Annual Report for Period: 11/2010 - 10/2011
Submitted on: 08/24/2011
Principal Investigator: Peters, Debra P.
Award ID: 0618210
Organization: New Mexico St University
Submitted By:
Peters, Debra - Principal Investigator
Title:
Jornada Basin LTER V: Landscape Linkages in Arid and Semiarid Ecosystems

Project Participants

Senior Personnel

Name: Peters, Debra
Worked for more than 160 Hours: Yes
Contribution to Project:
PI with overall responsibility for project; responsible for plant studies and modeling integration and synthesis

Name: Havstad, Kris
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI responsible for large animal studies and integration with ARS unit

Name: Herrick, Jeffrey
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI responsible for plant-soil feedback studies, and monitoring studies

Name: Monger, Hugh
Worked for more than 160 Hours: Yes
Contribution to Project:
CO-PI responsible for geomorphology and soil studies, lead contact with NMSU, and interactions with NMSU graduate students

Name: Bestelmeyer, Brandon
Worked for more than 160 Hours: Yes
Contribution to Project:
Co-PI responsible for animal studies, and state-and-transition models

Name: Archer, Steven
Worked for more than 160 Hours: Yes
Contribution to Project:
Senior scientist working on shrub invasion dynamics primarily in mesquite-black grama areas; cross-site comparisons with sites in Sonoran Desert.

Name: Sala, Osvaldo
Worked for more than 160 Hours: Yes
Contribution to Project:
Senior scientist responsible for precipitation manipulation studies and net primary production studies

Name: Fredrickson, Ed
Worked for more than 160 Hours: Yes
Contribution to Project:
Senior scientist responsible for livestock grazing studies with emphasis on comparing traditional cattle breeds with aridland-adapted breeds from Chihuahua, Mexico in terms of how the animals use and interact with their environment, and provide feedbacks to the vegetation. Point of contact with other large animal ecologists in the ARS unit. (through 2011)

Name: Throop, Heather

Worked for more than 160 Hours: Yes

Contribution to Project:

Senior scientist responsible for studies on decomposition, root dynamics, and soil organic matter dynamics

Name: Abbott, Laurie

Worked for more than 160 Hours: Yes

Contribution to Project:

Senior scientist working on plant-soil interactions and remediation studies in mesquite dunelands; NMSU animal and range science department representative on the project.

Name: Gutshick, Vincent

Worked for more than 160 Hours: Yes

Contribution to Project:

Senior scientist working on ecophysiology of shrubs (through 2007)

Name: Parsons, Anthony

Worked for more than 160 Hours: Yes

Contribution to Project:

Senior scientist responsible for hydrology studies in the field thru 2008.

Name: Wainwright, John

Worked for more than 160 Hours: Yes

Contribution to Project:

Senior scientist responsible for hydrological modeling through 2008.

Name: Rango, Al

Worked for more than 160 Hours: Yes

Contribution to Project:

Senior scientist responsible for remote sensing imagery and aerial photo image analysis, documentation, and archival

Name: Schlesinger, William

Worked for more than 160 Hours: Yes

Contribution to Project:

Senior scientist working on nitrogen and biogeochemical cycling; provides overall advice to the project

Name: Okin, Gregory

Worked for more than 160 Hours: Yes

Contribution to Project:

Senior scientist responsible for wind erosion-deposition experiments and modeling

Name: Skaggs, Rhonda

Worked for more than 160 Hours: Yes

Contribution to Project:

Senior scientist responsible for human demographic-economic studies in Dona Ana County, and point of contact for cross-site studies on linked human-natural systems.

Name: Vivoni, Enrique

Worked for more than 160 Hours: Yes

Contribution to Project:

ASU Associate professor leading watershed ecohydrology study and other hydrological efforts at the JRN

Name: Duniway, Mike

Worked for more than 160 Hours: Yes

Contribution to Project:

working on plant-soil water feedbacks and role of caliche in desert systems

Name: Buenemann, Michaela

Worked for more than 160 Hours: Yes

Contribution to Project:

participates in social science research with focus on mapping of land use types

Name: Wright, Jack

Worked for more than 160 Hours: Yes

Contribution to Project:

leads social science efforts to model population and land cover changes in Dona Ana County and southern NM; leads JRN participation in the ULTRA project with CAP and SEV

Name: Reichmann, Lara

Worked for more than 160 Hours: Yes

Contribution to Project:

ASU postdoc working with Sala to maintain and monitor the long-term water manipulation experiment (2011-)

Post-doc

Name: Steele, Caiti

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Brandon Bestelemyer on remote sensing studies; supported by BLM

Name: Rios Casanova, Leticia

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Bestelmeyer on ants and ecotones

Name: Wills, Skye

Worked for more than 160 Hours: Yes

Contribution to Project:

postdoc working with Herrick on monitoring methods (2008-2009)

Name: Peinetti, Raul

Worked for more than 160 Hours: Yes

Contribution to Project:

postdoc working with Peters and Fredrickson to develop animal modeling component, and to synthesize data on large animals (through 2010)

