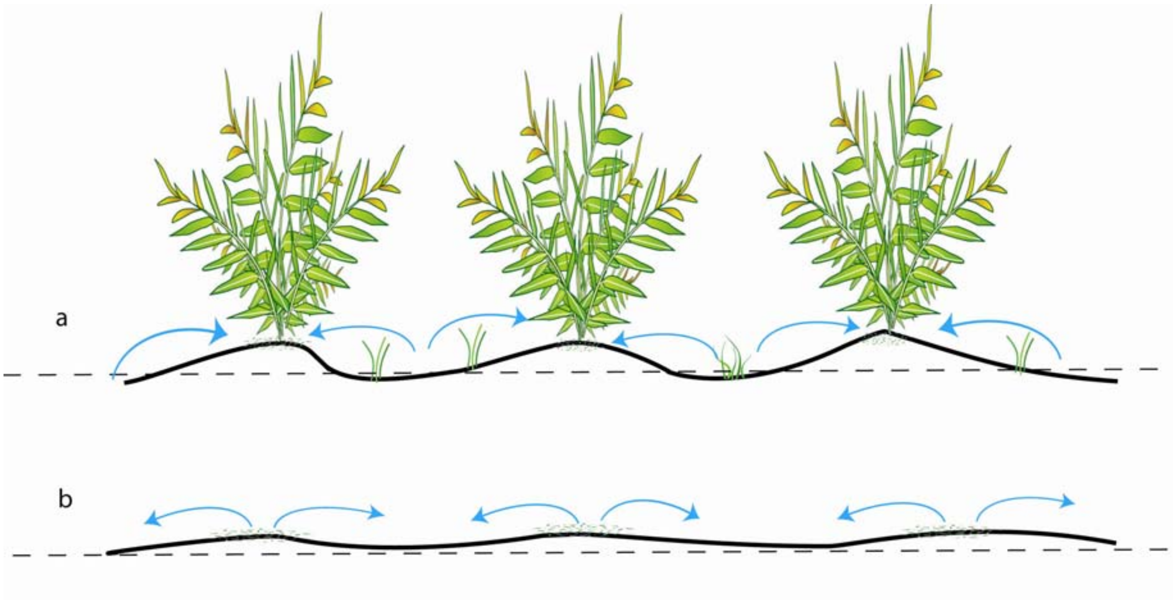


Figure 7. Schematic representation of the pre-fire accumulation of soil resources beneath the shrub canopy (a), and post-fire redistribution of soil particles from the resource islands to the interspaces (b).

Our results suggest that the post-fire increase in runoff and soil erosion rates around the burned shrubs occur because of the enhancement of hydrologic and Aeolian processes caused fire-induced water repellency. Due to these processes the resource islands are dynamic (Fig 7) rather than static features in these arid ecosystems. Fires contribute to a decrease in soil heterogeneity in arid landscapes, with a consequent negative feedback on shrub encroachment and desertification.

Stable isotope composition and soil CO_2 concentrations (Dan Breecker, Les McFadden)

Preliminary analyses are presented from a year-long study of the stable isotope composition and concentration of soil CO_2 in young, pedogenic carbonate-bearing soils at the Sevilleta. $\delta^{13}C$ values and concentrations as a function of depth and season are being measured in four distinct biomes. Below 50 cm, $\delta^{13}C$ values were lowest in winter and highest in spring (2-3‰ variation) while soil CO_2 was lowest in winter and highest in summer (2000-3000 ppm variation). Respiration rates estimated with a steady state model were lowest in winter and highest in summer while $\delta^{13}C$ values of soil-respired CO_2 were lowest in winter and highest in spring. Measured $\delta^{13}C$ values of recently formed pedogenic carbonate were always heavier than predicted from measured $\delta^{13}C$ values of soil CO_2 (Fig 8). Modeling soil CO_2 suggests that equilibrium with pedogenic carbonate occurs only when respiration rates decrease to their lowest values and the isotopic composition of soil-respired CO_2 increases to its highest value. These conditions likely occur during the driest, hottest season of dry years when soil moisture and respiration rates are low and reduced discrimination against ^{13}C during photosynthesis combined with an increase in the relative contribution from C_4 plants maximizes $\delta^{13}C$ soil-respired CO_2. We conclude that carbonate forms only during the driest times when soil CO_2 is

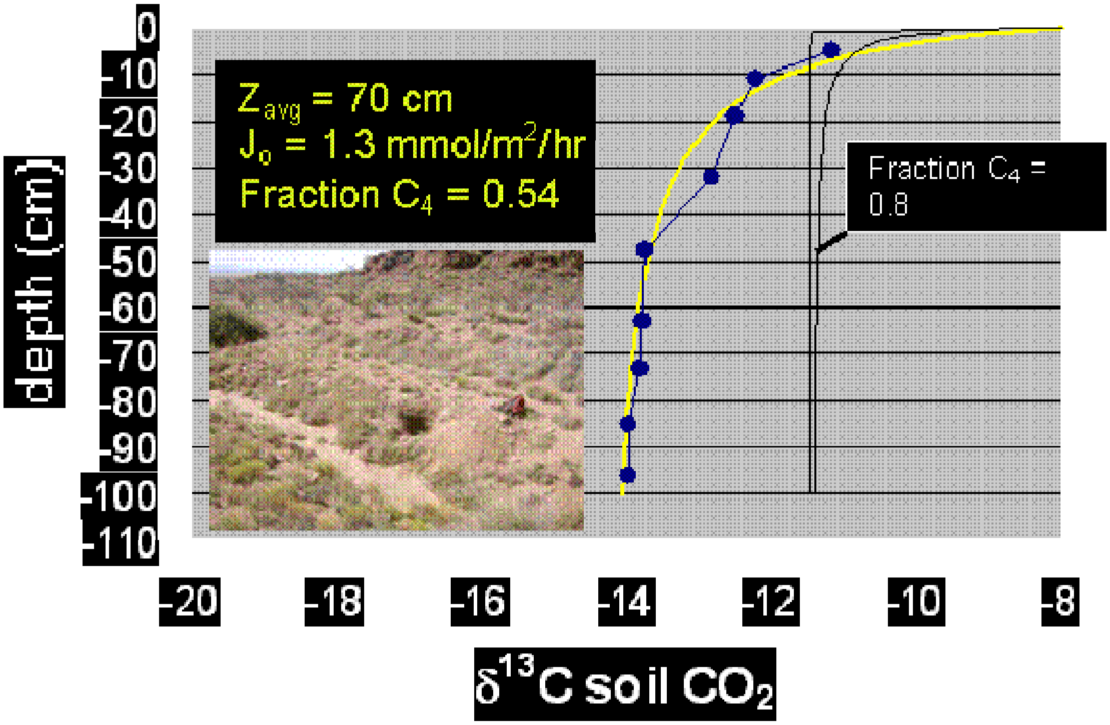


Figure 8. Distribution of δ^{13}C values with depth in a grassland soil at the Sevilleta. Thin lines are generated from a model based on C inputs that assume C4 plant species make up 80% of plant biomass.

