RESEARCH ACTIVITIES

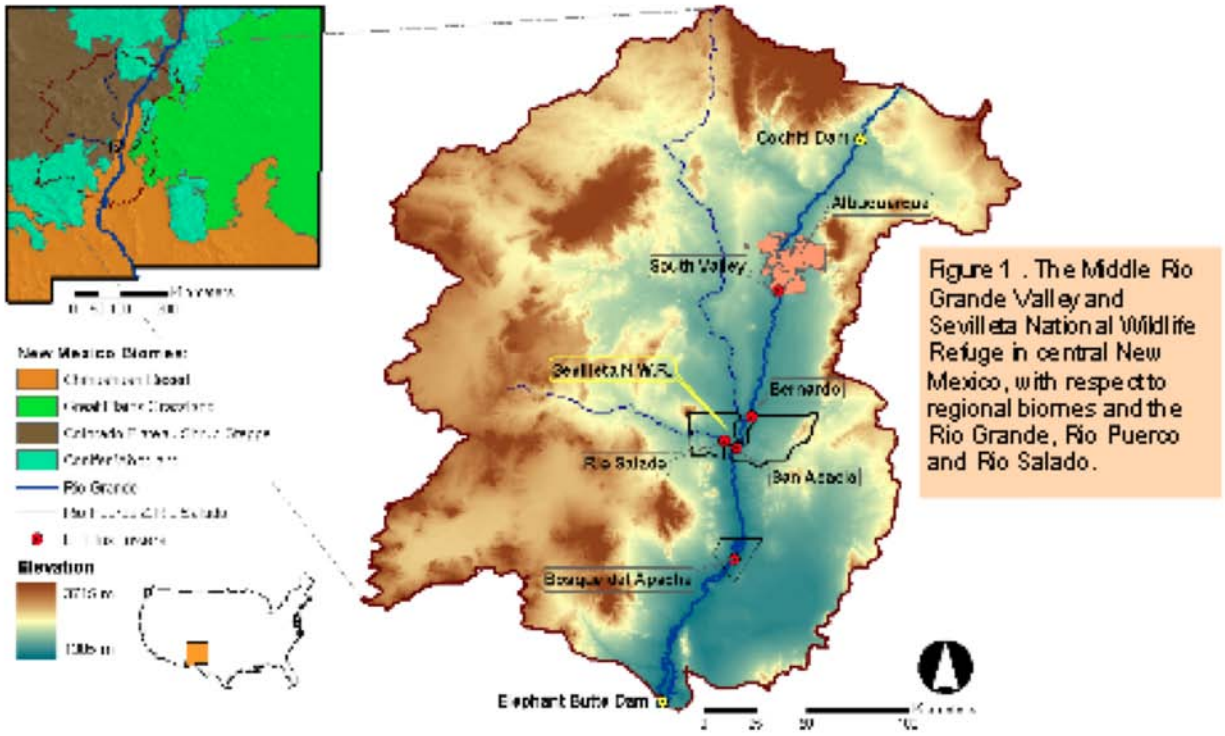


Figure 1 . The Middle Rio Grande Valley and Sevilleta National Wildlife Refuge in central New Mexico, with respect to regional biomes and the Rio Grande, Rio Puerco and Rio Salado.

The Sevilleta LTER Program 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.**

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.

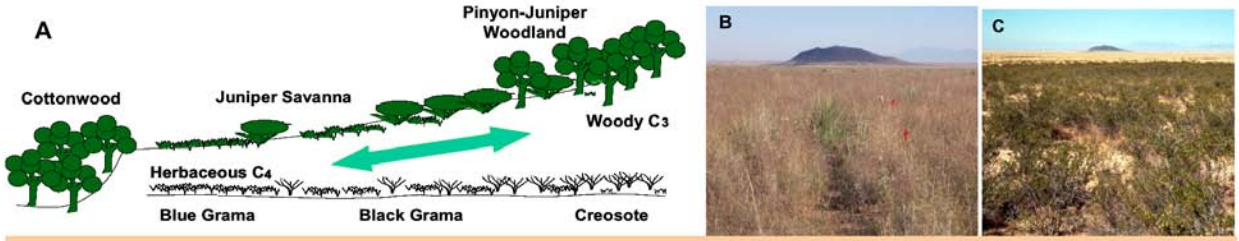


Figure 2. A) Schematic diagram of upland transitions at the Sevilleta National Wildlife Refuge. B) Black and blue grama grassland at Deep Well. C) Creosote dominates 4 km south.

The 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 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.

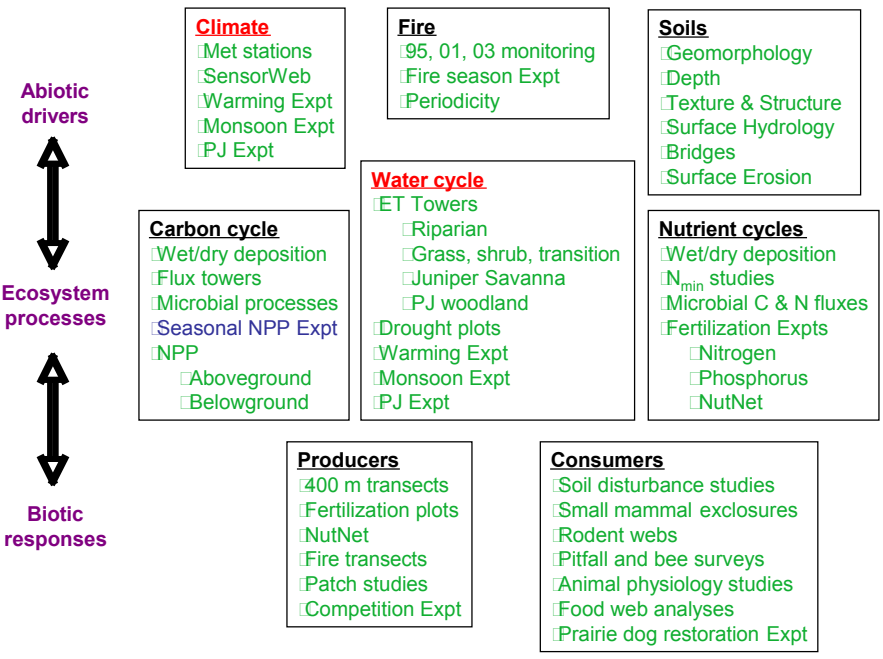


Figure 3. **Current** (GREEN) and **Planned** (BLUE) activities of the Sevilleta LTER Program, with a major focus on climate and water cycle interactions

This is the second 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.

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).

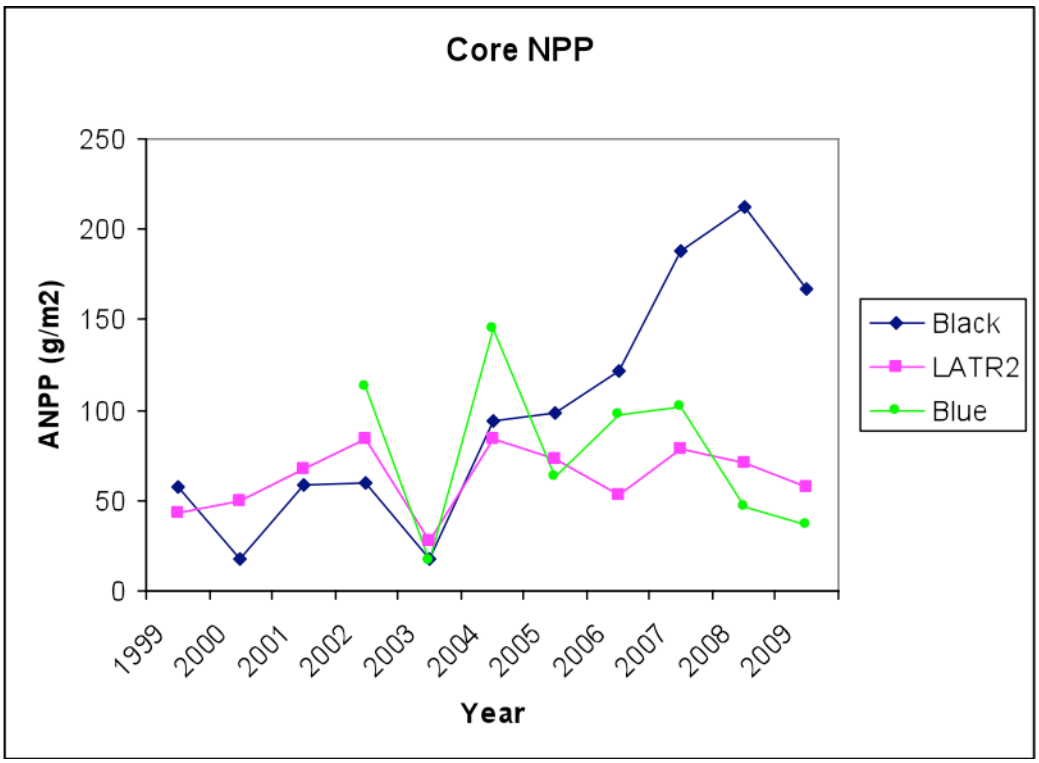
In 2009-2010 we continued all but two long-term data collection efforts described in our renewal proposal (LTER IV) and in the 2008-2009 annual report. These projects were discontinued because they were either destroyed by the 2009 ESA Wildfire that occurred on 4-5 August (small mammal exclosure study or SMES), or they were made redundant as a consequence of the wildfire (vegetation transects across the 1995 fire boundary near Deep Well). Therefore we are now able to focus some field crew time on one of our new emphases, the greatly expanded effort to restore Gunnison's prairie dogs at the Sevilleta as described later in this section (see also ANPP section below).

Above-ground Net Primary Production (ANPP). Sevilleta LTER has now been non-destructively sampling ANPP on replicated 1-meter quadrats at two core vegetation sites since 1999 (12 years). A third site dominated by blue grama was added in 2002. Four additional sites with mixtures of these core vegetation types were established in 2004 following a large prescribed burn in 2003. The lightning-caused fire on McKenzie Flats in August of 2009 resulted in the burning of a significant number of the original ANPP sites. Quadrats burned by the fire were not sampled in fall of 2009 because no growth was evident. An examination of the unburned plots variability indicated that a reduced number of quadrats were still sufficient to quantify ANPP for a given area, and the burned quadrats were not replaced.

Figure 4 shows the time series of ANPP for the 11 years of quadrat sampling from the core black grama and creosote bush sites on Mckenzie Flats as well as the more recently established core

blue grama site. Note that the black grama site has had a surge in production since 2006, and we are currently exploring the underlying causal mechanisms.

Figure 4. Patterns of aboveground net primary production (ANPP) since 1999 in black grama grassland, cresosote shrubland (LATR2) and blue grama grassland.



Following the 2003 prescribed fire, additional ANPP sites were established to study ANPP response, and some of these were disrupted by 2009 fire. At the core black grama control site, 18 of 40 ANPP quadrats were burned in 2009. We have added 8 new unburned permanent plots to this core area for ANPP sampling. Unfortunately the mixed blue/black grama control site established in 2003 was completely burned in 2009, so we shifted this control two km south to a comparable unburned area. And based on a variance analysis, the number of quadrats was reduced to 30 at this site. The mixed shrub plots at the transition between creosotebush and grassland were not affected by the 2009 burn. Because this is a very spatially diverse area no reduction in sampling intensity was considered and we continue to monitor ANPP in 40 permanent quadrats.