Name: Duniway, Mike

Worked for more than 160 Hours: Yes

Contribution to Project:

postdoc working with Herrick on monitoring impacts of linear disturbances through 2010

Name: Lee, Hanna

Worked for more than 160 Hours: Yes

Contribution to Project:

Postdoc working with Throop on studies of UV photodegradation effects on decomposition

Name: Sudderth, Erika

Worked for more than 160 Hours: Yes

Contribution to Project:

Precipitation controls of carbon and nitrogen cycles in arid-semiarid ecosystems - Sala. (through 2010)

Name: Browning, Dawn

Worked for more than 160 Hours: Yes

Contribution to Project:

Remote sensing of phenology - Rango.

Name: Pillsbury, Finn

Worked for more than 160 Hours: Yes

Contribution to Project:

Postdoc working with Peters on Ecotone modeling and cross-scale experiment

Graduate Student

Name: Crossland, Keith

Worked for more than 160 Hours: Yes

Contribution to Project:

graduate student working with Monger and Herrick on field data collection and lab analyses related to water dynamics at NPP plots (2006-2008)

Name: Rachal, David

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU PhD student with Monger on geomorphology and wind studies (2007 -)

Name: Weems, Stacey

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU MS student working with Monger on banded vegetation formation (2006-2008)

Name: Riggs, Justin

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU MS student working with Monger on soil studies (2006-2008)

Name: Cruz, Janella

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU MS student working with Monger on soil studies (2006-2008)

Name: Campanella, Andrea

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU PhD student working with Bestelmeyer on plant-animal interactions across ecotones with focus on small animals (2004-2008)

Name: Goolsby, Darroc

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU PhD student working with Bestelmeyer on landscape survey of vegetation and soils for sites located throughout the Jornada (2006-)

Name: Calkins, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU MS student working with Throop on decomposition studies (2006-2007)

Name: Kuok Choy, Lam

Worked for more than 160 Hours: Yes

Contribution to Project:

Univ Sheffield PhD student working with Parsons and Wainwright on hydrological analyses of NPP plots (2007-2008)

Name: Reichman, Lara

Worked for more than 160 Hours: Yes

Contribution to Project:

Brown University PhD student working with Sala on ANPP and rainfall study using shelters and water additions (2005 - 2010)

Name: Klass, Jeremy

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU PhD student working with Peters on ecotone studies (2007-)

Name: Hewins, Dan

Worked for more than 160 Hours: Yes

Contribution to Project:

Graduate student working with Throop on belowground studies in rainout shelter study (2008-)

Name: Gherardi, Laureano

Worked for more than 160 Hours: Yes

Contribution to Project:

Graduate student working with Sala on rainout shelter study (2008-)

Name: Baquera, Noemi

Worked for more than 160 Hours: Yes

Contribution to Project:

Graduate student working with Herrick on landuse patterns in Dona Ana county (2006-08)

Name: Hansen, Nicole

Worked for more than 160 Hours: Yes

Contribution to Project:

Graduate student working with Herrick on vegetation-soil patterns and wind-water redistribution patterns at Red Lake (2006-08)

Name: Smith, Jane

Worked for more than 160 Hours: Yes

Contribution to Project:

Decomposition and soil organic matter dynamics - Throop.

Name: Ponce-Guevara, Eduardo

Worked for more than 160 Hours: Yes

Contribution to Project:

Fire, grazing and prairie dogs on desert grassland heterogeneity and resilience - Fredrickson.

Name: Roacho-Estrada, Jose Octavio

Worked for more than 160 Hours: Yes

Contribution to Project:

Breed effects on livestock distribution and foraging behavior within Chihuahuan desert grasslands in US and Mexico - Fredrickson.

Name: Sierra-Corona, Rodrigo

Worked for more than 160 Hours: Yes

Contribution to Project:

Spatial and dietary overlap between livestock and prairie dogs on a extensive desert grassland - Fredrickson.

Name: James, Darren

Worked for more than 160 Hours: Yes

Contribution to Project:

Livestock grazing on optimal foraging dynamics of smaller mammalian herbivores - Fredrickson.

Name: Abu-Salem, Majd

Worked for more than 160 Hours: Yes

Contribution to Project:

Biogeochemical consequences of fire - Throop.

Name: Coffman, John

Worked for more than 160 Hours: Yes

Contribution to Project:

Bird responses to grassland restoration efforts - Bestelmeyer

Name: Alvarez, Lorelei

Worked for more than 160 Hours: Yes

Contribution to Project:

Feedbacks between wind, wind erosion, and vegetation - Okin. (through 2010)

Name: Slutz, Shasta

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU MS student in Ag Economics) working with Skaggs on BLM allotment history data collection and analysis. Completed degree in May 2010.

Name: Hestir, Kristen

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU MS student in Geography working with Buenemann. Generated land cover/land use maps for the past 25 years. Data are being used to predict land use and urbanization trends in the future. Completed degree in 2011.