anomalously low and δ^{13}C values are anomalously high. This model is supported by the fact that evaporation of soil water, low soil CO_2 and high temperature all favor calcium carbonate precipitation. If we are correct, then pedogenic carbonate is biased toward high δ^{13}C values (C_4 signal) and typically does not record average compositions of vegetation growing in the soil. If carbonate indeed forms under dry, hot conditions, with low soil CO_2 and reduced discrimination, then previously calculated values for atmospheric pCO_2 using carbonate paleosol barometry are probably overestimated by up to 1000 ppm.

Carbon storage across the grassland-shrubland transition zone (Bryan Brandel and Carol Wessman)

The goals of this research are to assess changes in ecosystem properties following woody plant encroachment in semiarid grasslands and to utilize remote sensing to scale these measurements to the landscape level. This will allow us to better estimate the contributions of woody plant expansion to ecosystem carbon storage, especially with current uncertainty in carbon stocks. Recently, soil organic carbon (SOC) concentrations were determined for soil samples collected in research plots established across the gradient from grassland to shrubland at the Sevilleta. Area-weighted SOC for each plot was calculated based on field estimates of cover. Allometric equations relating plant cover to biomass C for black grama (*Bouteloua eriopoda*) and creosotebush (*Larrea tridentata*) have also been developed to calculate plant biomass C in each plot. Total C storage at the plot level was calculated as the sum of area-weighted SOC and plant biomass C (Fig 9).

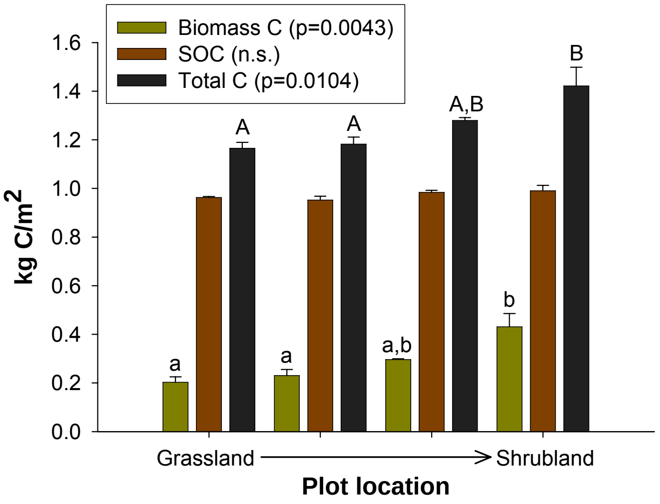


Figure 9. Average plant biomass C, SOC, and total C storage (±s.e.) for plots across the grassland-shrubland transition based on area-weighted field measurements and allometric equations (N=12). Different letters above the bars indicate significant differences ($p<0.05$). Total C storage is significantly higher in shrubland compared to grassland ($F_{3,8}=7.48$, $p=0.01$), which is driven by increases in plant biomass C following woody plant encroachment.

Field measurements of SOC and plant biomass C are being scaled to the landscape level using remote sensing analysis. Preliminary linear spectral unmixing of AVIRIS imagery was performed to derive fractional cover for the dominant cover types in the research area. These fractional cover images are being used to scale field measurements to the landscape level and estimate total ecosystem C storage across the grassland-shrubland transition. Increases in total ecosystem C storage following woody plant encroachment appear to be driven by increases in plant biomass C, which may be vulnerable to land management and disturbance. These findings suggest rapid land use/cover change may contribute to uncertainty in regional C budgets and ecosystem models.

Biogeochemistry and microbial dynamics (Bob Sinsabaugh, Jose Herrera, Jennifer King, Chelsea Crenshaw, Martina Stursova, Marcy Gallo, Andrea Porras-Alfaro, Laura Green)

A series of biogeochemical and microbial community composition studies have led to development of a new conceptual model (Fig. 10) that links the belowground C and N dynamics of desert grassland to ecosystem-scale abiotic constraints conceptualized by the threshold pulse reserve model of aridland ecosystems. The new model, which serves to organize much of our microbial ecology research (see summaries below), proposes that the concentration of soil organic matter in desert grassland is low because photodegradation of surface litter limits aboveground input while high oxidative enzyme activity, stabilized on soil particles, limits humus accumulation. Low soil nutrient reserves, in turn, promote the cycling of nutrients within existing biomass. The dominant grasses are heavily colonized by dark septate endophytes that confer drought resistance and translocate nutrients. These taxa also dominate the fungal community of soil and microbiotic crusts, which are sites of C and N fixation. The combination of low soil organic matter content and typically low soil water content, concentrates belowground nutrient cycling around a loop of biotrophically supported fungi that mineralize protein,