Pinyon Juniper Net Primary Production Study. We are now completed seven full years of sampling of aboveground herbaceous net primary production measurements stratified by slope positions of ridge, north, and south-facing, and valley bottom. The ridge and south-facing slopes tend show more production than north-facing slopes (Fig 5). This attributed to the more open tree canopies in ride and south-facing positions that allow for increased grass production. Whereas north-facing slopes are more shaded and with a different suite of species, particularly among forbs. Overall, production on all slopes is low when compared to the valley bottoms (12.8 g/m^2 versus 85 g/m^2) where grass cover can exceed 90% and trees are few and scattered.

We have initiated tree production studies including allometric tree and bole increment measurements that will allow us to compute needle and wood production based on diameter and height measurements along with actual branch stem leader growth (pinon). We have now installed dendrochromneter bands on over 70 trees and plan to add another 30 more along with litter sampling to capture long term trends in production of needles.

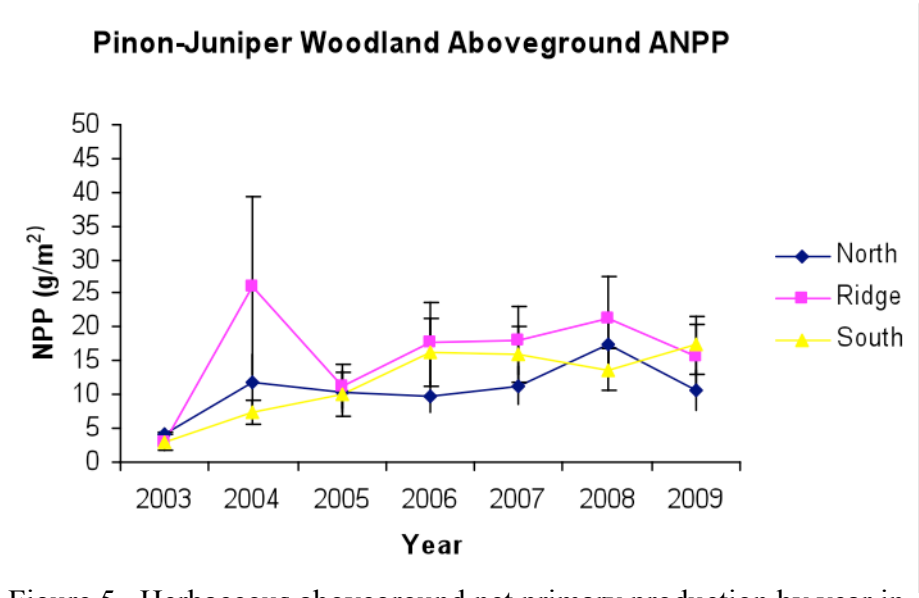


Figure 5. Herbaceous aboveground net primary production by year in piñon-juniper woodlands, stratified by slope position.

Desert Grassland and Shrubland Fire Studies (Burn X and NPP). We have now completed six years of post fire measurements on McKenzie Flats following an experimental burn conducted in 2003 (Fig 6). We used a random blocks design that was previously installed for a 1993 experimental burn (Antelope Exclosure Experiment). This allowed us to not only evaluate fire effects of the 2003 fire but also detect legacy effects of the 1993 fire. Results indicate that black grama (*Bouteloua eriopoda*), the dominant grass, had significant mortality possibly a result of conducting the fire under drought conditions. While standing biomass is approaching pre-fire conditions, recovery of black grama has been at slower pace than expected. Mortality among the Creosote bush (*Larrea tridentata*), the dominant shrub, was less than 10% with most individuals

2003 **2008**

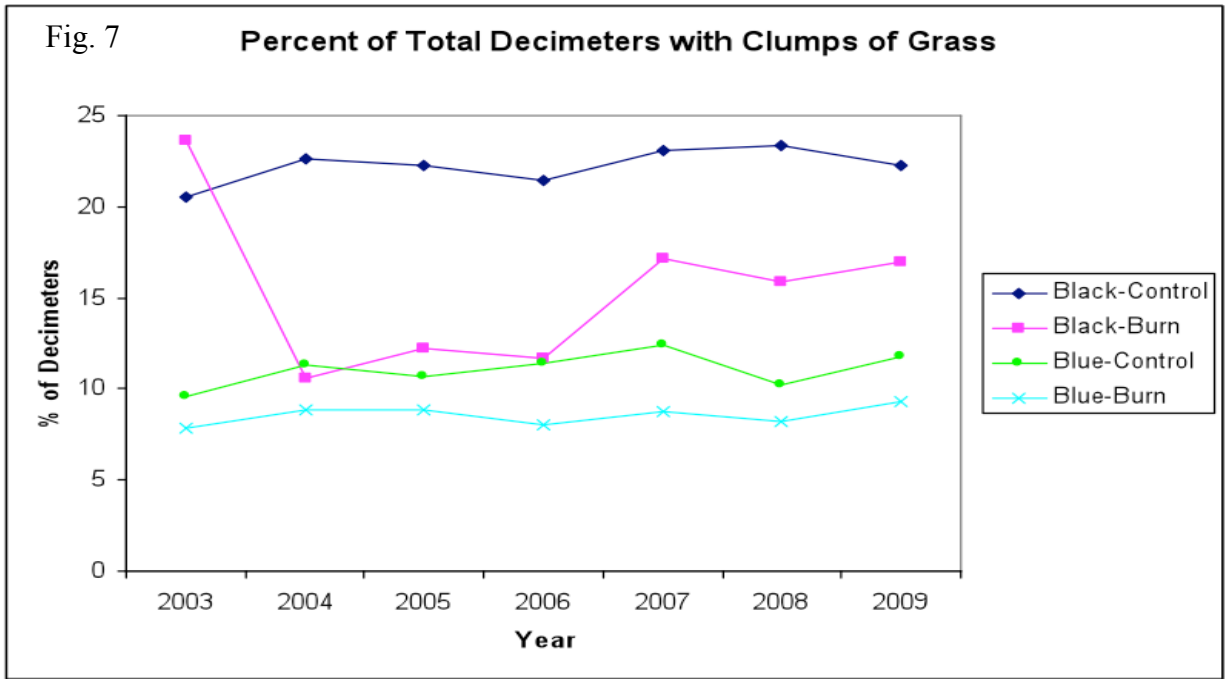
Figure 6. Example of regrowth of desert grasslands following the experimental burn of 2003.

re-sprouting from root crowns.

There has now been 7 years since the 2003 prescribed burn. Starting in 2004 the BurnX plots have been sampled for 1) species coverage and composition in the spring and fall, 2) grass recovery through time using annual measure of grass species, and 3) fuel load change through time.

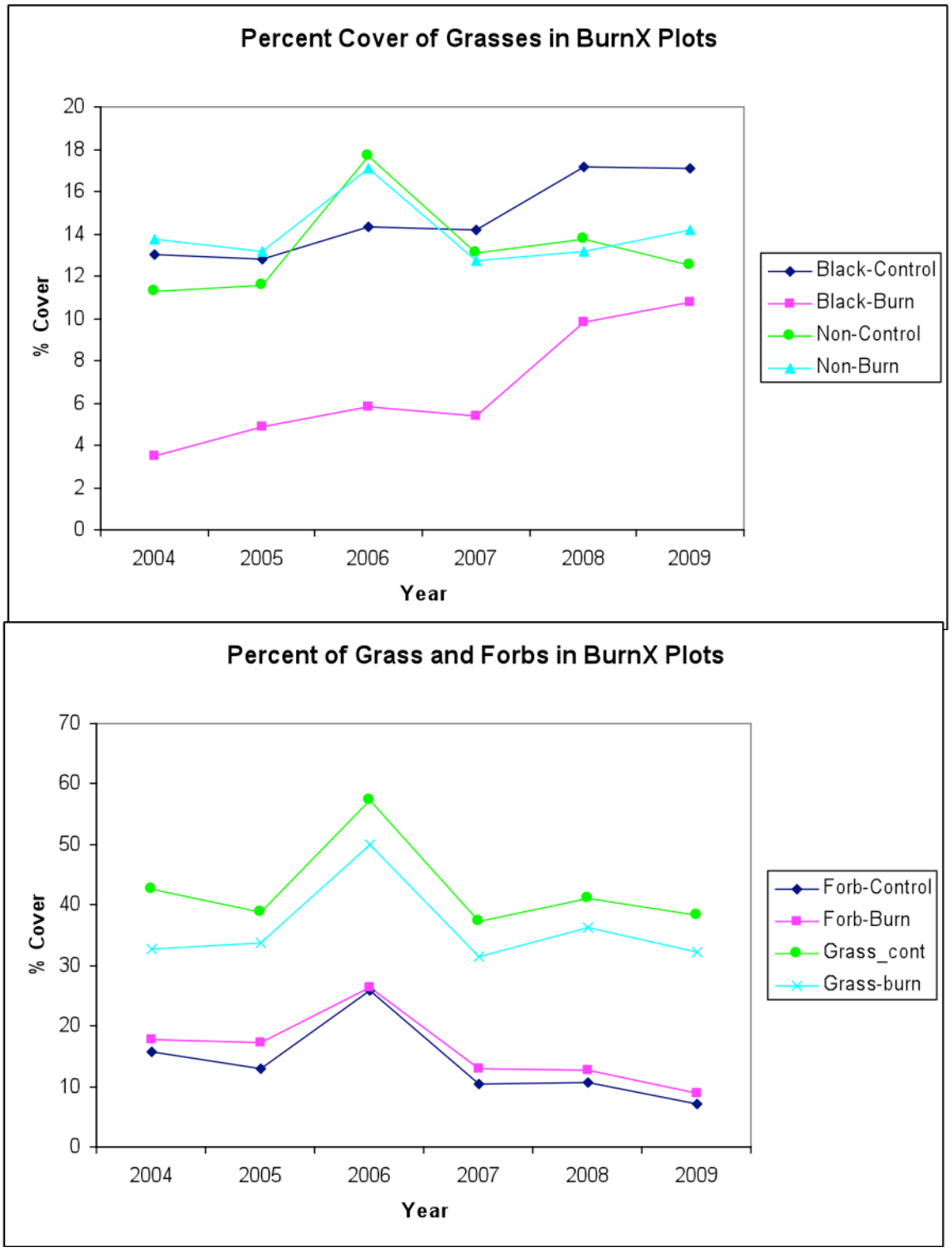
Black grama was significantly impacted by the 2003 fire, and annual repeated measures of grass recovery indicate that it has regained about 50% of it abundance based on occupancy of square decimeters in a 3x3 decimeter sampling grid. (Fig 7). The other dominant grass, blue grama, showed no significant reduction in density as a result of the fire (this was the case for all of the other associated grasses as well).

Fig. 7



Annual spring and fall measurement of species cover using ¼ m^2 quadrats on the BurnX plots have also been measured since 2004. These also show the slow recovery of black grama following the fire while the total cover of the other grasses was actually higher in the burn area than in the unburned area. Figure 8 shows the annual trends of the grasses and the forbs following the fire.

Figure 8. Percent cover of dominant grasses (A) and all grasses and forbs following the 2003 management burn at the Sevilleta.



Other continuing research activities include (1) meteorological monitoring at our seven comprehensive met stations across the Sevilleta, (2) measurment of Belowground NPP at 4 locations, and long-term vegetation and small mammal dynamics, (3) measurements in our multiple factor global change experiment that manipulates nighttime temperature, N-deposition, and winter rainfall frequency, (4) measurements in our summer monsoon rainfall manipulation experiment, (5) measurements in our rainfall manipulation experiment in piñon-juniper woodlands, (6) use of stable isotopes to understand food web dynamics, with specific focus on grasshoppers and box turtles, (7) monitoring of CO2 and H2O fluxes in riparian, grassland, shrubland, grass-shrub transition zone, piñon-juniper woodland, juniper savanna and mixed conifer forest, and (8) NutNet plots and seasonal fire experiment. Also in 2009-2010, a number of Sevilleta LTER graduate students and REU students 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."