Name: Svejcar, Lauren

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU M.S. student working with B. Bestelmeyer on stressor experiment

Name: Pierce, Nate

Worked for more than 160 Hours: Yes

Contribution to Project:

UofA graduate student working with Archer on grass demographic responses to sand deposition

Name: Templeton, Ryan

Worked for more than 160 Hours: Yes

Contribution to Project:

ASU MS student working with Vivoni on watershed ecohydrology study on creosotebush bajada.

Name: Mendez, Luis

Worked for more than 160 Hours: Yes

Contribution to Project:

ASU PhD student assisting in field deployment and instrumentation in the Watershed Ecohydrology Study

Name: Laney, Katie

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU M.S. student working with Monger on geomorphology and vegetation change

Name: Sankar Tummalapalli, Sai

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Peters on Jornada database development and the EcoTrends Project through 2010

Name: Catoni, Marcella

Worked for more than 160 Hours: Yes

Contribution to Project:

PhD student working with Monger on carbon and calcium isotopes
Universita degli Studi di Torino, Grugliasco, Italy

Name: Sammetha, Swathi

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU student working with Monger on Jornada soil climate studies

Name: Perry, Samuel

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU MS student in Ag Economics working with Skaggs on field data collection and analysis related to human dimension-economic studies in the region (2011-)

Name: Yu, Yang

Worked for more than 160 Hours: Yes

Contribution to Project:

Working with Parsons and Wainwright at Univ. Sheffield on PhD in Geography. Title of thesis: Land use decision making and landscape degradation: a case study in the American Southwest (completed 2011).

Name: Kahn, Patrick

Worked for more than 160 Hours: Yes

Contribution to Project:

Ph.D. student at UCLA Department of Geography with Okin working on a tracer study of aeolian and fluvial transport using rare earth elements

Name: Fitzgerald, Allison

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU MS student working with D. Bailey on black grama population genetics study

Name: McKenna, Owen

Worked for more than 160 Hours: Yes

Contribution to Project:

ASU student who studies playas as biogeochemistry hot spots in the Chihuahuan desert working with Sala (2011-)

Undergraduate Student

Name: Adhikari, Pradip

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Bestelmeyer on landscape survey and soil studies (2007)

Name: Romig, Kirsten

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Bestelmeyer on plant inventories (2007)

Name: Sprague, Jesse

Worked for more than 160 Hours: Yes

Contribution to Project:

worked with Throop on soil organic matter studies (2007)

Name: Meyer, Nichole

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Throop on decomposition studies (2007)

Name: Chisala, Ngawina Veronic

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Throop on decomposition studies (2008)

Name: Midez, Jaime

Worked for more than 160 Hours: Yes

Contribution to Project:

assisted Sala on rainout shelters (2007)

Name: De Lao, Cheryl Maria

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Monger on soil studies (2007-08)

Name: Lewis, Jeremy

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Throooop on decomposition studies (2008)

Name: Perez, Jesus Adrian

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Throop on soil organic matter dynamics (2008)

Name: Clawsen, Tim

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Throop on soil organic matter dynamics (2008-2010)

Name: Sebasky, Kristin

Worked for more than 160 Hours: Yes

Contribution to Project:

Brown undergrad working with Sala on rainout shelter study (2008)

Name: Cortner, Owen

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU undergrad working with Monger on soil studies (2008)

Name: Buchanan, Michael

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU undergrad working with Monger on soil studies (2008)

Name: Kanof, Lauren

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU undergrad working with Monger on soil studies (2008)

Name: Patel, Amith
Worked for more than 160 Hours: Yes
Contribution to Project:
worked on EcoTrends project to check data and metadata from 50 sites (2008)

Name: Venkata, Sri Harsha Veda
Worked for more than 160 Hours: Yes
Contribution to Project:
worked on EcoTrends project assisting Christine Laney in the formatting of data from 50 sites for inclusion in the book (2008)

Name: Fitzgerald, Jessica
Worked for more than 160 Hours: Yes
Contribution to Project:
Soil movement and leaf litter decomposition studies. New Mexico State University - Throop.

Name: Pardee, Renee
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Throop on decomposition and soil organic matter dynamics

Name: Morrison, Elizabeth
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Throop on decomposition and soil organic matter dynamics

Name: Leon, Francisco
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Throop on decomposition and soil organic matter dynamics

Name: Velasco, Erika
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Throop on UV and litter decomposition studies

Name: Toussaint, Vladimir
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Throop on decomposition and soil organic dynamics

Name: Lyman, Danielle
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Throop on decomposition and soil organic dynamics

Name: Sylvas, Breeana
Worked for more than 160 Hours: Yes
Contribution to Project:
NMSU student working on EcoTrends Project

Name: Wootton, Stephen
Worked for more than 160 Hours: Yes
Contribution to Project:
NMSU student working on EcoTrends Project

Name: John, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:

NMSU student working on EcoTrends Project

Technician, Programmer

Name: Burkett, Laura

Worked for more than 160 Hours: Yes

Contribution to Project:

GIS analyst working with Bestelmeyer

Name: Van Zee, Justin

Worked for more than 160 Hours: Yes

Contribution to Project:

project manager for Herrick's plant-soil studies and monitoring research

Name: Anderson, John

Worked for more than 160 Hours: Yes

Contribution to Project:

Site manager for Jornada Basin LTER

Name: Nolen, Barbara

Worked for more than 160 Hours: Yes

Contribution to Project:

Spatial database expert for Jornada Basin LTER (50% NSF, 50% ARS)

Name: Ramsey, Ken

Worked for more than 160 Hours: Yes

Contribution to Project:

Information manager for the Jornada Basin LTER

Name: Kuehner, John

Worked for more than 160 Hours: Yes

Contribution to Project:

LTER field crew technician

Name: Huang, Haitao

Worked for more than 160 Hours: Yes

Contribution to Project:

computer programmer working with Peters on ECOTONE model

Name: Toledo, David

Worked for more than 160 Hours: Yes

Contribution to Project:

worked with Bestelmeyer and Herrick on soil sampling

Name: Laney, Christine

Worked for more than 160 Hours: Yes

Contribution to Project:

Coordinator for EcoTrends project (2006-2010)

Name: James, Darren

Worked for more than 160 Hours: Yes

Contribution to Project:

assists in field sampling and lab analyses

Name: Courtright, Ericha

Worked for more than 160 Hours: Yes

Contribution to Project:

project manager for Herrick's soil and monitoring studies

Name: Slaughter, Amy

Worked for more than 160 Hours: Yes

Contribution to Project:

working with LTER scientists on field data collection

Name: Tucker Britt, Chandra

Worked for more than 160 Hours: Yes

Contribution to Project:

member LTER field crew (2005-2007)

Name: Wang, Mei

Worked for more than 160 Hours: Yes

Contribution to Project:

LTER lab technician working for Monger

Name: Salembier, Dan

Worked for more than 160 Hours: Yes

Contribution to Project:

LTER field crew member (2008-)

Name: Schauer, Lisa

Worked for more than 160 Hours: Yes

Contribution to Project:

LTER field crew member (2007-)

Name: Williamson, Jeb

Worked for more than 160 Hours: Yes

Contribution to Project:

Spatial analyst - Bestelmeyer.

Name: Edwards, Zach

Worked for more than 160 Hours: Yes

Contribution to Project:

GIS analyst digitizing of historical BLM maps - Bestelmeyer, Skaggs.

Name: Feng, Yanhua

Worked for more than 160 Hours: Yes

Contribution to Project:

Lab technician working for Monger in soils lab

Name: Domingo, Jimm

Worked for more than 160 Hours: Yes

Contribution to Project:

Programmer working with Peters on EcoTrends Project through 2011

Name: Frank, Roxanne

Worked for more than 160 Hours: Yes

Contribution to Project:

LTER field technician working for John Anderson

Name: Baker, Stephanie

Worked for more than 160 Hours: Yes

Contribution to Project:

LTER field technician working for John Anderson

Name: Yao, Jin
Worked for more than 160 Hours: Yes
Contribution to Project:
Statistical programmer working with Peters on the EcoTrends Project

Name: Cooper, Brad
Worked for more than 160 Hours: Yes
Contribution to Project:
Assists with experimental plot measurements and maintenance of ConMod pilot study

Name: Merth, Katie
Worked for more than 160 Hours: Yes
Contribution to Project:
R and database programmer on the EcoTrends Project (2011-)

Other Participant

Name: Laliberte, Andrea
Worked for more than 160 Hours: Yes
Contribution to Project:
collaborator on remote sensing studies

Name: Whitford, Walt
Worked for more than 160 Hours: Yes
Contribution to Project:
working with LTER scientists on small animal studies

Name: Bestelmeyer, Stephanie
Worked for more than 160 Hours: Yes
Contribution to Project:
Asombro Institute for Science Education.

Name: Brown, Joel
Worked for more than 160 Hours: Yes
Contribution to Project:
working with LTER scientists on carbon sequestration issues (NRCS)

Name: Tugel, Arlene
Worked for more than 160 Hours: Yes
Contribution to Project:
working with LTER scientists on soil studies (NRCS) (through 2010)

Name: Belnap, Jayne
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Herrick on soil surface disturbance studies (USGS)

Name: Bleiweiss, Max
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Al Rango on assembling high resolution satellite data base

Name: Brazier, Richard
Worked for more than 160 Hours: Yes
Contribution to Project:

working with Parsons and Wainwright on hydrology studies (Univ Sheffield)

Name: Kustas, Bill
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Rango on JORNEX project (ARS)

Name: Pyke, Dave
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Herrick on soil and vegetation monitoring

Name: Schmugge, Tom
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Rango on JORNEX project

Name: Roemer, Gary
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Bestelmeyer on plant-animal studies across ecotones

Name: Ulery, April
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Herrick and Monger on soil chemical properties

Name: Collins, Scott
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Peters on cross-site studies of ecotones

Name: Gosz, James
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Peters on cross-site ecotone studies

Name: Bailey, Donovan
Worked for more than 160 Hours: Yes
Contribution to Project:
working with Peters and Bestelmeyer on black grama genetics.