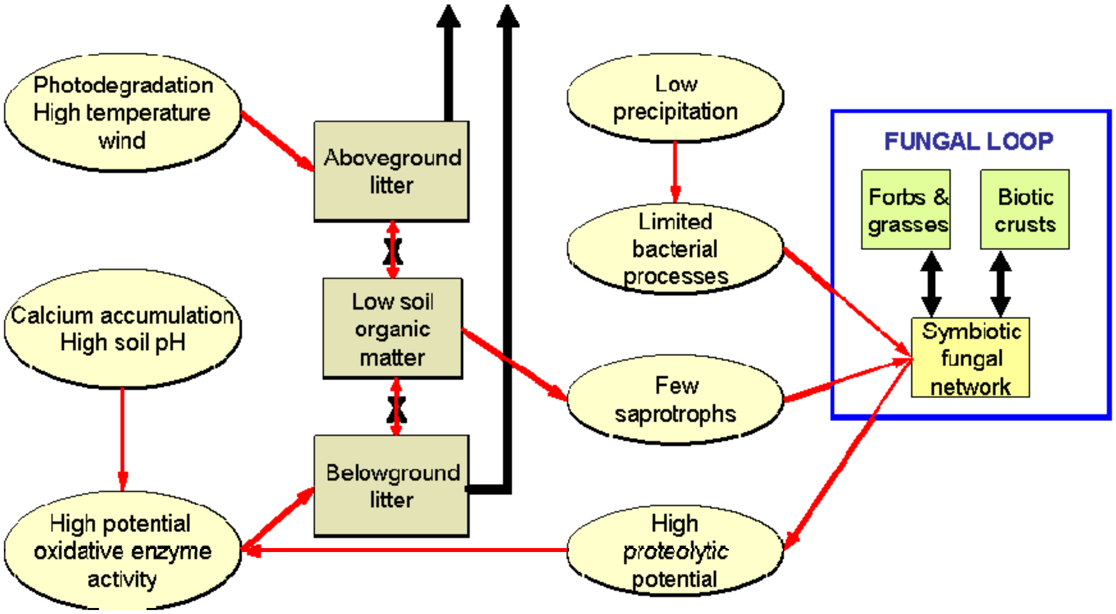


Figure 10. Interaction of factors that lead to the key role of fungi in aridland soils. Hot, dry, and calcium rich soils favor fungi over bacteria. Decomposition of aboveground litter is primarily abiotic. In addition, high oxidative enzyme potentials from fungi break down recalcitrant carbon compounds in the soil. Together, these processes lead to low rates of soil organic matter formation. As a consequence, fungi form a connective web that moves C and N between biotic crusts and the dominant perennial grasses.

transform N and translocate N and C between grasses and microbiotic crusts. Current activities related to the evaluation of this model are detailed below.

➔*Photodegradation*: Marcy Gallo (PhD 2007) completed a comparative study of cottonwood, juniper and piñon litter decomposition in relation to sunlight exposure. This work included measurements of litter chemistry, microbial extracellular enzyme activity, and molecular analyses of fungal community composition. Sunlight exposure accelerates decomposition and photo-oxidation can replace enzymatic oxidation, an interesting finding because the fungal community colonizing the litter does not include well known lignin decomposers. Two papers on this work are currently in review.

Another photodegradation project, funded by NSF (PI Jennifer King, UMN), is in its second year. The project involves comparing the magnitude of photodegradation at three LTER grassland sites. Results to date show significant effects of UV on decomposition of grass litter, with the biggest effects observed at the Sevilleta site.

➔*Soil oxidative activity*: An investigation into the nature of the extreme soil oxidative potentials was undertaken in 2007 by Martina Stursova. The results showed that activity was uniformly distributed in relation to soil particle size. The catalytic activity was not abiotic but sorbed enzymes were stabilized to the extent that autoclaving had no effect on activity. A paper on this work has been reviewed and is in revision.

➔*Fungal community composition*: A comprehensive molecular analysis of the fungal diversity and distribution continues led by Andrea Porras-Alfaro (PhD student) and Jose Herrera (Truman State University). This work has been supported by various NSF sources and will continue through the next two years. A paper describing arbuscular mycorrhizal fungi of grasses, comparing control and long term N fertilized plots was published this year (Fig 11). A second paper comparing root, soil and crust communities in control and N fertilized plots has been submitted. Multiple other papers are likely including fungal community descriptions in relation to plant species, season, and soil type.

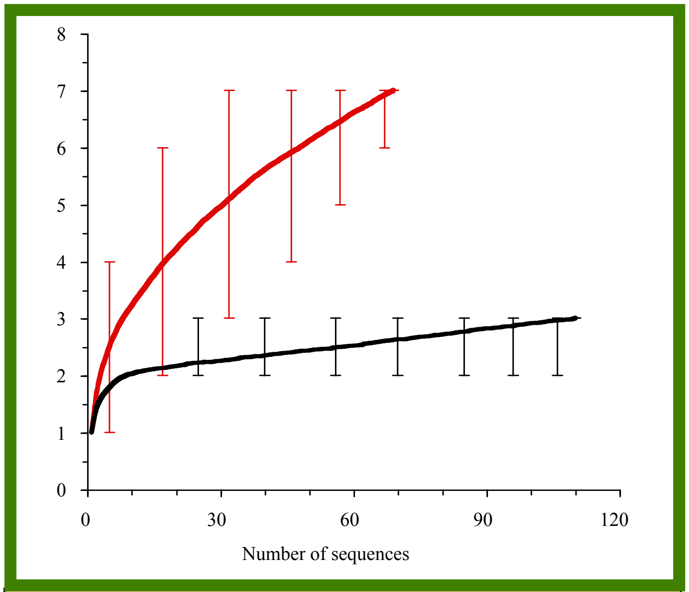


Figure 11. Rarefaction curves showing arbuscular mycorrhizal fungal diversity in N-fertilized and control plots at the Sevilleta (Porras-Alfaro et al. 2007).

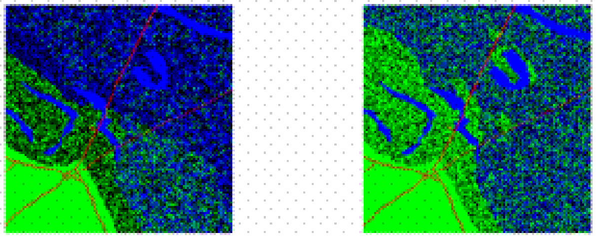
➔*N transformation*: A paper describing fungal vs. bacterial contributions to nitrous oxide production from soils collected in control and N fertilized plots was accepted for publication in 2007. This work was led by Chelsea Crenshaw (Ph.D. 2007). Results indicate that fungi, rather than bacteria, are the primary microbes for N transformation in dryland soils.

➔*N translocation*: A paper describing the translocation of ^{15}N glutamate and nitrate between grass and crust patches has been submitted. This work was led by Laura Green (M.S. 2007). This line of research is continuing. In late summer of 2007, we will evaluate the use of ^{15}N labeled quantum dots to better resolve the mechanisms of N exchange between grasses and crusts.

ECOTONE simulation of patch structure and patch dynamics (Deb Peters, Greg Okin, John Wainwright, Tony Parsons)

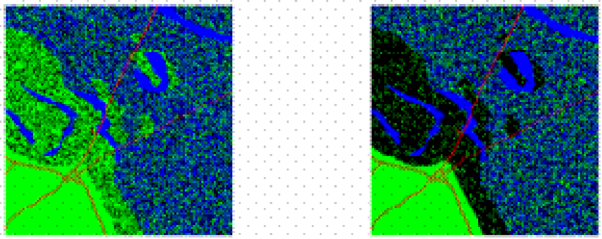
Simulation modeling. In collaboration with the Jornada LTER, we continue to modify the ECOTONE simulation model by incorporating the horizontal and vertical distribution of water, nutrients, and soil particles by wind and water across a range of spatial scales, from plants to patches and landscape units. We are working with Greg Okin at UCLA to link ECOTONE with his model of wind redistribution of soil particles to allow effects of dynamic vegetation on wind erosion-deposition dynamics. We are also working with Tony Parsons and John Wainwright (University of Sheffield) to link ECOTONE with their model of horizontal soil water redistribution across ecotones.