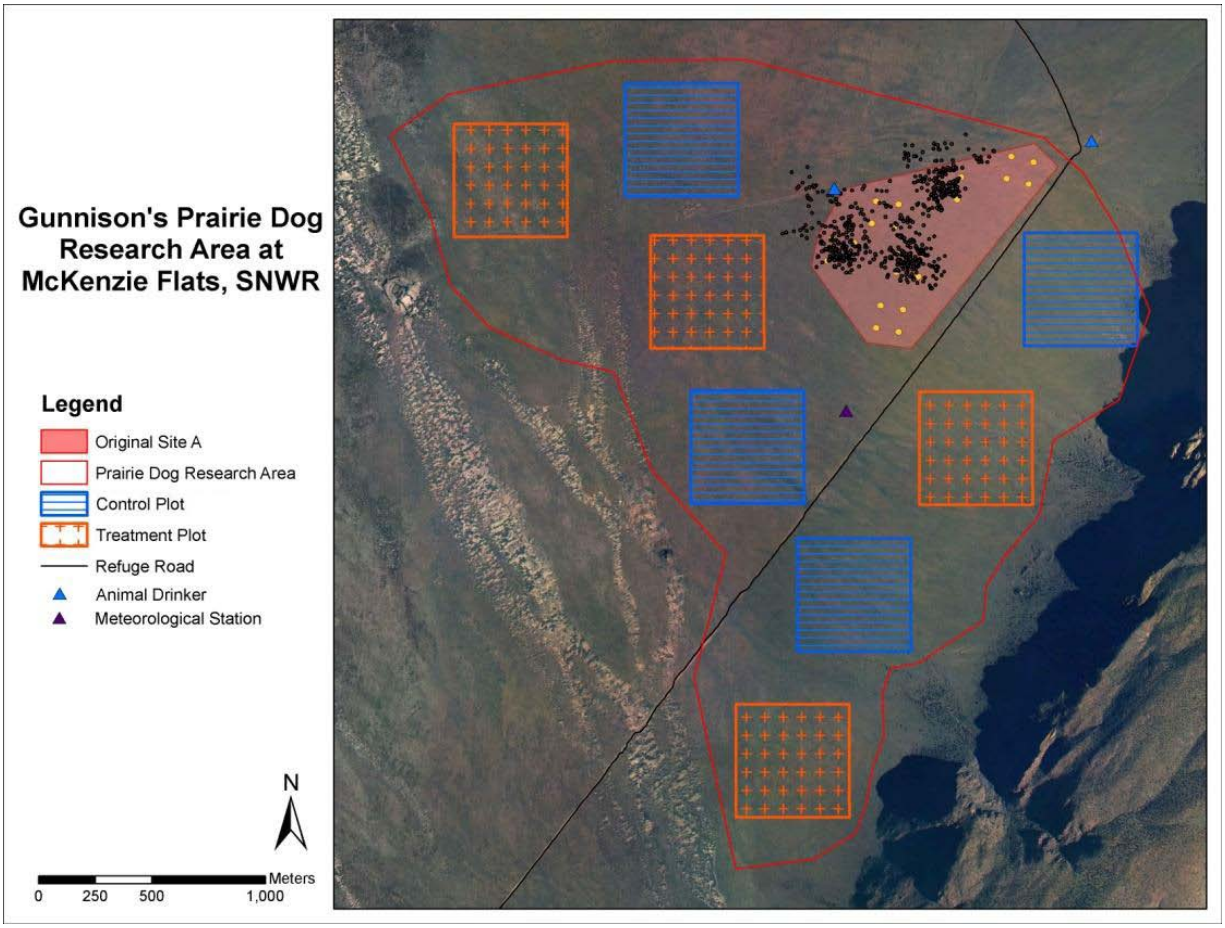
Meteorological Network. The Sevilleta now has 22 years of meteorological data from as many as 10 stations across the Sevilleta. This past year saw refurbishing and replacement of certain sensors acquired through a supplemental grant. Acquisition of a number of tipping bucket rain gauges fitted with HOBO dataloggers allowed establishment of seven more precipitation-measuring systems across the refuge. This allows better measurement of the spatially and temporally variable precipitation common on the Sevilleta, particularly during the monsoon portion of the year. In addition, Natural Resources Conservation Service (NRCS) installed a Soil Climate Analysis Network (SCAN) station adjacent to one of our existing met stations in the spring of 2010. While this station duplicates several of the standard meteorological variables, it will provide a more complete set of temperature and soil moisture readings than we have at any of other met stations.

Nutrient Input Quantification. As with the meteorological network, the nutrient input collection system continues after 22 years in place. In 2009, it was decided to reduce the size of the collection funnel from 10 ½" in diameter to 7 5/8". This was primarily a cost cutting measure as costs of funnels have risen drastically over recent years. However, it does have the added advantage that it reduces the chances that the collection bottles will overflow with large storms during the summer.

Prairie dog colony restoration experiment. During a workshop at the Sevilleta Field Station in February 2010, interested scientists and Sevilleta Fish and Wildlife Service (USFWS) employees agreed to combine the prairie dog restoration effort with studying plague, predator, and climate interactions following restoration of prairie dog populations at the SEV. In addition to the restoration effort at the SEV, another site at Vermejo Ranch in Northeastern New Mexico will serve as a replicate where bison co-occur with prairie dogs. The experimental design for this expansion study is a paired plot design with four control plots and four treatment plots where prairie dogs will be released. The plots are 16 hectares and are separated by at least 250 m (Fig 9). At Vermejo Ranch, one treatment and one control plot will be established. The Sevilleta LTER hosted a workshop to develop a research plan as well as determine funding options. Initial questions from this workshop include: 1) What is the reservoir for plague populations? 2) Where does the reservoir go when it is not present in the community? 3) What is the size of the reservoir

when it is present in the community? 4) How do prairie dogs become infected over time? 5) What are the optimal climatic conditions (temperature and precipitation) for large plague and flea populations? 6) What are the temporal patterns of climate? 7) How do these climatic patterns relate to consumer population sizes? 8) How do consumer population sizes relate to plague and flea population sizes? The scientists leading this expanded study are Mike Antolin from CSU who specializes in plague dynamics, Gary Roemer from NMSU whose research focuses on consumer populations, and Ana Davidson from UNM who is an expert regarding prairie dog research. They will serve as principal investigators on an Emerging Infectious Diseases (EID) grant proposal to be submitted in December 2010.

Establishment of new study plots. Mike Friggens and Terri Koontz (SEV LTER), and Jon Erz (SEV FWS) established four of eight study plots along the base of the Los Pinos Mountains in winter/spring 2010. Prior to the construction of the artificial burrows, the area was surveyed to verify that the landscape was proper habitat for a successful prairie dog restoration. Terri Koontz with the assistance of two volunteers pounded rebar and placed marked pvc for 81 vegetation points in a 9 x 9 grid in each restoration and control plot. Jon Erz led the USFWS team in the construction of the artificial burrows. Seventy-two burrows in a bull's eye pattern were located in each plot. This pattern is intended to facilitate prairie dogs to move to the center of plots rather than expanding into adjacent control plots. All four treatment plots now have artificial burrows (Fig 10) and are ready to receive prairie dogs. In summer 2010, approximately 300



Gunnison's prairie dogs were introduced into a subset of the treatment plots. These populations were surveyed and monitored during summer 2010 by SEV Staff, graduate students and summer REU students. A single release consisted of a maximum of 100 prairie dogs per relocation effort. Sex, weight, origin and social dynamics of each prairie dog were determined prior to release. Additionally, prairie dogs were ear tagged and blood samples were taken. In addition, this past spring we determined where active prairie dog mounds are located on the original treatment plots established in 2005.

The protocol for vegetation measurements for the existing and the expanded study can be found at the following web address:

Figure 9 (above) and 10 (left). GIS maps of the study design showing the layout of the new colonies and control plots. The shaded area is the original prairie dog introduction in 2005 and black dots are existing mounds. Photo showing an artificial burrow used for introducing individuals or family units, and a vegetation plot marker (inset).

http://tierra.unm.edu/wikis/im/index.php/Prairie_Dog_Reintroduction_Study

Wildfire update. As reported in our 2009 annual report, a large wildfire occurred at the Sevilleta on 4-5 August. This fire was caused by multiple dry lightening strikes, and aided by 48.3 kph winds and 38^{o}C temperatures, which combined to create a wildfire that burned nearly 3200 ha of desert grassland at the Sevilleta. This fire burned through several of our major climate change experiments including our monsoon rainfall manipulation experiment (MRME), annual drought and rainfall augmentation plots, and our nighttime warming, winter rain, N deposition experiment ("warming"), as well as our grassland flux tower site, our grassland small mammal exclosure study (SMES), and our NutNet plots. Most of the fire damage was confined to shelter infrastructure at warming and nearly all cables to soil moisture, temperature and CO_2 probes were burned. Various pieces of small equipment (radios, cables, batteries, boxes) were destroyed at most sites. A 20 passive rainout shelters were destroyed along with a water tank.

The nighttime warming experiment is functioning again. Warming shelters were completely reengineered to improve reliability. Soil moisture sensors have been purchased, but we await soil temperature, air temperature, and CO2 sensors. Nevertheless, all treatments are being imposed again. MRME has been completely rebuilt, sensors installed and all data are being recorded and transmitted via our wireless cloud. A new flux tower was installed in unburned grassland across the road from the burned area so we can monitor grassland NEE during postfire succession. This tower was relocated from an alfalfa field south of the Sevilleta. Soil moister and CO2 sensors still need to be installed at some tower sites. Passive rainout shelters were rebuilt over the winter

and that experiment has gone swimmingly this summer. Infrastructure repairs and replacement parts for warming, drought, MRME and flux towers, plus labor costs will be covered by UNM insurance. We recently learned that the State of New Mexico would issue an insurance claim check for $120,540.36. These funds will be used to purchase and re-instrument experiments and pay for labor costs. Postfire recovery of nutrient availability, vegetation composition, ANPP, and consumer population dynamics occurred in 2010 as part of our normal LTER sampling protocols. In addition on 26 August 2009, we submitted a RAPID proposal requesting $150,055 to address some key hypotheses based on pre-fire background data related to fire effects on (1) plant-microbial coupling, (2) carbon fluxes during postfire succession, and (3) seasonal and interannual dynamics of consumer-ANPP linkages. As of 23 August 2010 the money had not hit campus, but the proposal was recommended for funding.

PUBLICATIONS AND GRANTS

In calendar year 2010, Sevilleta LTER scientists have published one book chapter and 18 peer reviewed journal articles thus far with 12 manuscripts currently in press and several more manuscripts in review. In addition, Sevilleta scientists were actively involved in the Ecotrends project and are co-authors on numerous chapters, as well as the book itself.

The following grants were awarded in 2010:

2010 RAPID: Ecosystem reconstruction under climate change conditions following fire. NSF - $150,055. (6/1/10-12/31/11). PI: Scott Collins, CoPIs: Marcy Litvak, Will Pockman, Bob Sinsabaugh, Blair Wolf.

2010 ULTRA-Ex: Collaborative research: Land and Water Use Decision-Making and Ecosystem Services along a Southwestern Socio-Ecological Gradient. NSF - $120,000. (9/1/10-8/31/12). PI: Scott Collins, CoPIs: Kristine Grimsrud, Cliff Dahm and Kristin Vanderbilt.

2010 Student research and teaching improvements at the Sevilleta Field Station. NSF - $95,290. (10/1/09-9/30/10). PI: Don Natvig, CoPI: Scott Collins.

2010 Assessing the role of bark beetle activity in drought induced mortality of pinon pine. LANL/DoE - $185,939. (9/1/10-8/30/13). PI: Will Pockman.