Name: Davidson, Ana
Worked for more than 160 Hours: Yes
Contribution to Project:
Interactive effects of prairie dogs and livestock - Fredrickson.

Name: Somerday, Marianne
Worked for more than 160 Hours: Yes
Contribution to Project:
Schoolyard LTER program - S. Bestelmeyer.

Name: Sayre, Nathan
Worked for more than 160 Hours: Yes
Contribution to Project:
Collaborator working on MALS cross-site project

Name: Khormali, Farhad

Worked for more than 160 Hours: Yes

Contribution to Project:

Associate professor spending sabbatical working with Monger on carbon isotopes and desert soils; from Gorgan University, Iran

Research Experience for Undergraduates

Name: Sanders, Brandon

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Bestelmeyer on soil studies

Years of schooling completed: Sophomore

Home Institution: Same as Research Site

Home Institution if Other:

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Ebbs, Lisa

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Throop on belowground studies

Years of schooling completed: Sophomore

Home Institution: Same as Research Site

Home Institution if Other:

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Johnson, Eric

Worked for more than 160 Hours: Yes

Contribution to Project:

Brown University REU student working with Sala on ANPP and rainfall study

Years of schooling completed: Other

Home Institution: Other than Research Site

Home Institution if Other: Brown University

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: Ricketts, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

working with Monger on soil studies

Years of schooling completed: Junior

Home Institution: Same as Research Site

Home Institution if Other:

Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree

Fiscal year(s) REU Participant supported: 2007

REU Funding: REU supplement

Name: O'Brien, Orfhlaith

Worked for more than 160 Hours: Yes

Contribution to Project:
REU from Brown working with Sala on NPP-rain addition/rainout study (2008)

Years of schooling completed: Sophomore
Home Institution: Other than Research Site
Home Institution if Other: Brown University
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2008
REU Funding: REU supplement

Name: Fitzgerald, Allison
Worked for more than 160 Hours: Yes
Contribution to Project:
REU student working with D. Bailey on black grama genetics project (2008)

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2008
REU Funding: REU supplement

Name: Holcomb, Patrick
Worked for more than 160 Hours: Yes
Contribution to Project:
Role of plant-fungal interactions on plant performance. New Mexico State University - Lucero.

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2008 2008
REU Funding: REU site award

Name: Webb, Frank
Worked for more than 160 Hours: Yes
Contribution to Project:
worked with Ed Fredrickson (Co-PI) and Raul Peinetti (postdoc) to synthesize animal data as input parameters and testing of new animal dynamics model. Collected data in field for testing animal responses to different vegetation-soil conditions. (2008)

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other:
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2008
REU Funding: REU supplement

Name: Easter, Shane
Worked for more than 160 Hours: Yes
Contribution to Project:
Brown student working with Sala on studies of root responses to long-term changes in precipitation (2011)

Name: Fuchs, Miriam
Worked for more than 160 Hours: Yes
Contribution to Project:
Brown student working with Sala on studies of soil respiration responses to long-term changes in precipitation (2011)

Name: Gurnea, Danielle

Worked for more than 160 Hours: Yes

Contribution to Project:

Worked with Jon Hunner (collaborator in History Department) to edit and prepare the '1912' manual and to support presentations for Centennial Saturday. This effort was the first by the JRN to collaborate with the History Dept, and is being conducted as preparation for the Centennial Celebration for the state of NM in 1912.

Organizational Partners

USDA ARS JER

Houses Jornada Basin LTER main office and laboratories. Provides salary for lead PI and ARS scientists working on the LTER. Collaborative research with other ARS scientists.

Chihuahuan Desert Nature Park

The CDNP is our partner in K-gray educational outreach programs. The CDNP coordinates the Schoolyard LTER program with schools in the region, operates field trips and classroom visits to relate LTER science to students and teachers, direct summer workshops for regional science teachers, and conducts on-site events for the public.

USDA NRCS

Provides collaborative research through activities of Joel Brown and Arlene Tugel, NRCS scientists housed in the same building as the LTER.

USDI BLM

Provides collaborative research on state-and-transition models (Bestelmeyer) and monitoring of vegetation and soils (Herrick, Havstad).

University of Sheffield

Office space, computer, and salary support to Parsons and Wainwright.

Brown University

Provides office space, computers, and salary for Sala and his students.

University of California at Los Angeles

Provides office space, computers, and salary support for Okin and his students.

Duke University

Provides office space, computers, and salary support to Schlesinger (2006-07).

University of Arizona

Provides office space, computers, and salary support to Archer and his students.