Synthesis using simulation modeling. In 2006, Deb Peters (Sevilleta Senior Scientist) continued her research on ecotone and patch characterization and dynamics at the Sevilleta. As part of her patch dynamics studies, she conducted analyses using a cellular automata model to simulate landscape-scale dynamics across different types of boundaries (stable, shifting, directional) between the three dominant species (blue grama, black grama, creosotebush) (Peters et al. submitted). The model represents vegetation dynamics under changes in climate and grazing regime through time.



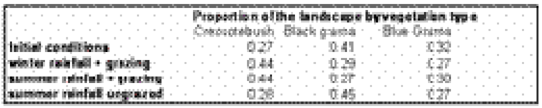
(a) Initial condition

(b) winter rainfall with grazing



(c) summer rainfall with grazing

(d) summer rainfall without grazing



	Proportion of the landscape by vegetation type		
	Creosotebush	Black grama	Blue Grama
initial conditions	0.27	0.41	0.32
winter rainfall + grazing	0.44	0.29	0.27
summer rainfall + grazing	0.44	0.27	0.30
summer rainfall ungrazed	0.28	0.45	0.27

Fig. 12. Simulated output from a cellular automata model showing response of each boundary type to climatic fluctuations and grazing by livestock at the Sevilleta National Wildlife Refuge LTER site in central New Mexico. (a) 1915 start of each simulation, and following 88 years of (b) winter rainfall and livestock grazing that promote expansion of the shrub, creosotebush (green), (c) summer rainfall and livestock grazing that promote expansion of the grazing-tolerant grass, blue grama, and (c) summer rainfall without grazing that promotes the grazing-intolerant grass, black grama (black). Note that stationary boundaries (blue) do not change in any of the simulations.

Results show that landscape dynamics depend on the mosaic of boundary types that occurs within the landscape. Stationary boundaries occur most frequently between two grass species, blue grama and black grama, which dominate on different soils. These boundaries are controlled by soil texture constraints and soil water availability interacting with plant life history traits. These boundaries are stable even under conditions of changes in seasonal rainfall (winter, summer) and grazing by or exclusion from cattle (Fig 12). By contrast, shifting boundaries are responsive to both seasonal rainfall and cattle gazing (Fig 12). At the Sevilleta, shifting transitions occur between blue grama and black grama grasslands located on soils with intermediate sand and clay contents. Black grama expands into boundaries under summer rainfall without grazing whereas blue grama expands with livestock grazing under a similar rainfall regime. These responses reflect different plant traits by these two species. Black grama, a characteristic species of the Chihuahuan Desert, is less grazing-tolerant than blue grama, a characteristic species of the Shortgrass Steppe, a system that evolved with heavy grazing by large herbivores, in particular bison. Finally, directional transitions occur at the Sevilleta as a result of the invasion by the native woody plant, creosotebush, primarily into black grama grasslands (Fig 12). This expansion and subsequent conversion of grasslands into shrublands is promoted with grazing and either summer or winter rainfall.

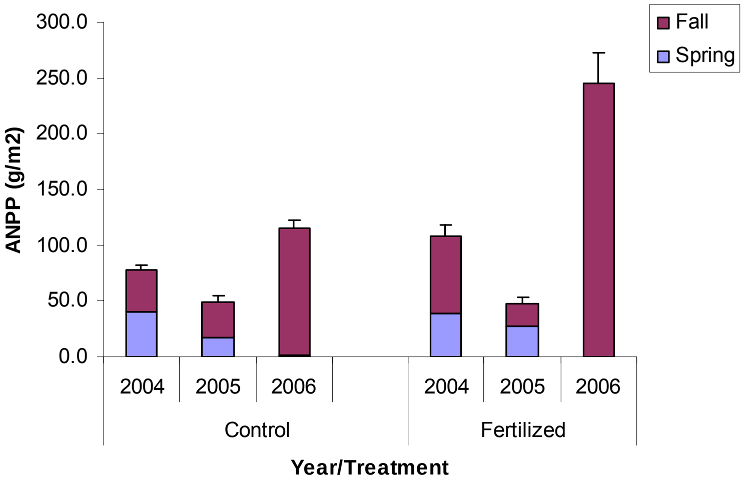


Figure 13. Mean (+SE) seasonal and annual aboveground net primary productivity (ANPP) on control and fertilized (10 $gNm^{-2} yr^{-1}$) plots in 2004-2006. For each year n =10 control and n = 10 fertilized plots. Significant differences ($p < 0.05$) between control and fertilized means within a year are indicated by differing lower case letters.

Nitrogen fertilization and plant community structure of desert grassland (Scott Collins, Michell Thomey, Doug Moore)

As noted above, aridland ecosystems are strongly limited by water availability. The unimodal model of productivity and species diversity predicts that diversity will increase with productivity in low productivity systems such as desert grasslands. We analyzed the relationship between aboveground net primary production (ANPP), species diversity and climate variability in a 10-yr long nitrogen