INFORMATION MANAGEMENT

Information Management. The Sevilleta has long sought a relational database system for capturing, managing and accessing metadata that will also produce EML. A solution, proposed by Inigo San Gil and Marshall White of LNO, is to use the Drupal content management system to create a website with an integrated EML editor. In 2010, Sevilleta IM Vanderbilt collaborated with Inigo and Marshall to make such a website a reality. Migrating the “old” Sevilleta website in to Drupal has been a complex process and is ongoing.

The big advance on this project in 2010 was parsing all Sevilleta EML into the MySQL backend of Drupal. Now that the metadata are in a relational database, they can be exposed in many different ways via Drupal "views", a query interface into MySQL. One view writes metadata out in a human-readable form, for instance, while another view allows users to search for Sevilleta datasets by owner, keyword, or LTER research theme.

The Drupal website represents a big step toward Sevilleta's goal of having an information management framework where all data products are integrated. The website is also the site's metadata management system, and views have been created for entering new metadata, updating existing metadata, and downloading metadata as well as data files. Drupal preserves all versions of the metadata, another desirable feature, and supports the use of defined sets of keywords to link content. Sevilleta will adopt the LTER controlled vocabulary defined by the IM committee to improve discoverability of Sevilleta data on the site website and also across sites via the NIS.

Outreach. IM Vanderbilt served as the chair of the ILTER Information Management committee and is presently the acting co-chair of the LTER International Committee. She is also a member of NISAC.

SEV received funds from an international supplement to the SEV grant to support information managers and LTER graduate students to participate in a workshop in Malaysia. The workshop focused on using EML-oriented tools to analyze data collected on large forested plots that are part of the Center for Tropical Forest Science (CTFS) network and also the ILTER. This workshop is the second in a series, and was entitled "The Second Analytical Workshop on Dynamic Plot Database Application and Tool Design by Forest Research Institute Malaysia (FRIM)". IM Vanderbilt recruited two graduate students (Matthew Vadeboncoeur (HBR) and Jennifer Holm (LUQ)) to attend the workshop. Jennifer and Matt also spent a week with Taiwan Ecological Research Network IM guru Chau-Chin Lin in Taipei before traveling to Malaysia. IMs John Porter (VCR), Eda Melendez-Colom (LUQ), Don Henshaw (AND) and Vanderbilt also attended the workshop, along with scientists from Viet Nam, Taiwan, and Malaysia.

The purpose of the workshop was to investigate tools to support data synthesis and integration, have the scientists use the tools to determine if they might be broadly applicable to synthesis research, and also to analyze data for publication. During the workshop, workflows were developed using Kepler that formatted the CTFS datasets for analysis and then piped them through scripts from the Biodiversity R module. The analyses begun in Malaysia will continue into Fall 2010 via workgroups spearheaded by the two graduate students: Matt leads the spatial analysis team, and Jennifer leads the biodiversity team. Products of this workshop are expected to be an informatics paper describing the use of Kepler, Metacat and EML as aids to data integration, a paper describing patterns of tree biodiversity relative to site characteristics from CTFS sites in Panama, Puerto Rico, Taiwan, Japan, and Malaysia, and a paper describing spatial patterns of tree species across these same sites.

Sevilleta updates meteorology data in the cross-site ClimDB database on a weekly basis. Cross-site personnel, site, and publication databases are updated at least twice a year. Sevilleta EML is harvested once a week and resides in the LNO Metacat.

EDUCATION, OUTREACH, CROSS-SITE AND NETWORK LEVEL ACTIVITIES

The SEV LTER continues its activity involvement in education and outreach through BEMP (our Schoolyard LTER), the SNWR, E-MRGE (our GK-12 program), our REU Sites 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.

Schoolyard LTER. The Bosque Ecosystem Monitoring Program (BEMP) is the schoolyard portion of the Sevilleta LTER. Last year BEMP involved 5,156 community members (students, teachers, etc.) in science-related outreach activities. Of these people, 2,116 were actually in the field collecting long-term data about ecosystem variables and the ecological drivers of flood, fire, river flow, climate and management. Experiences of these community members supports science education reform efforts and helps increase each person's understanding and appreciation of science in general and the Rio Grande riparian ecosystem in particular. BEMP findings derived from K-12 student-gathered data are used by government agencies to inform multi-million dollar river and riparian management decisions. In addition to receiving funding from the sLTER program, BEMP is funded by federal and state sources as well as private foundations.

Schoolyard LTER funding helped pay for bus money, teacher stipends, guest lecturers and outreach support. BEMP used sLTER money to pay for K-12 classes to come to field sites, collect scientific data and learn about ecological research. After students collected data in the field, BEMP staff conducted classroom outreach, such as leaf litter identification, sorting and weighing, and graphing of data. In addition, guest lecturers were paid to present different view points on the current and historic water issues of the Middle Rio Grande to the 408/508 BEMP biology class at the University of New Mexico. Finally, two high school students were employed part-time during the summer of 2010. Attached is a photo of one student collecting groundwater chemistry data in the field.

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). In November 2006, Sevilleta hosted a national SEEDS field trip and career forum. In September 2008 the Sevilleta LTER hosted a research visit and career forum for the SEEDS chapters at NAU and UTEP. In addition, in February 2009, the Sevilleta LTER hosted the annual

SEEDS Leadership Conference and we are planning another regional SEEDS workshop to be held at the Sevilleta in December 2010.

Sevilleta REU Program. We have just completed the third year of our first REU Sites Award. This award supported 32 undergraduate students from a total of 29 institutions. Only 2 of the 32 students were from UNM. Demographic statistics on participants and applicants are given in Table 1 and 2, respectively. Overall, 68% of the participants were female, 53% had completed either their freshman or sophomore year, and 55% of the students were members of underrepresented groups (16 out of 22 in years 2 and 3). Of these participants, 19 are still undergraduates, 9 are in or entering graduate school, and 5 are doing other things. We also used LTER supplement funds to include two REU Art students in collaboration with Catherine Harris, Assistant Professor of Fine Arts and facultymember in the Arts in Ecology Program at UNM.

Art and Ecology teaches students about engaged, ecological and experimental art. Building from Robert Smithson, Agnes Denes, Joseph Beuys and other early practitioners of Land Art and ecological art, the practices can be performance art, sculptural, planning documents, hand crafting, audio, visual pieces or other media. As a new area in the Department of Art and Art History, Art and Ecology creates a signature discipline for the University of New Mexico. Building from the successful D.H. Lawrence Summer Arts Projects, Southwest Geographic Arts and Land Arts of the American West courses, the Art and Ecology area provides a full curriculum based on the environments and communities of the southwest. The Art and Ecology Program guides students through collaborations (both interdisciplinary and cross-cultural) and the mechanisms of public process.

During 2010 we were able to fund two Art in Ecology students using a supplement to our LTER award. The response from the REU science students was both curiosity and inclusion. Art students met the same requirements as the science students in terms of expectations and products (field notebooks, leading journal club discussions, turning in graphs, helping with field and lab research, and introducing their art pieces at the end of the summer in our annual REU symposium). In addition, all ecology REU students participated in art projects over the summer led by the Art REUs, including photography with handmade pin-hole cameras and papermaking from natural materials.


Native Alaskan and 2010 Art REU student Melissa Shaganoff with her paper sculpture

NETWORK-LEVEL INTERACTIONS

At the Network level and beyond, SEV LTER scientists continue to be involved in a variety of cross-site and international projects. The Sevilleta Information Manager (Vanderbilt) has been active in Network level activities. She has served on the Network Information System Advisory Committee (NISAC) since 2007. She has been the Chair of the International LTER Information Management Committee since 2006, and has organized and participated in ILTER IM Workshops in China, Korea, and Taiwan. She is likely to be the next Chair of the ILTER. She is collaborating with other US Information Managers and LTER Network Office

personnel to create a series of training videos for new Information Managers, the first of which can be seen at http://www.ilternet.edu/training/training-online-resources-collection.

PI Collins represents the SEV on the LTER Science Council, and prior to that was an elected member of the LTER Executive Committee. Collins accidently got himself elected to be the next Chair of the LTER Science Council and Executive Board. Collins served as PI on the NSF-funded LTER Planning Grant that over a three year period developed an ambitious funding initiative and research agenda for the LTER Network (the LTER Decadal Plan) to increase network-level research coordination, cooperation, collaboration and capability. Two papers resulted from that effort (Smith et al. 2010 Ecology and Collins et al. 2011 Frontiers in Ecology and the Environment). Finally, Sevilleta researchers are involved in numerous synthesis efforts and networks, such as Chapman conferences, PrecipNet, DireNet, TraitNet, and PDTNet (Clark et al. 2007, Cleland et al. 2008, Collins et al. 2008), and other cross site projects on compensatory dynamics (Houlahan et al. 2007), shrub encroachment (Knapp et al. 2008), and the international Nutrient Network (NutNet) to name a few. Sevilleta LTER continues to participate in the National Phenology Network.

SOCIAL-ECOLOGICAL RESEARCH

The Sevilleta LTER Program has not had a social-ecological research component to date, but is currently expanding in that realm via three collaborative efforts:

1. The Sevilleta LTER is part of a five site social sciences funding collaboration (JOR, CAP, SGS, KNZ and SEV), "**Socio-ecological gradients and land use fragmentation: a cross-site comparative analysis."** The objective of this cross-site collaboration is to answer the following research question: *Is the degree of land fragmentation a function of magnitude and/or rate of change of water availability, population growth, and urbanization?* At each site we will investigate the role of these drivers, in addition to other proximate drivers, in the process of land fragmentation. This effort has produced one publication thus far (York et al. 2011 Urban Ecosystems).

2. Our 2009 supplement included a request for a related, site based project to be conducted by Mike Agar, Professor Emeritus, University of Maryland, currently a resident of Santa Fe, who is an expert in agent-based modeling. In this research activity Professor Agar reviewed current literature in ecological anthropology with emphases on the "new ecology," historical ecology, and political ecology. He coordinated this background work with relevant work being conducted as part of the five site cross-site project. The problem focus was land fragmentation, in part because of the ongoing supplement, mentioned above. The focal community for this supplement was Albuquerque from about 1950 to 1970. Results of this work have been presented at the 2009 LTER All Scientists Meeting and at the AAAS annual meetings in San Diego in February 2010.

3. The Sevilleta LTER Program was notified that its collaborative ULTRA-ex (Urban Long-Term Research Areas) planning proposal with two other LTER Sites, JOR and CAP will be funded in late 2010. Understanding the socio-ecological dynamics of urban areas is limited by inadequate knowledge of the type, quantity, and quality of ecosystem services delivered in metropolitan regions and how actors incorporate considerations of ecosystem services *and*

household preferences into management decisions. The principal question of our proposed research is to understand how decision makers respond to and make land and water use decisions based on measured and preferred ecosystem services at the wildland-rural-urban fringe in the arid Southwest. If funded, we will employ a comparative, gradient approach using the metropolitan areas of Las Cruces and Albuquerque, NM and Phoenix, AZ as case studies. Primary methods include stakeholder forums and focus groups with decision makers, hedonic modeling of houses prices and ecosystem service amenities, and biophysical modeling of ecosystem services.

Together these activities illustrate how the Sevilleta LTER and its scientists are committed to (1) conducting cutting edge research, (2) achieving the goals of the LTER Network, (3) expanding the spatial, temporal and conceptual bases of our research through the addition of new participants, and (4) furthering our education, outreach and training efforts at K-12, undergraduate, graduate, postgraduate, and informal levels.

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. In addition to some of the results presented under "Activities", below we present highlights of some of the key results from Sevilleta research produced or published in late 2009 through August 2010.