New Mexico Institute of Mining and Technology

NM Tech provides office, computer, and lab support for E. Vivoni to participate in the JRN LTER

Arizona State University

provides support for Vivoni and Sala

NMSU Spatial Applications Research Cente

Other Collaborators or Contacts

World Wildlife Fund, Chihuahuan Desert priority program: sharing information and data regarding patterns of biodiversity and ecological threats to biodiversity.

The Nature Conservancy, Las Cruces office: conservation planning.

UNAM: collaborations with scientists at the Mapimi Biosphere reserve, Mexico.

INIFAP: collaborations with Dr. Alicia Melgoza in Chihuahua, Mexico.

Institute of Ecology and Botany, Vacratot, Hungary: collaborations with Drs. Edit Kovacs Lang and Gyuri Kroel Dulay.

CARSAME (Center for Applied Remote Sensing in Agriculture, Meteorology, and the Environment): collaborations with Dr. Max Bleiwess.

INRAM (Institute for Natural Resource Analysis and Management): NMSU lab for equipment and soil analyses.

University of New Mexico: collaborations with Scott Collins and others on cross-site research.

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:
Teacher training workshops each summer directed by the Chihuahuan Desert Nature Park, including participation by LTER scientists.

Outreach Activities:
see Activities file

Journal Publications

Abrahams, AD; Gao, P, "A bed-load transport model for rough turbulent open-channel flows on plane beds", EARTH SURFACE PROCESSES AND LANDFORMS, p. 910, vol. 31, (2006). Published, 10.1002/esp.130

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Web/Internet Site

URL(s):

http://www.ecotrends.info

http://jornada-www.nmsu.edu

Description:

The EcoTrends web site was funded by a supplement to the Jornada LTER, and is a joint project with the LTER Network Office, and collaborations with all 26 LTER sites. More than 20,000 long-term datasets are accessible on this website.

The P2ERLS web site was partially funded by the Jornada LTER. This web site contains general information about >600 research sites located globally. P2ERLS is a portal in that it proves users the ability to search for research sites using defined criteria, and then link to those sites.

The Jornada Basin LTER web site delivers data and associated metadata, and ancillary information about the people and research being conducted at the site.

Other Specific Products

Contributions

Contributions within Discipline:

The original resource redistribution framework for desertification that was articulated by Jornada researchers in the late 1980s has been a primary conceptual model for ecosystems research in arid and semiarid systems globally. The concept that shrub dominance in former grasslands establishes and exacerbates patchiness in soil resources and provides a positive feedback to shrub dominance has stimulated research at the Jornada and many other sites globally. More recently, our landscape linkages framework expands on the plant-interspace model to explicitly include other spatial scales by focusing on transport processes that connect patches. This framework has been successfully used to explain historic patterns that could not be explained with the simple plant-interspace model of Schlesinger et al. (1990). Recent publications describe the landscape linkages framework and new insights provided by it (Peters et al. 2004. PNAS; Peters et al. 2006. BioScience). This framework has also provided new insights beyond desertification with a focus on cross-scale interactions (Peters et al. 2007. Ecosystems) and expansion of the framework to the continental scale (Peters et al. 2008. Frontiers in Ecology and the Environment).

The Jornada Basin has long been a key location for empirical studies of shrub invasion and desertification. The infrastructure provided by the

LTER program has facilitated the Jornada's status as a premier location for desert ecology studies.

Key findings from our long-term studies illustrate the pace of response of desert organisms to environmental drivers and disturbance.

Contributions to Other Disciplines:

LTER research on desertification has promoted an understanding by soil scientists about the development and properties of arid-land soils that influence their resilience and resistance. LTER research has been particularly important in allowing geomorphologists and soil scientists to explore the feedbacks between soil properties and vegetation cover over a range of temporal and spatial scales. Range managers are using LTER research to develop State-and-Transition Models for millions of acres of land in the western US.

Jornada research is contributing to the development of Earth system science and the understanding of phenomena linked to global environmental change. Specific examples include interactions between desertification and the generation and export of dust that feeds back to influence ecosystem processes. Recent research on inorganic carbon at the Jornada is increasing knowledge about global carbon balance.

Jornada research is actively supporting the development of remote sensing technology and analysis. Remote sensing in arid regions has traditionally been constrained by technical difficulties (e.g., predominance of the soil surface signal), but the vast expanses of relatively inaccessible arid lands with significant large-scale variation will demand improved remote sensing techniques. Ground truth data and extensive process-level studies are available at the Jornada for cross-referencing with remotely sensed imagery from aerial and satellite platforms (e.g., JORNEX). There are few such well-studied locations in semiarid and arid regions of the world, thus the Jornada will continue to make important contributions to this field.

Contributions to Human Resource Development:

The Jornada LTER and associated projects support several postdoctoral researchers, and attract visiting scientists supported by other institutions. We typically house 2-3 visiting scientists for 3-12 months each year. The program typically directs 6-12 graduate students each year working on LTER-related questions. The program also supports 2-4 REU students each summer, NMSU is a minority, Hispanic-serving institution, and we routinely include minority and female students in our REU program. In addition, Jeff Herrick is active as a mentor in the SEEDS (Strategies for Ecological Education and Development) program for the Ecological Society of America, a Mellon Foundation-supported program that recruits and supports students of color in ecology.