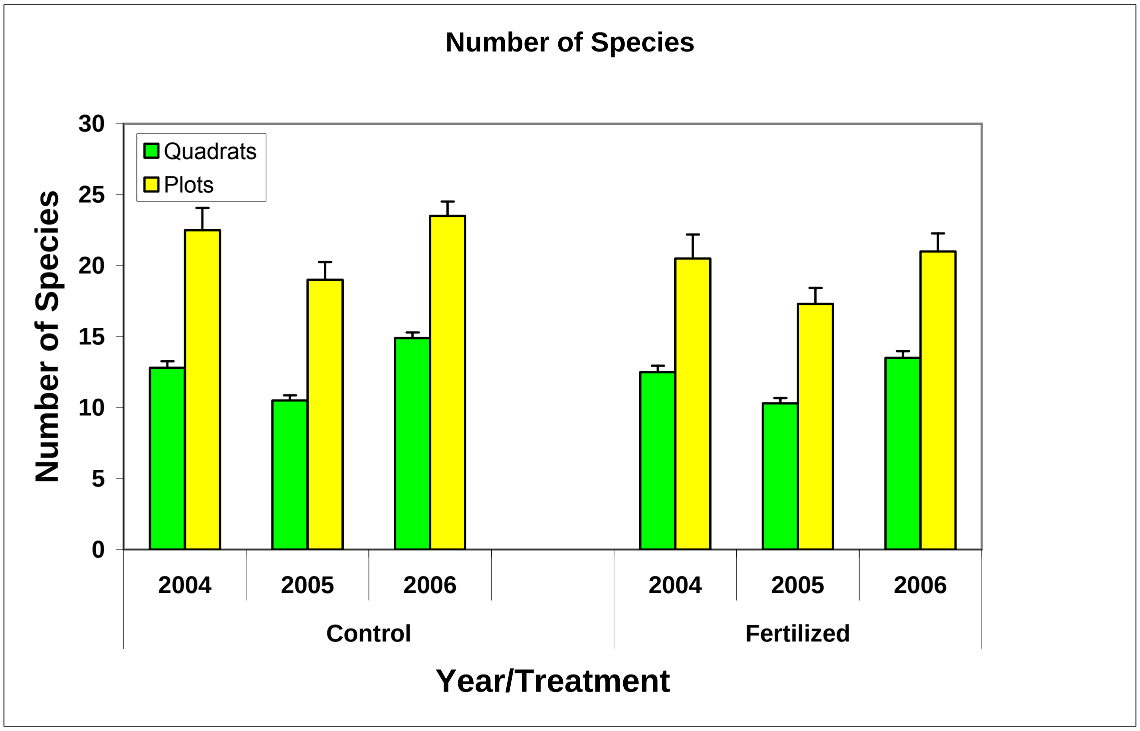


Figure 14. Mean plant species richness at the subplot ($1m^2$) and plot ($4m^2$) scales on control and fertilized ($10gNm^{-2}yr^{-1}$) plots in 2004-2006. There were no significant differences in species richness between fertilized and control plots in any year.

fertilization experiment in low productivity desert grassland at the Sevilleta LTER site in central New Mexico. We hypothesized that diversity and ANPP would increase in high rainfall years, but ANPP and diversity would be similar in fertilized and control plots in years of average or below average rainfall.

To test this hypothesis we measured species composition and ANPP during 2004-2006 in four 1m^2 subplots located in each of twenty 5x10m2 plots ten of which were fertilized with 10gNm^{-2}yr^{-1}. Fertilization treatments started in 1995. Seasonal and annual rainfall differed among years: non-monsoon precipitation was 155, 178, and 29 mm and monsoon precipitation was 149, 143, and 196 mm in 2004-2006, respectively. In 2004, ANPP was significantly higher on fertilized (108.1 gm^{-2}) compared to control plots (77.3gm^{-2}), yet there were no significant differences in species diversity in fertilized (12.5m^{-2}) or control (12.8m^{-2}) plots (Figs 13, 14). There were no differences in ANPP (48.0 vs. 49.5 gm^{-2}) or species diversity (10.2 vs. 10.4m^{-2}) in fertilized and control plots in 2005. The 2006 growing season experienced very low winter/spring rainfall and above average monsoon rainfall. In response, ANPP was more than double on fertilized (245 gm^{-2}) compared to control plots (115 gm^{-2}) and diversity was 13.5 vs 14.8 m^{-2}. Much of the increase in ANPP in 2006 was in forb biomass. These results show that (1) slight changes in the amount and seasonality of precipitation have strong impacts on ANPP, (2) ANPP is strongly N limited in periods with high soil water availability, but (3) species diversity and ANPP are generally decoupled in this aridland ecosystem.

Our results extend the experimental analysis of ANPP and species richness into arid native grassland vegetation. Although the original hump-shaped model predicts an increase in species richness with increasing productivity potential in low productivity ecosystems, we found that species diversity showed little consistent response to large intraseasonal and interannual fluctuations in ANPP in this aridland ecosystem. Understanding how environmental factors influence ANPP and the degree to which productivity affects species diversity are important challenges as global climate change interacts with increasing atmospheric nitrogen deposition to affect the structure and function of aridland ecosystems globally