General synthesis publications. Using data from terrestrial soils and freshwater sediments, Sinsabaugh et al. (2009 *Nature*) showed that heterotrophic microbial communities share a common functional stoichiometry in relation to organic nutrient acquisition. As shown Figure 1, organic nitrogen acquisition and organic phosphorous acquisition both show a 1:1 ratio with organ carbon acquisition. Essentially, microbial biomass is the basis for all detrital food webs and the elemental stoichiometry of microbes directly impacts nutrient cycling processes. Based on the activities of four extracellular enzymes associated with hydrolysis of the principle sources of C, N and P from detritus it appears that stoichiometry reflects the equilibria between elemental composition of microbial biomass and detritus, and the efficiencies of microbial nutrient uptake and growth. These enzymatic activities link stoichiometric and metabolic theories, and provide a measure of the threshold at which control of community metabolism shifts from nutrient to energy flow.

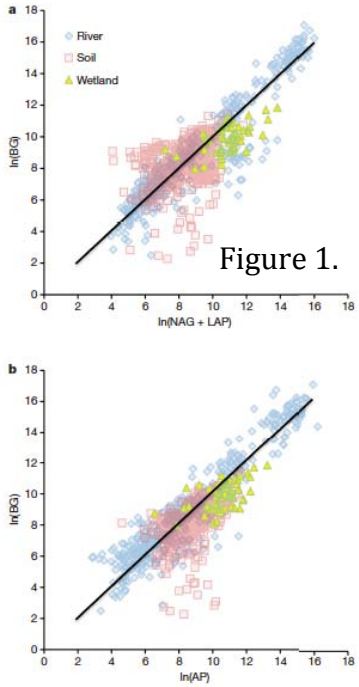


Figure 1.

In another general synthesis, Smith et al. (2009 *Ecology*) developed a multi-scale model (Figure 2) for understanding comparative ecosystem dynamics under global environmental change. Ecosystem drivers can be classified generally as *presses*, which are chronic yet may change in strength, or *pulses*, which are relatively discrete events that vary in frequency, intensity and magnitude. Current ecological theory emphasizes the important of pulse disturbances as key drivers of change. However, the chronic influence of presses from elevated CO2,

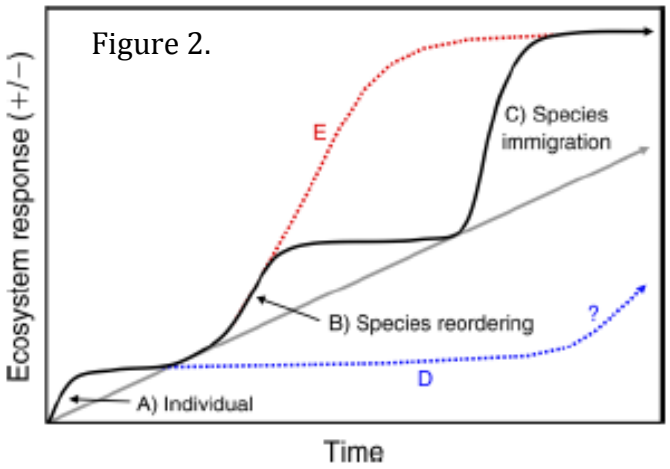


Figure 2.

increasing temperature, elevated N deposition, sea level rise, etc., are sufficient to alter community dynamics in the absence of disturbance. A hierarchy of responses may occur including ecological plasticity, genotypic change, population change, community reordering and finally, immigration and extinction dynamics. In combination, increasing (or decreasing) presses and new or altered pulse regimes may interact lead to rapid transitions and alternative stable states in some ecosystems. Because this is a comparative framework, information is gained primarily through cross-site and collaborative approaches to understanding ecosystem dynamics in response to global environmental change.

Romme et al. (2009 *Rangeland Ecology and Management*, including SEV Co-PI Este Muldavin) published an interesting invited synthesis paper in Rangeland Ecology and Management on past and present disturbance regimes, stand structure and landscape scale dynamics of piñon-juniper woodlands. The goal of this paper was to summarize information for land managers and to stimulate further research on the dynamics of this widespread forest ecosystem.

Species responses to climate variability.
Woody plant encroachment is affecting vegetation composition in arid grasslands worldwide and has been associated with a number of environmental drivers and feedbacks. It has been argued that the relatively abrupt character (both in space and in time) of grassland-to-shrubland transitions observed in many drylands around the world might result from positive feedbacks in the underlying ecosystem dynamics. For example, Mederios and Pockman (2010 *Journal of Arid Environments*) recently found that small (younger?) creosote plants are wiser than larger (older) plants. That is, smaller plants had higher growth rates but maintained larger safety margins from transpiration rates under water stress that could lead to hydraulic failure and death. Building on that information, D'Odorico et al. (in review, *Ecosystems*) showed that in the Chihuahuan Desert climate feedbacks could emerge from interactions between vegetation and microclimate conditions. Creosote establishment modifies surface energy fluxes, causing an increase in nighttime air temperature, particularly during wintertime. The resulting change in winter air temperature regime is important because the northern limit of the dominant shrub at the site, *Larrea tridentata*, presently occurs where minimum temperatures are sufficiently low to be a potential source of mortality. Using freezing responses from published studies in combination with the observed temperature record at the site, D'Odorico *et al*. predict that a small warming can yield meaningful changes in plant function and survival (Figure 3). Moreover, they also suggest that the effect of the change in air temperature on vegetation depends on whether plants experience drought during winter. Thus, in the Chihuahuan Desert region a positive feedback exists between shrub establishment and changes in microclimate conditions, with implications for the response of this ecosystem to regional changes in temperature and precipitation.

Also related to climate and climate change, Collins et al. (2010 *Journal of Arid Environments*) reported that nighttime warming and low level N fertilization led to rapid responses among dominant species at the Sevilleta. Specifically, blue grama increased with small additions of nitrogen but not under nighttime warming, black grama increased

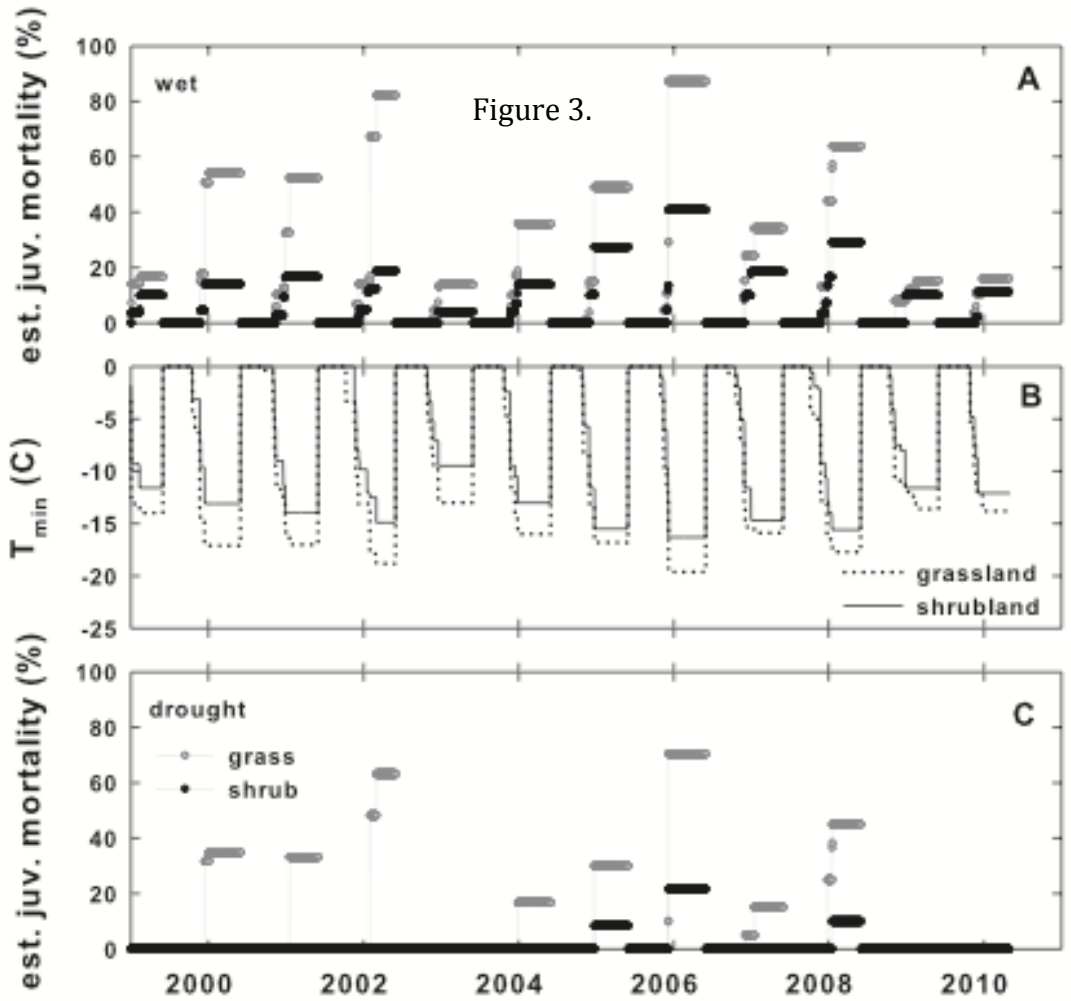


Figure 3.

production under nighttime warming but did not respond to N, and broom snakeweed, a C3 shrub, also increased under nighttime warming. These initial results changed in the third year of this long-term multifactor manipulative experiment. By year 3 black grama and blue grama were both responding to nitrogen additions, yet blue grama still showed little response to nighttime warming. The increase in the grasses negatively affected broom snakeweed in that growth of this shrub declined over the growing season.

Moving from grass-shrub interactions to piñon-juniper woodlands, Allen et al. (2010 *Journal of Arid Environments*) reported on the effects of long-term N fertilization on mycorrhizae abundance and piñon and juniper responses in relationship to drought. Fertilization led to a decrease in mycorrizae and an increase in leaf production in piñon but not juniper. As a consequence, piñons on the fertilized plots started to suffer mortality a year earlier than piñons on control plots during the 2000-2003 drought. Thus, N enrichment and loss of ectomychorrizae from piñon could enhance their susceptibility to future climate extremes, particularly drought.

Continuing with climate impacts on piñon-juniper woodlands, the pinon-juniper rainfall manipulation completed three years of treatment in August 2010. In two of three blocks,

those with shallowest soils and more southerly exposure, pinon mortality occurred after one year of treatment. Our recent analysis of sap flow, soil moisture and xylem hydraulic conductance data using a hydraulic model shows that the critical transpiration rates associated reached zero in April 2008 in advance of observed mortality in August 2008 (Figure 4). In contrast, critical transpiration rates in Juniper declined sharply but remained positive, allowing transpiration and carbon uptake to continue, until drought was relieved by monsoon precipitation.

During the recently completed third year of drought, imposed by fixed rainout structures that exclude roughly 45% of all precipitation, juniper individuals began to exhibit dieback and mortality. The third block, with the least slope and deepest soils, has yet to exhibit any mortality of pinon or juniper although both species exhibit treatment effects.