Contributions to Resources for Research and Education:

Jornada headquarters has a fiber optic and T-1 connectivity supported by an LTER supplement. Renovations of a historic building at the site (Turney House) provided a small meeting room and limited office space. The Jornada GIS and spatial database maintained by the JRN site office are being increasingly used by local and visiting researchers for selection and coordination of field sites. The LTER site bibliography with search/query capabilities are increasingly used by students, instructors, and researchers. The EcoTrends web site is being used by educators from other institutions for classes and demonstrations on the value and importance of long-term data to understanding environmental change.

Contributions Beyond Science and Engineering:

LTER research findings have been used in the development of assessment and monitoring methods for semiarid and arid ecosystems. Much of the American west comprises such systems, thus there is substantial and contentious debate over the appropriateness of particular land uses and their impacts on ecosystem and economic sustainability. Our applications provide tools needed by regulatory and land management agencies as well as individuals.

Human populations and land use patterns are changing rapidly globally, and in particular in the American Southwest. Jornada research provides a basic understanding of the limits to management of livestock in these systems. Moreover, Jornada research on biodiversity, rangeland air and water quality, and other aspects of human-environment interactions are being used in regional efforts to understand and manage other human activities in arid systems beyond livestock production.

Our Schoolyard LTER program and affiliated educational programs are explicitly attempting to improve the rigor and appeal of scientific education and literacy at the K-12 level. We operate in a region of the US with largely poor, minority populations: Las Cruces school are 50-80% Hispanic with 60-90% of the students qualifying for free or reduced lunches. Thus, our program addresses scientific literacy at early stages for a diverse, under-served population.

Conference Proceedings

Special Requirements

Special reporting requirements: None
Change in Objectives or Scope: None
Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Any Product
Any Conference

JORNADA BASIN LTER ACTIVITIES (2006-2011)

Overview: The Jornada Basin LTER program has maintained a long-term focus on desertification, encompassing both mechanics and consequences. Through the first three funding cycles, our conceptual model highlighted fine-scale spatial heterogeneity of both biotic and abiotic elements of semi-arid and arid ecosystems. Our focus was on the redistribution of soil resources at the plant-interplant scale – the Jornada "teeter-totter" desertification model. In LTER IV, we embarked on a new framework aimed at a better understanding of the consequences (and interactions with other agents of global change) of desertification, and of integrating our approaches to better understand redistribution processes and consequences at multiple scales. In LTER V, we are furthering our understanding of these multi-scale processes that lead to cross-scale interactions. In particular, we are interested in the degree to which redistribution of resources (soil, nutrients, water) and propagules form the basis of linkages among spatial units across a range of scales, and explain spatial and temporal variation in patterns and dynamics across the Jornada Basin and throughout the deserts of the American Southwest.

I. Synthesis activities

A. Conceptual framework development, team building, and new connectivity experiment. Based on comments by the site review team in 2003, we spent a considerable amount of time prior to writing our LTER V proposal discussing: a unifying framework, collaborative research, and multi-scale experiments that would integrate all parts of our research. We met at least monthly, and often more frequently, to discuss the framework and overall hypotheses, and to develop specific testable hypotheses. We had four major PI meetings: one in Cloudcroft, NM in November (2004) and three in Las Cruces, NM in May and July (2005), and April (2007). We agreed on an overall design and hypotheses for our integrated experiment as well as teams of researchers to work on various aspects of the design. Our group became much better integrated as part of this planning process. Two major papers were published describing these ideas (Peters et al. 2004. PNAS, Peters et al. 2006. BioScience). We advertised nationally for three GRA positions that we filled by spring 2007. These students participated in the April 2007 science meeting, and are very quickly contributing to the new and exciting science being developed by our group. Our focus is the importance of connectivity and resource redistribution to landscape complexity across a range of scales, from individual plants to the entire Jornada Basin. We initiated a pilot study in 2007 to test basic assumptions about experimental design and methods to increase or decrease connectivity in resources at multiple scales. We should be in an excellent position to begin our full integrative cross-scale experiment in early 2008.

2007-08
Our goal is to develop an experiment to test the relative importance of broad-scale drivers (drought) and fine-scale redistribution of water, soil, and seeds via connectivity by water and wind on the ability of grasses to persist through time despite encroachment by shrubs. Because our methods are novel, we are testing two key aspects using pilot studies in 2007-08. We expect to initiate the full design in 2009 in grass-shrub ecotones at the Jornada and at the Sevilleta. After we have tested these two main components independently, we will design an experiment that

combines large rainout shelters with fine-scale changes in connectivity of resources within each shelter.