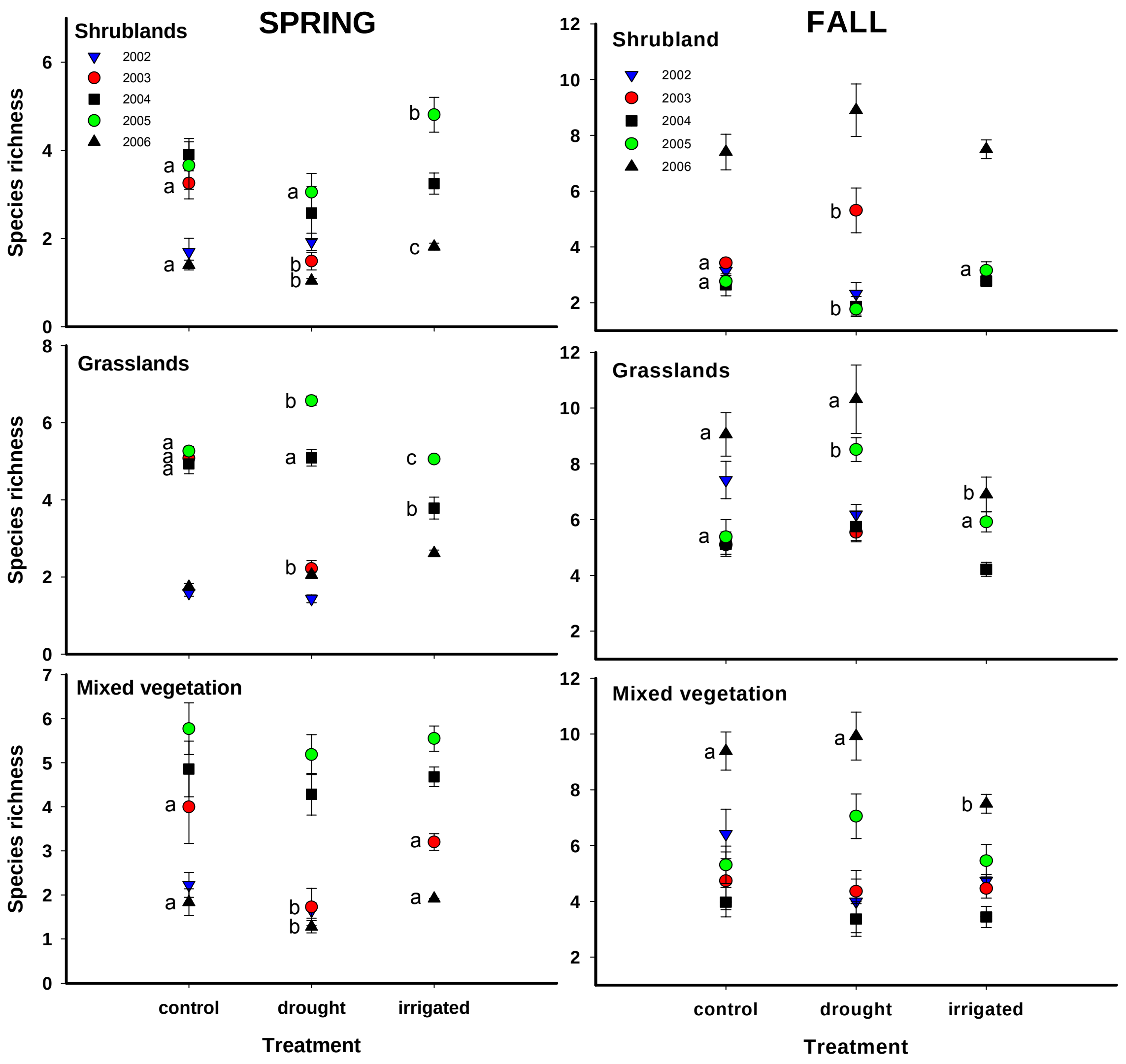


Figure 15. Mean (+SE) seasonal species richness from 2002-2006 in black grama grassland, creosotebush shrubland and mixed grass-shrub communities subjected to either ambient (control), decreased (-50%) or increased (+50%) annual precipitation. Significant differences in species richness ($p < 0.05$) between ambient, drought, and irrigated treatments within a year are indicated by differing lower case letters.

Impacts of drought on plant community structure and ANPP (Will Pockman, Scott Collins, Jennifer Johnson, Selene Baez, Eric Small)

Aridland ecosystems are subjected to wet and dry cycles that vary seasonally and annually. Evidence suggests that many aridland ecosystems are highly responsive to wet years and resistant to short term drought periods, but severe chronic drought may greatly alter community structure and ecosystem function. To test community response to different precipitation regimes, we experimentally altered precipitation inputs in desert grassland, creosotebush shrubland and mixed grass-shrub communities at the Sevilleta LTER site in central New Mexico. Manipulations (N=3) included a 50% reduction in ambient annual rainfall starting in 2001 and a 50% rainfall addition treatment based on the long-term average of 250mm per year starting in 2005. Plant community composition was measured seasonally in nine permanently located 1m^2 quadrats in each replicate of each treatment. We report here on changes in plant species composition from 2002-2006 in all communities, and ANPP responses in grassland and mixed communities. Seasonal and annual rainfall differed among years: non-monsoon precipitation was 50.8, 55.5, 176.0, 214.0, and 29.8 mm (long-term mean is 98.0 mm) and monsoon precipitation was 181.6, 70.0, 114.7, 163.5 and 257.9 mm (long-term means is 140.0) in 2002-2006, respectively. Rainfall reduction treatment had little impact on total plant cover in creosotebush shrubland, but richness averaged 1-2 species lower in drought plots compared to control and water addition plots (Fig 15). Total plant cover was nearly half that of control plots and water addition treatments under experimental drought in the mixed grass-shrub community but both richness and cover increased rapidly in 2006, a year of above average monsoon precipitation. Chronic drought also reduced cover in the grassland community (Fig 16), but drought treatments had higher plant species richness, on average than controls or rain addition plots. As expected, rainfall reduction lowered grassland ANPP whereas rainfall addition increased ANPP in dry years (Fig 17). Results suggest that desert plant communities differentially respond to chronic drought and interannual precipitation variation, with greatest changes in cover and richness occurring in areas dominated by herbaceous vegetation. Our results provide strong support for the key role of precipitation in controlling ANPP in aridland ecosystems (Muldavin et al. *in review*). Although irrigation significantly increased ANPP, the community response may have been further constrained by resource limitation, although evidence suggests that black grama grasslands do not respond strongly to nitrogen addition (Báez et al. 2007). What was surprising, however, was the somewhat inconsistent and variable responses in community structure among treatments within a community and among communities. Previous work has shown that plant community structure is strongly governed by season and annual precipitation and that plant community structure in grass- and shrub-dominated communities is strongly governed by bottom-up forces (Báez et al. 2006).

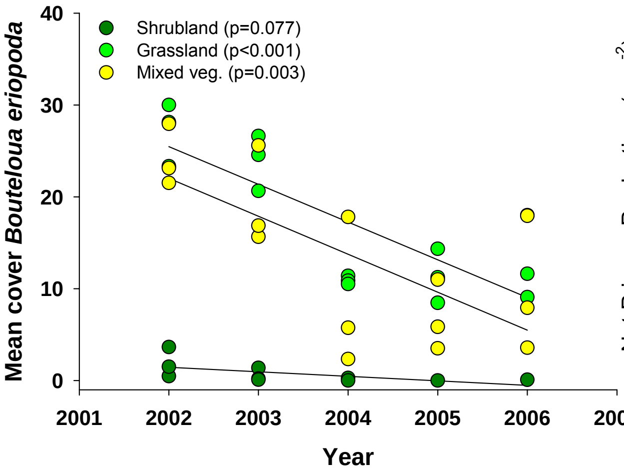


Figure 16. Change in cover of black grama over time in the drought treatment.

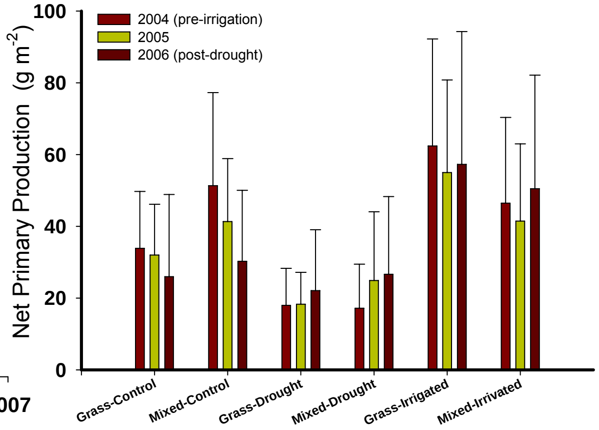


Figure 17. Mean (+SE) aboveground net primary production in ambient (control), drought, and irrigation treatments in grassland and mixed communities from 2004 (before irrigation started) through 2006.