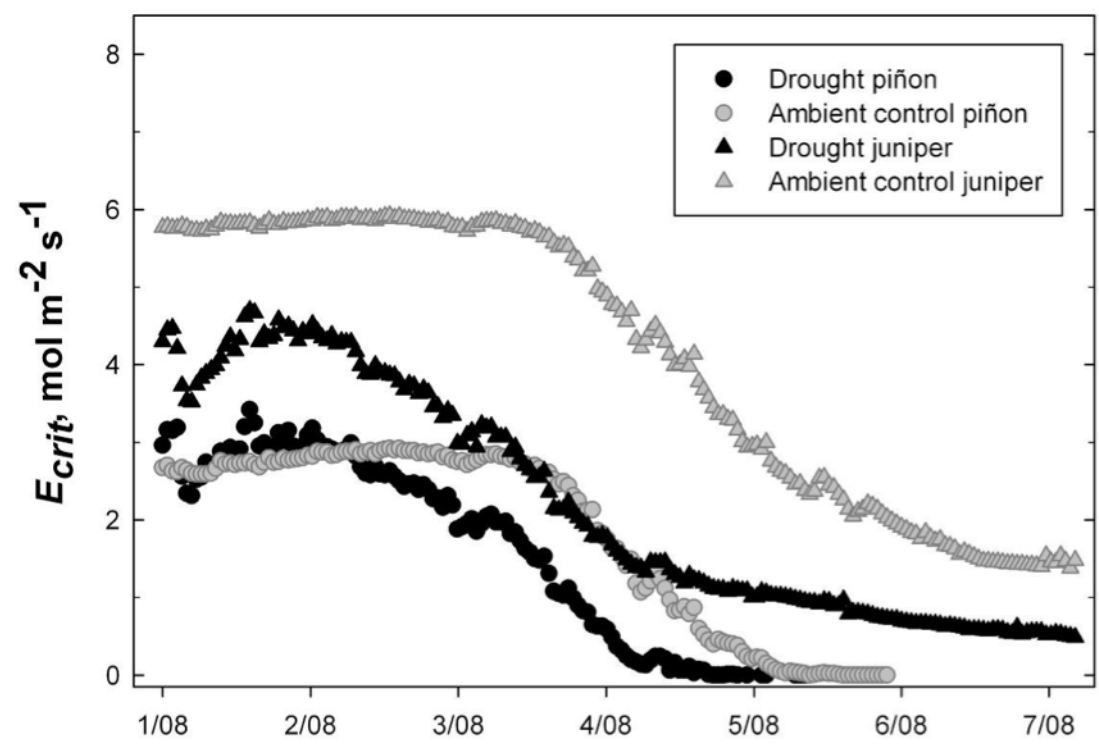


Figure 4. Modeled critical transpiration (E_{crit}) for piñon (circles) and juniper (triangles) in the drought (filled symbols) and ambient control (gray symbols) treatments. Source: Plaut et al., manuscript for submission to Plant Cell Environment.

We are in the process of establishing an additional treatment plot to assess the role of bark beetle activity in drought-induced mortality of pinon by combining the same drought treatment with regular application of pesticide to prevent bark beetle colonization of these trees.

Microbial ecology.
Communities of root-associated fungi (RAF) commonly have been studied under the auspices of arbuscular mycorrhizal fungi (AMF) or ectomycorrhizal fungi. However many studies now indicate that other groups of endophytic RAF, including dark septate

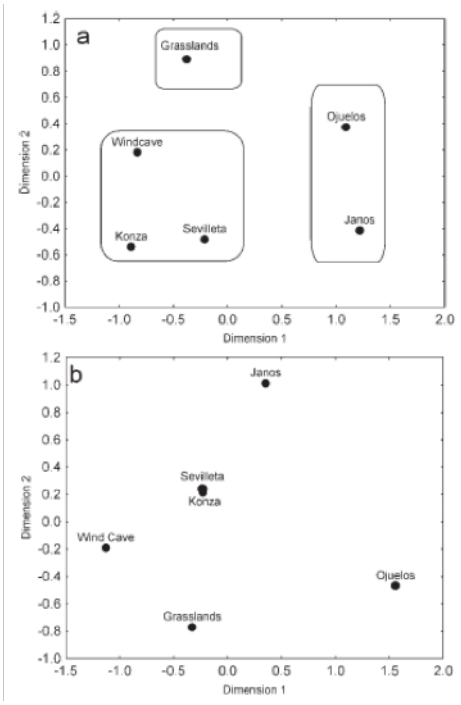


Figure 5. NMDS ordination of root associated fungi of *Bouteloua gracilis* from sites across the Great Plains

endophytes (DSE) are more abundant in some plants and environments. Herrera et al. (2010 *Mycologia*) used *Bouteloua gracilis*, a dominant grass at the Sevilleta, as a model system to examine whether RAF also colonize different organs within the same plant and to compare RAF communities from sites across North America, spanning the latitudinal range of *B. gracilis* from Canada to Mexico. We compared the RAF communities of organs within individual plants at one site and within plant roots among six sites. With the possible exception of one group related to genus *Paraphaeosphaeria* there was little evidence that RAF colonized vertically beyond the crowns. Furthermore, although there was some variation in the constitution of rare members of the RAF communities, several taxonomically related groups dominated the RAF community at all sites. These dominant taxa included members in the Pleosporales (related to the DSE, *Paraphaeosphaeria* spp.), Agaricales (related to *Moniliophthora* spp., or *Campanella* spp.) and Hypocreales (related to *Fusarium* spp.). AMF were notable by their near absence. Similar phylotypes from the dominant groups clustered around adjacent sites so that similarity of the RAF communities was negatively correlated to site inter-distance and the RAF communities appeared to group by country (Figure 5). These results increase the possibility that at least some of these common and widely distributed core members of the RAF community form important, intimate and long lasting relationships with grasses.

Although research has shown that RAF are necessary for plant success in harsh environments, few studies have examined RAF community variability between different plant species coexisting in arid habitats. As a follow-up to the work on *B. gracilis* RAF, Khidir *et al*. (2010 *Journal of Arid Environments*) compared the diversity and composition of the fungal communities colonizing dominant and important forage grasses, *Bouteloua gracilis* and *Sporobolus cryptandrus*, at the Sevilleta. A third sympatric plant, *Yucca glauca* (Agavaceae), also was analyzed. ITS rDNA from roots, collected and amplified in 2007, yielded 447 fungal sequences. Sequences obtained from all three species suggest that grasses share a core group of RAF (90% of sequences representing the orders Pleosporales, Agaricales, and Sordariales). Conversely, 57% of the fungal community within *Y. glauca* was dominated by a different RAF cohort. The two most common OTUs within the grasses are related to *Paraphaeospheria* sp. and *Moniliophthora* sp. (91 and 85 of 331 sequences, respectively). These same two species accounted for 58% of isolates in culture-based analysis of the same grass root tissue. The presence of these RAF in several grass species, over several years, and at several sites suggests that grasses in semiarid landscapes share a similar cohort of fungal dominants.

Ecohydrology.
During the last 150 years, land degradation across the arid and semiarid grasslands of the southwestern US has been associated with an increase in runoff and erosion, and a loss of biodiversity. Scientists at the Sevilleta LTER are investigating both the causes and consequences of land degradation in this region. Ravi et al. (2010 *Geomorphology*) reviewed recent contributions to the study of biotic and abiotic drivers of dryland degradation and proposed a more holistic perspective of the interactions between wind and water erosion processes in dryland systems, how these processes affect vegetation patterns and how vegetation patterns, in turn, affect these processes (Figure 6). They note that climate change may lead to increased regional aridity, which could increase the importance of abiotic processes in land degradation in the future.

In another contribution, Ravi et al. (2010 *Rangeland Ecology and Management*) summarize a potential form of aridland pulse dynamics. In this case, they review the concept of shrub encroachment and the development of islands of fertility. However, they also discuss how fire, through alterations in soil hydrophobicity and enhanced surface erosion, can reverse the development of fertility islands. To do so requires burning at a key transition stage before the system passes a threshold of shrub encroachment and loss of grass cover. The results have important management implications for restoring and maintaining grassland in areas where shrub encroachment is occurring.

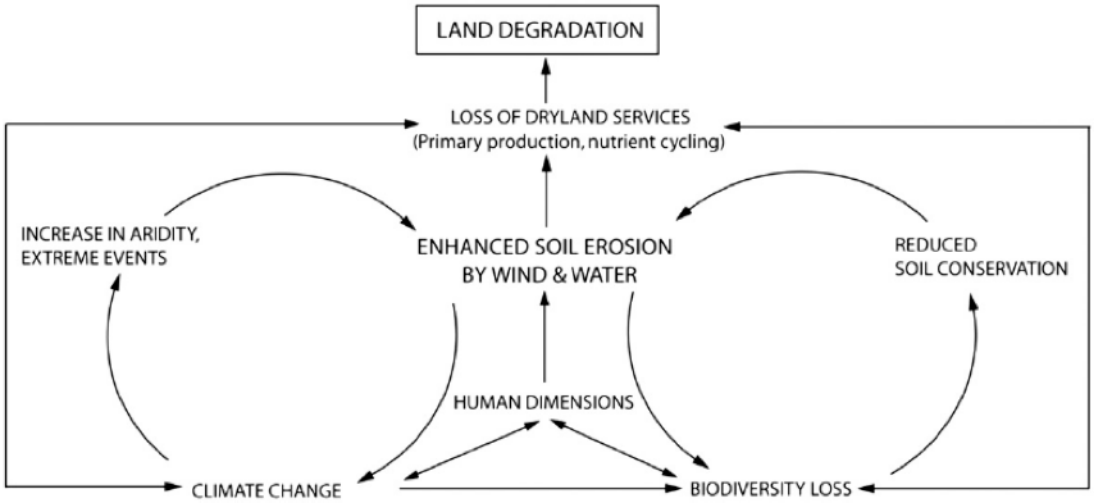


Figure 6. Conceptual diagram showing the interrelations among soil erosion, land degradation, climate change and biodiversity loss (modified from MEA, 2005).

Pockman and Small (2010 *Ecosystems*) found that redistribution of water following a 15mm precipitation event in the grass-shrub ecotone at Sevilleta led to enhanced infiltration and higher soil water content under grasses as well as shrubs compared to patches of unvegetated soil. However, redistribution of surface water led to a greater amount of soil water in the root volume of grasses relative to shrubs, which led to lower plant water stress in grasses compared to shrubs following this one rain event. The results suggest that redistribution and infiltration under grasses can increase their competitive ability and perhaps slow shrub encroachment by creosote into these grasslands.

Turnbull et al. (2010a, *Hydrological Processes*) investigated the runoff-driven redistribution and loss of dissolved and particulate-bound N and P that occurs during natural runoff events over a trajectory of degradation, from grassland to degraded shrubland, at the Sevilleta. Runoff-driven nutrient dynamics were monitored at four stages over a transition from grassland to shrubland, for naturally occurring rainfall events over 10 by 30 m bounded runoff plots. Results show that particulate-bound forms of N and P are responsible for most of N and P lost from the plots due to erosion occurring during runoff events. Results suggest that for high-magnitude rainfall events, the output of N and P from the plots may greatly exceed the amount of N and P input into the plots, particularly over shrub-dominated plots where erosion rates are higher. As these results only become apparent when monitoring these processes over larger hillslope plots, it is important to recognize that processes of nutrient cycling related to the islands of fertility hypothesis may have previously been overstated when observed only at smaller spatial scales. Thus, the progressive degradation of semi-arid grassland ecosystems across the south-western United States and other semi-arid ecosystems worldwide has the potential to affect N and P cycling significantly through an increase in nutrient redistribution and loss in runoff.

Building off this empirical work, Turnbull et al. (2010b *Journal of Hydrology*) evaluated Mahleran, the Model for Assessing Hillslope to Landscape Erosion Runoff, And Nutrients, against runoff and erosion data from empirical research in four plots representative of different stages of land degradation over the transition from grassland to shrubland at the Sevilleta. In addition, they developed a new particulate-bound nutrient module to include a representation of particulate-bound nutrient dynamics, which is an important form of nutrient transport in these ecosystems (see above). Understanding dynamics of both dissolved and particulate-bound nutrient dynamics during runoff events is imperative, because of their differing roles in terms of nutrient bioavailability and

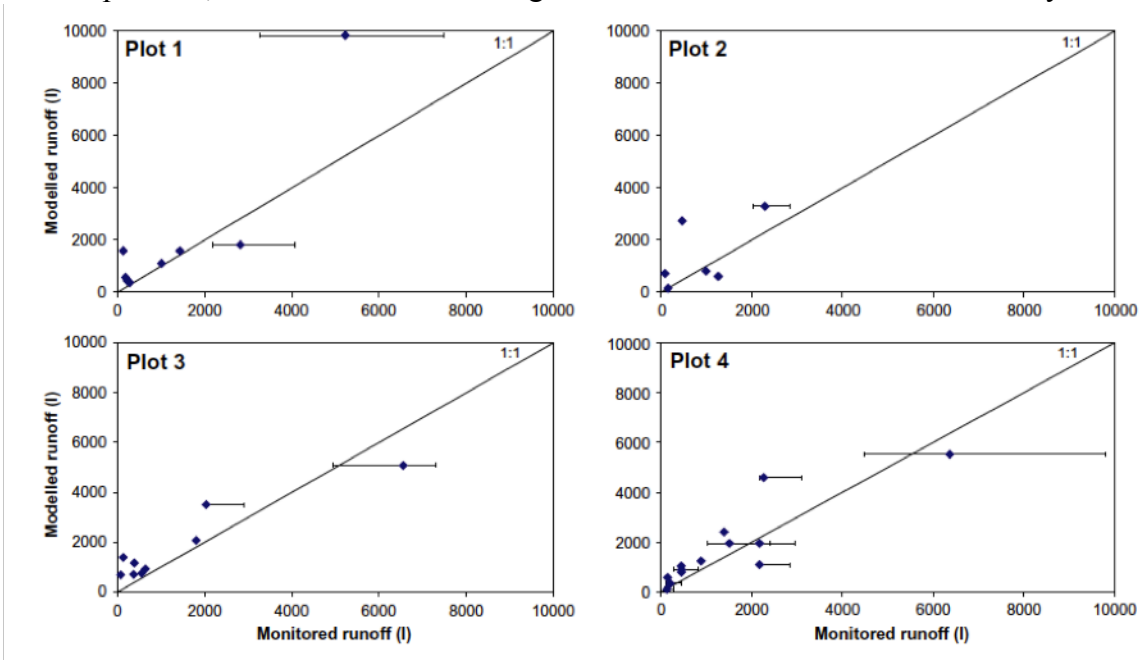


Figure 7. Monitored and modelled runoff (l), with bars showing potential uncertainty in the volume of total runoff that was monitored derived using the approach outlined in Turnbull et al. (2010a).

potential implications for plant dynamics as well as their impact on shrub encroachment processes.

This model evaluation showed that the runoff and erosion components of Mahleran perform reasonably well (Figure 7), as does the new particulate-bound nutrient sub-model, though not consistently. Performance of the particulate-bound nutrient model was better for the end-member plots (pure grassland or pure shrubland), because of better parameterization data available for end-member vegetation types. Since the particulate-bound nutrient sub-model is by necessity strongly dependent on the simulated erosion rate, the performance of the particulate-bound nutrient model is dependent on the performance of the erosion component of Mahleran, so that when erosion is well represented by the model, so typically are particulate nutrient transfers. The performance of the dissolved nutrient component of Mahleran was poor in this application, which indicates that the process representation for this semi-arid environment and the parameterization of the dissolved nutrient component were inadequate. Results from the model evaluation suggest that an improved understanding of dissolved nutrient dynamics during runoff events and simulation if inter-event nutrient dynamics is required, in order to improve the level of process representation within modeling approaches and thus the ability to simulate dissolved nutrient dynamics and their subsequent effects on other ecosystem processes.

Consumers.
In work related to our plans to vastly increase prairie dog populations at the Sevilleta (see Activities), Megan Friggens and colleagues (2010) recently reported in the *Journal of Wildlife Diseases* on a three-year survey of fleas on rodents and in prairie dog burrows in the Valles Caldera Preserve north of the Sevilleta. This research was supported with a SEV LTER Summer Fellowship for a regional comparative study of fleas and plague including in populations from our original prairie dog restoration plots established in 2005. Overall, they found a small number of fleas and prairie dogs with evidence of plague but their results suggest that fleas in burrows can be an important reservoir for plague that can help lead to outbreaks under appropriate summer conditions. This information will contribute to the design and monitoring of disease dynamics at the Sevilleta as the current restoration efforts continue.

Robin Warne along with Alaina Pershall and Blair Wolf reported in *Ecology* (2010) on the impacts of interannual climate variability and its effects on C3 and C4 plants, grasshoppers, and lizards at the SEV. They found that during normal rainfall years consumers used an increasing proportion of C4 derived resources over the growing season. However, during a spring with below average precipitation consumers relied on C4 resources that were likely carried over from previous year's production. This demonstrates the degree of diet flexibility that consumers like grasshoppers and lizards need to have to survive in this highly variable system, which has implications for community composition and structure under future patterns of climate variability. In a second paper in *Physiological and Biochemical Zoology*, Warne, Gilman and Wolf (2010) used stable isotopes to determine the tissue incorporation rates of carbon in two species of lizards. They found that carbon incorporation rates in various tissues were

much slower than for comparably sized endotherms.

Rominger et al. (2009 *Oecologia*) investigated whether neutral or deterministic factors structure grasshopper communities at the Sevilleta. They studied the spatial structure of a desert grassland grasshopper community to test predictions for species sorting based on niche differentiation (deterministic) and dispersal limitation (neutral). To do so, they contrasted the change in species relative abundance and community similarity along an elevation gradient (i.e., environmental gradient) against community change across a relatively homogeneous distance gradient. They found a signifcant decrease in pairwise community similarity along both elevation and distance gradients (Figure 8), indicating that dispersal limitation plays a role in structuring local grasshopper communities. However, the distance decay of similarity was significantly stronger across the elevational gradient, indicating that niche-based processes are important as well. To further investigate mechanisms underlying niche differentiation, Rominger *et al*. experimentally quantified the dietary preferences of two common species, *Psoloessa texana* and *P. delicatula*, for the grasses *Bouteloua eriopoda* and *B. gracilis*, which are the dominant plants in Sevilleta grasslands. Cover of the preferred host plant explained some of the variation in relative abundances of the two focal species, although much variance in local *Psoloessa* distribution remained unexplained. These results indicate that the composition of local communities can be influenced by both probabilistic processes and mechanisms based in the natural histories of organisms.

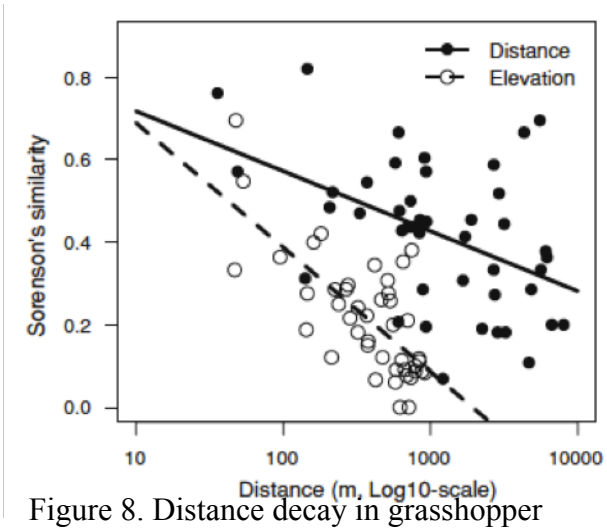


Figure 8. Distance decay in grasshopper community similarity across elevational and spatial gradients.

Finally, work by graduate student Virginia Seamster of the University of Virginia is addressing how woody plant encroachment affects foraging behavior of predators. Woody plant encroachment, or the spread of woody plants into a grassland area, is a widespread process of habitat change and some of the arid and semi-arid areas affected by woody plant encroachment are subject to strong seasonal variation in rainfall and thus in primary productivity. The primary goal of this project is to assess the consequences of both woody plant encroachment and seasonal climatic variation for the feeding ecology of a top, omnivorous predator. The specific questions being addressed are: 1) What is the base of the food chain for coyotes living in grassland vs. shrubland


Figure 9. Scat collection.

habitats in an area where woody plant encroachment has been occurring over the past century? and 2) Is there seasonal variation in the base of the coyote food chain in this same area? The hypotheses are that: 1) woody plant encroachment will lead to a shift in coyote feeding ecology such that coyotes in shrubland areas will obtain a significantly higher percentage of their food resources directly or indirectly from shrubs than coyotes in the native grassland habitat and 2) the percentage of coyote diet coming from shrubs will decrease significantly from spring to fall as grass productivity increases during the summer monsoon season. To test these hypotheses, data was collected in the spring, summer and fall of 2009 at the Sevilleta National Wildlife Refuge (NWR) and Long Term Ecological Research (LTER) site in New Mexico. Data collection consisted of scat collection along 22 one mile long, road based transects. Half of all transects were located in grassland habitat, the other half in shrubland. A subsample of each scat was collected for genetic analysis (Figure 9) and the remainder was dried for stable carbon isotope analysis. All samples were run through a species identification test and coyote samples were identified to individual using microsatellite techniques. Bone, hair and seeds were removed from a subset of the dried samples and run through stable carbon isotope analysis.

So far, 935 scat samples have been collected. Just over two thirds of the samples were from coyotes and a total of 81 individuals were identified. Preliminary stable carbon isotope data indicates that, contrary to expectations, coyotes derive roughly 50% of their food resources directly or indirectly from shrubs regardless of the habitat type ($t=0.66$, $p=0.51$; Figure 10a) and that there is no significant seasonal variation in the base of the coyote food chain in either habitat type (grassland: $F=0.45$, $p=0.64$; shrubland: $F=0.63$, $p=0.54$; Figure 10b). There is however a slight increase in the use of shrub-derived food resources from grassland to shrubland (Figure 10a) and slight decrease in shrub-derived resources from spring to summer in the shrubland habitat (Figure 10b) which does match expectations.