Understanding how environmental factors influence ANPP and the degree to which productivity affects species diversity are important challenges as global climate change interacts with increasing atmospheric nitrogen deposition to affect the structure and function of aridland ecosystems globally.

Trophic structure and dynamics (Blair Wolf, Robin Warne, Alaina Pershall, Sophia Engel, Casey Gilman, Hillary Lease, Nate McDowell)

Understanding resource exploitation by consumers is central to understanding the structure and dynamics of ecosystems at the individual, population and community levels. We are investigating the affects of short and long-term climate variability on the dynamics of carbon flow through a mixed grassland/shrubland food web. At the Sevilleta, winter rains drive the growth of spring annuals and perennials (C_3 photosynthetic pathway) and the summer monsoon drives warm season grasses (largely C_4 photosynthesis) and perennials. Because C_3 and C_4 plants have distinct isotopic signatures of $\delta^{13}C$ we can quantify the proportion of these plants in animal diets through stable isotope analysis. Several on-going projects include:

Resource use by the lizard community and reproductive allocation of nutrients. During 2005 and 2006 we looked at resource use by the lizard community by measuring the $\delta^{13}C$ and $\delta^{15}N$ values of lizard plasma. We show seasonal shifts by the lizard community in the sources of assimilated carbon, which can be linked to dietary shifts in the insect community and tied to precipitation inputs (Fig 18). At inter-annual scales we show how a failure in winter precipitation during 2006 impacts pathways of carbon flow and potentially productivity in a food web when compared to a “normal” year. Preliminary findings from this project resulted in a funded DDIG in 2007 and a manuscript on these findings has been submitted to Ecology.

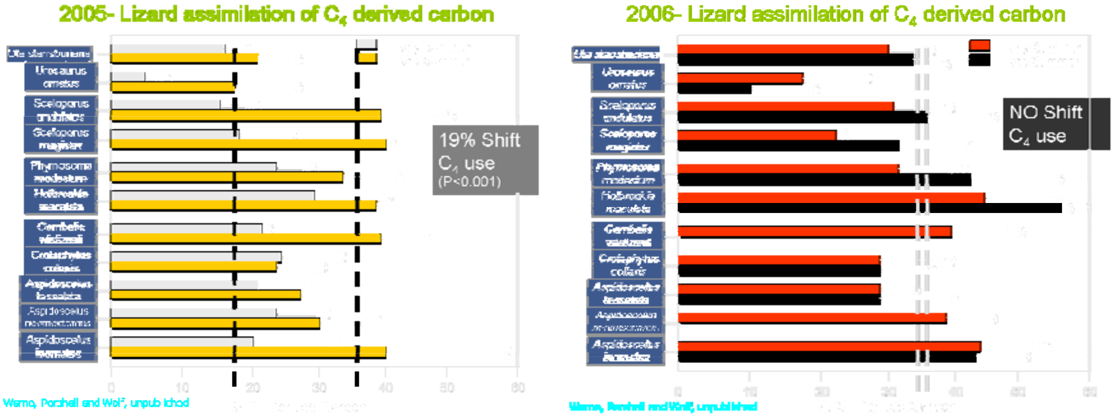


Figure 18. Isotopic analysis of seasonal dietary shifts in the lizard community during 2005 and 2006 at the Sevilleta LTER site, central New Mexico.

Seasonal and inter-annual dynamics of resource use by the small mammal community. This project links ongoing net primary productivity and small mammal studies by demonstrating how the populations interact in a food web and how the populations respond to seasonal variations in resource production of C_3 and C_4 plants in a vegetative transition zone. We also analyzed $\delta^{15}N$ to reveal the trophic postion of the animals. The results of the stable isotope analysis of rodent blood plasma indicated an increase in $\delta^{13}C$ from June to November in genera such as *Dipodomys, Onychomys and Peromyscus,* indicating an increasing proportion of C_4 plants in their diet as expected(Fig 19) . In contrast, the diet of *Reithrodontomys megalotis* actually decreased in the proportion of C_4 plants and *Perognathus flavus* showed little change in the composition of its diet. Analysis of $\delta^{15}N$ showed, as expected, that the omnivorous grasshopper mouse, *Onychomys arenicola*, was at the highest trophic position compared to the strictly herbivorous rodent species. The three species of *Dipodomys* were also separated by $\delta^{15}N$ values, which probably reflect the differences in their relative habitat and plant utilization.

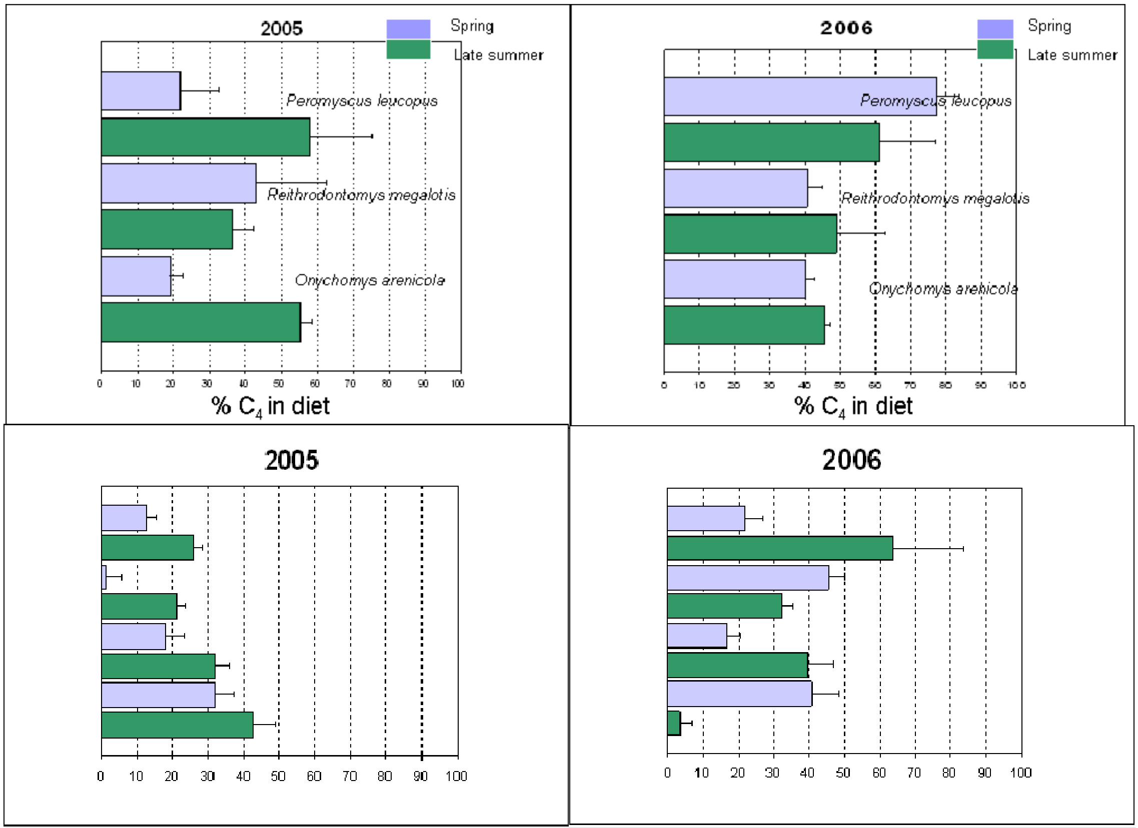


Figure 19. Isotopic analysis of seasonal dietary shifts in the small mammal community (top=Murids, bottom=Heteromyids) during 2005 and 2006 at the Sevilleta LTER site, central New Mexico.

Arthropod community resource use. We used real-time measurements of grasshopper "breath" $\delta^{13}C$ to estimate the use of C_3 versus C_4 plant resources during the fall of 2006. We determined the $\delta^{13}C$ of expired "breath" CO_2 of a grasshopper community from the Sevilleta LTER in central New Mexico using tunable diode laser (TDL) absorption spectroscopy (Fig 20). This approach allowed us to quantify the use of specific plant functional groups, as defined by photosynthetic pathway (C_3 or C_4), by grasshoppers of 15 species with body sizes ranging from 0.024g to 9.2 g. Measurements of breath $\delta^{13}C$ show that resource use by the grasshopper community is diverse and includes both generalist and specialist species. We found species that fed only on C_4 grasses, on a mix of C_3 and C_4 plants, and a specialist that fed only on C_3 plant resources. Because our grasshoppers were post-absorptive and thus metabolizing energy stores, breath isotope ratios were correlated closely ($R^2 = 0.86$) with values from isotopic analysis of body tissues. Plant physiology and thus primary production are tightly coupled to a variety of climate drivers, both in the short and long-term, therefore our approach provides researchers with a tool to directly link consumer nutritional ecology and population dynamics to climate dynamics and explore the influence of these drivers on entire food webs in real-time in the field. As part of this project, RUE’s Sophia Engel and Alyssa Corbett examined seasonal shifts in the use of C_3 and C_4 plant functional groups throughout the summer by sampling the community every two weeks and using TDL “breath” analyses.

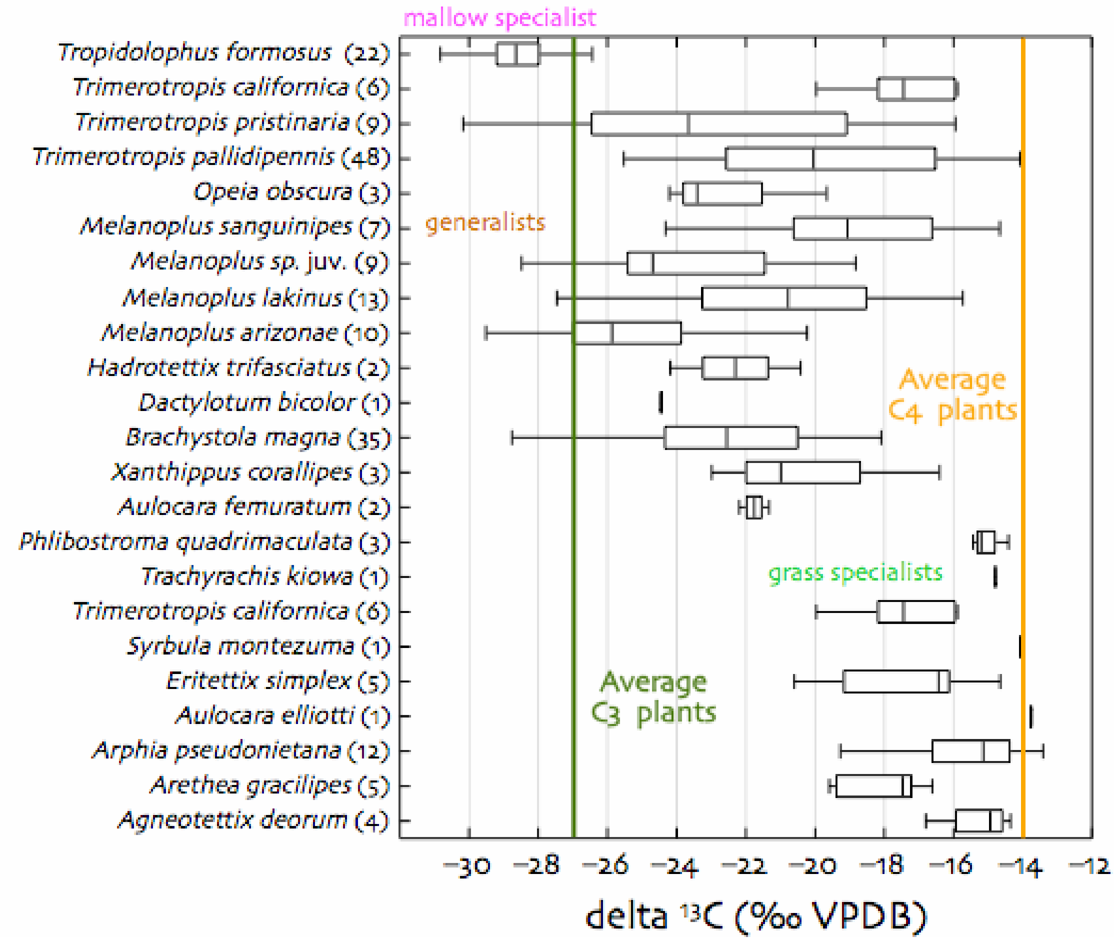


Figure 20. Tunable diode laser absorption spectroscopy was used to generate real-time estimates of grasshopper “breath” $\delta^{13}C$ to assess the use of C3 versus C4 plant resources during the fall of 2006.