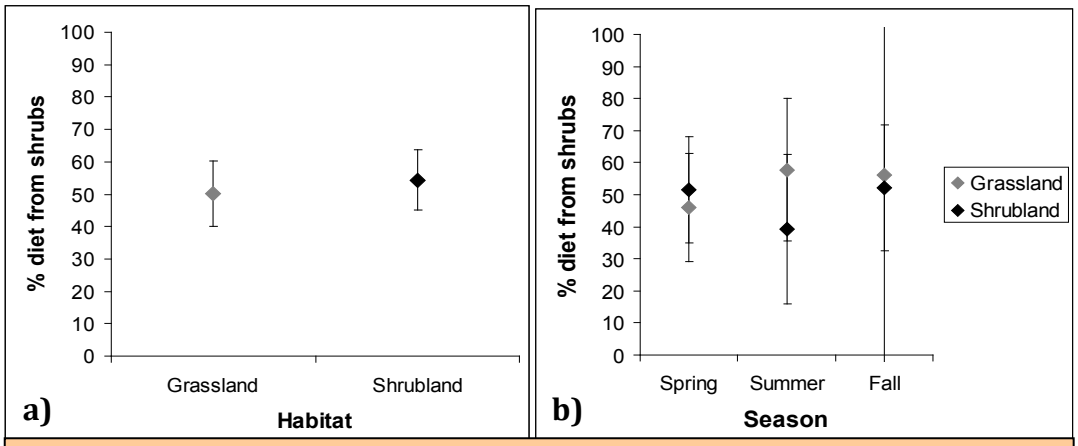
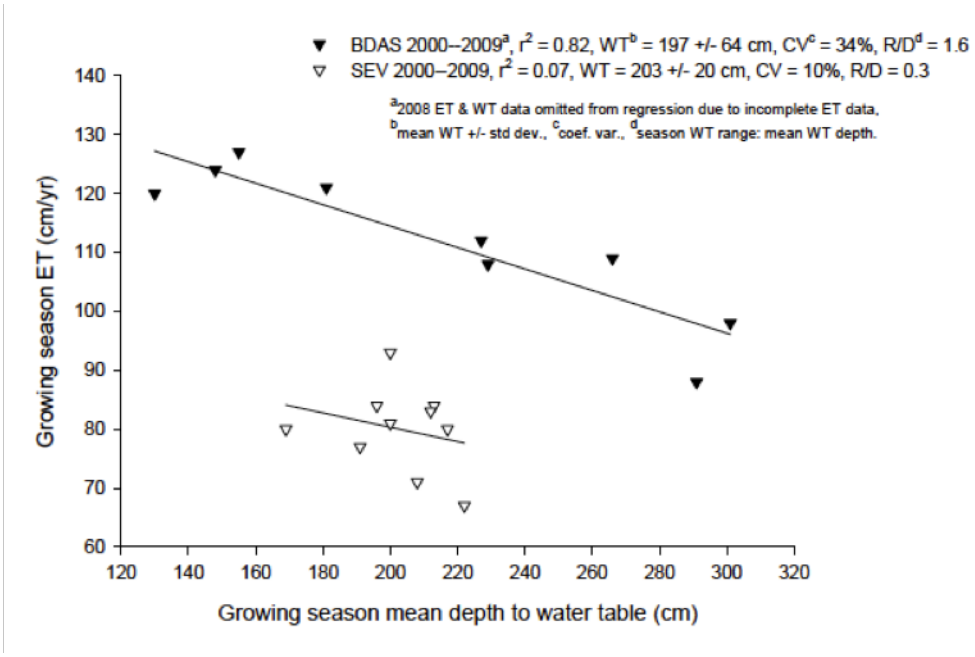


Figure 10. Differences in % coyote diet from shrubs a) between habitats, b) among seasons.

Biosphere-Atmosphere coupling.
Phreatophytic vegetation such as salt cedar relies heavily on ground water transported from upstream sources. ET exceeds local precipitation by a factor greater than 3 at the riparian sites. Growing season ET averages 80 cm/yr at SEV, approximately 70% of the more densely vegetated BDAS (112 cm/yr). Growing season WTs at both sites average nearly 2 m depth although hydrographs at BDAS are much more variable. Unlike SEV, the WT at BDAS has a strong hydrological connection to the river. The absolute WT range at BDAS averages 2.3 m and has reached 4 m, while SEV WTs range about 0.6 m. Ratios of seasonal WT range to mean WT depth are 1.6 at BDAS and 0.3 at SEV. Total growing season ET declines with deeper mean WTs at both sites, and they are strongly correlated at BDAS, but not at SEV (Figure 11). Similar correlations were also observed at two mixed native/non-native communities along the Rio Grande with nearly identical range to depth ratios. While wet years with shallow WTs likely increase ET, pulses of extended snowmelt flooding at BDAS in two recent years did not elevate ET during inundation. In these riparian ecosystems with near-surface ground water, it appears that variability in water table depth, which exposes a greater extent of vadose zone throughout the growing season, may play a more important role than depth itself on transpiration rates by phreatophytes. The phenology of native riparian communities is dependent on

Figure 11. Mean growing season water table depth vs. total ET at Sevilleta (SEV, 2000--2009) and Bosque del Apache (BDAS 2000--2007, 2009) National Wildlife Refuges.



seasonal flooding, which has been greatly diminished by hydrologic alterations and competing allocations. Runoff managed to flood targeted restoration sites with concomitant flooding into invasive salt cedar stands would not likely result in excessive water consumption.

Southwestern North America faces an imminent transition to a warmer, more arid climate, and it is critical to understand how these changes will affect the carbon balance of southwest ecosystems. Anderson-Tiexera et al. (2010 *Global Change Biology*) test the hypothesis that differential responses of production and respiration to temperature and moisture shape the carbon balance across a range of spatio-temporal scales in ecosystems across New Mexico. They quantified net ecosystem exchange (NEE) of CO2 and carbon storage across an elevational gradient, using six eddy-covariance sites representing biomes ranging from desert to subalpine conifer forest in central New Mexico. Within sites, hotter and drier conditions were associated with an increasing advantage of respiration relative to production such that daily carbon uptake peaked at intermediate

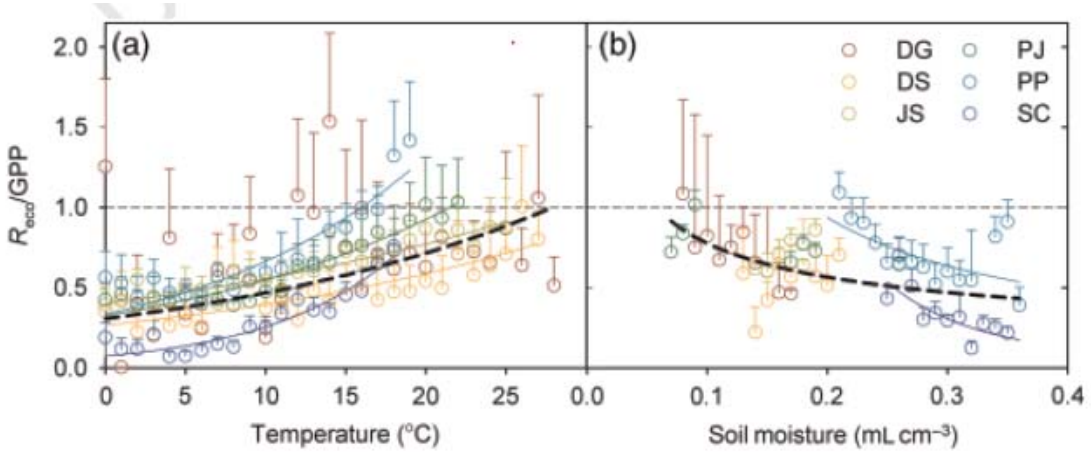


Figure 12. Relative advantage of daily respiration over production (Reco/GPP) as a function of (a) air temperature and (b) soil moisture (30–40cm depth; months where low temperatures do not limit growth) for all six sites across the gradient. Colored lines represent significant within-site relationships, and dashed black lines represent the average response across sites. GPP, gross primary production; Reco, release through ecosystem respiration; DG, desert grassland; DS, desert shrubland; JS, juniper savannah; PJ, pinon-juniper woodland; PP, ponderosa pine forest; SC,subalpine conifer forest.

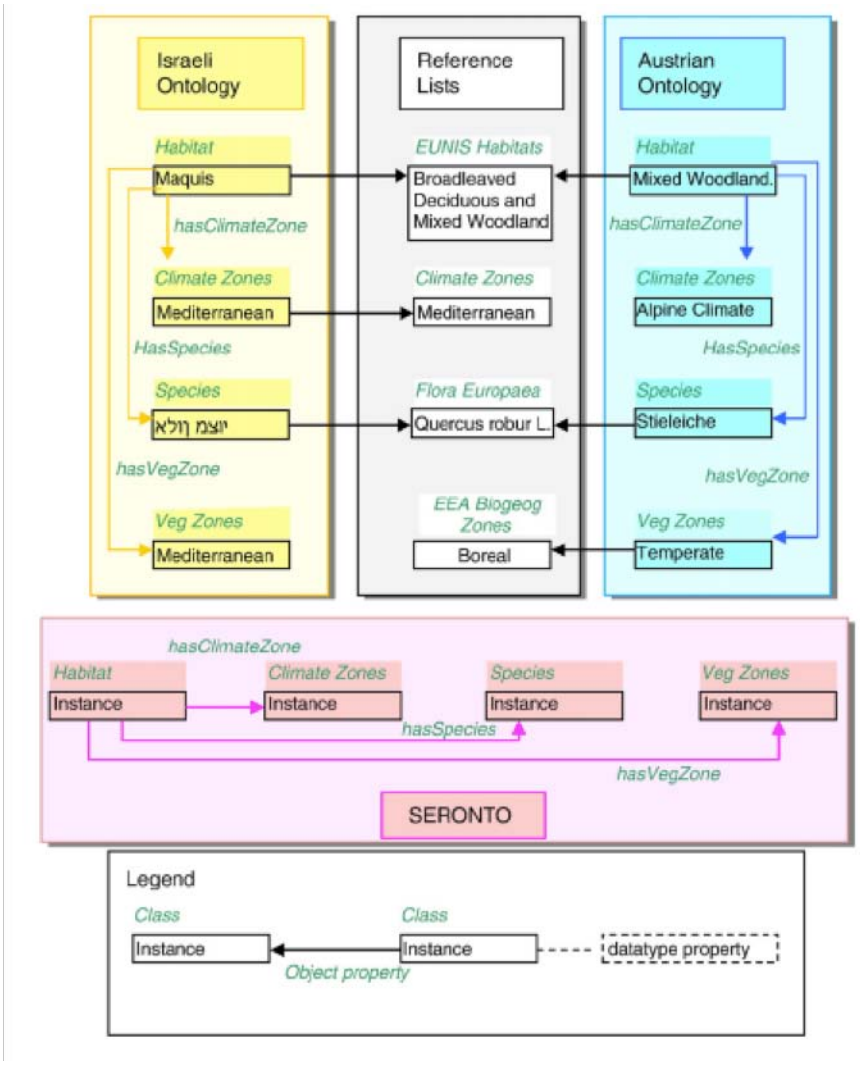
temperatures – with carbon release often occurring on the hottest days – and increased with soil moisture (Figure 12). Across sites, biotic adaptations modified but did not override the dominant effects of climate. Carbon uptake increased with decreasing temperature and increasing precipitation across the elevational gradient; NEE ranged from a source of 30 gCm-2 yr-1 in the desert grassland to a sink of -350 gCm-2 yr-1 in the subalpine conifer forest. Total aboveground carbon storage increased dramatically with elevation, ranging from 186 gCm-2 in the desert grassland to 26 600 gCm-2 in the subalpine conifer forest. These results make sense in the context of global patterns in NEE and biomass storage, which add support to the finding that increasing temperature and decreasing moisture shift the carbon balance of ecosystems in favor of respiration, such that the potential for ecosystems to sequester and store carbon is reduced under hot and/or dry conditions. This implies that projected climate change will trigger a substantial net release of carbon in these New Mexico ecosystems (-3Gt CO2 statewide by the end of the century), thereby acting as a positive feedback to climate change.

Information management

Vanderbilt et al. (2010 *Ecological Informatics*) discuss the significant barriers to creating and using common EML protocols and keywords in an international context. The ILTER Network has agreed to provide EML in English, but translation remains the burden of

data providers for whom English may be a second (or third, or fourth, or…) language. In many cases, there are no direct translations between languages making the use of EML challenging globally. Vanderbilt et al. lay out a roadmap (Figure 13) to address the difficulties of multilingual translation and facilitate the development of an international EML framework that will benefit data synthesis globally.

Figure 13. An example of ontology mediated translation. SERONTO is a core ontology (pink) where concept classes such as habitat, species, and climate zone are related by object properties such as hasClimateZone, hasSpecies, and hasVegZone. The Israeli (yellow) and the Austrian (blue) plant community ontologies are based on SERONTO. In this example, there is a direct mapping between the Hebrew and German common names for *Querqus robur* L. using the Flora Europaea reference list. Even though the two habitats are instances of the EUNIS "Broadleaved Deciduous and Mixed Woodland" Habitat, they are not identical because the Israeli climate zone and the Austrian climate zone are not equivalent. Additional rules in the domain ontology would be needed to determine if the data from the two sites could be integrated.



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