First, we are testing our ability to modify connectivity via the flow of water and wind at the patch scale. We installed small connectivity obstructions (50 cm tall, 50 cm wide) constructed of hardware cloth in three locations expected to differ in the effects of wind versus water erosion and deposition. Obstructions (ConMods) were located in bare interspaces ca. 1m wide within areas ca. 10 m x 10m. Locations were on a sandy soil dominated by mesquite where wind is the primary vector, and two thin, rocky soils dominated by creosotebush where water is the primary vector: one on a stable surface and the other on an eroding surface. Initial observations show that the obstructions are successful in catching sediment and litter moved by either wind or water. Measurements and photos are being used to document the effects of obstructions. Future studies will determine the number and spatial arrangement of obstructions required for maximum entrapment of material. Our goal is to reduce connectivity of shrubs and bare interspaces thereby increasing connectivity of herbaceous plants. We expect that the accumulation of material under the obstructions will result in feedbacks to seedling establishment such that grasses will become established and grow through time. The result would be a decrease in the areal extent of the bare interspaces and a greater capture of water and materials by the herbaceous plants; thus reducing erosion by wind and water.

Second, we are testing our ability to modify the broad-scale driver of water using large rainout shelters. Small shelters (< 2 m2) are being by Sala and others in a number of herbaceous ecosystem types, including at the JER. We needed to test the durability and microclimatic effects of much larger shelters (300 m2) built by modularizing the Sala design. Large shelters are needed such that connectivity can be manipulated within each shelter using our small obstructions. We installed two large (10m x 30m) rainout shelters based on the Sala design below, but modularized to cover a much larger area. Shelters were constructed in summer 2008: one in a mesquite dominated area with a small amount of grass cover, and one in a mesquite-black grama codominated area. Shelters are being monitored following extreme rain and wind events, and instrumented for soil temperature, soil sediment flux, soil moisture, and light and UV penetration compared to control plots.

2008-09

Based on our pilot studies last year, we made two important decisions. First, we decided that ConMods are effective at trapping litter and seeds such that positive plant-soil feedbacks may be initiated through time. Second, we decided that large rainout shelters are not feasible on the Jornada. Strong wind gusts resulted in major damage to pilot structures, and resulted in the lack of attachment of roofs. We also had major concerns about the amount of water running off large shelters, and our ability to redistribute this water in an effective manner to avoid damage to rainoff plots and to evenly distribute water to rain-on plots. Thus, we designed a multi-scale experiment to take advantage of spatial variability in rainfall across the Jornada. In our manipulations, we are focusing on reversing shrub-dominated states to a mosaic of grasses and shrubs to grass-dominated states.

2010-2011

The LTER established these plots in 2010-2011, and conducted initial vegetation and soil measures. Plots were located across a 10,000 ha area at the Jornada on predominantly sandy

loam soils with similar temperature and rainfall. Vegetation contains a mixture of perennial grasses (primarily black grama, Bouteloua eriopoda) and shrubs (honey mesquite, Prosopis glandulosa). The area was dominated by black grama grasslands in the 1850s, and converted to dominance by honey mesquite since that time. Ongoing soil sampling and GIS studies suggests that there is no inherent reason that existing black grama grasslands cannot be converted to mesquite or vice versa. Livestock grazing is excluded from this area for this initial study to focus on climatic effects and to minimize damage to sensors. Herbivory by native grazers (typically <10% of plant production) will not be excluded. We are focusing on reversing shrub-dominated states to a mosaic of grasses and shrubs to grass-dominated states. Manipulations will be conducted in plots with similar soils in the primary rooting zone (0-30 cm) and similar total vegetation cover, but a variable proportion of grass and shrub cover that is related to gap size distribution. We are using our Unmanned Aerial Vehicle (UAV; 6 cm resolution) and Quickbird imagery to identify a large number of plots that fit our criteria. From these plots, 15 locations are randomly selected to characterize a gradient in grass and shrub cover (i.e., gap size distribution). Four 15m x 25m plots are randomly selected at each location, and each plot is randomly assigned to one of four connectivity treatments: (1) at the plant scale, shrubs will be killed to modify competitive interactions between grasses and shrubs, (2) at the patch scale, small barriers will be added to reduce gap size and modify movement of water, soil, nutrients, and litter to promote grasses, (3) both patch- and plant-scale manipulations will be conducted, and (4) no manipulations [controls]. The plot size was tested in a pilot study to be sufficient to include three large bare gaps between shrubs.

We expect that our plant- and patch-scale manipulations will modify wind and water redistribution of materials with resulting modifications to water and N availability. Because water redistribution is not uni-directional on this nearly level topography, but occurs at fine scales between individual plants or patches, plots are oriented in the direction of the prevailing wind (SW to NE), and gaps in each plot are identified as upwind, focal, or downwind. Initial conditions are currently being characterized, however, treatments will not be conducted until fall 2011 to allow characterizations needed for this proposed study. Plant-scale manipulations (+WPl). We will kill all mesquite plants from plots in the plant-scale treatments to reduce competition for soil water and N with grasses. Based on previous studies, mesquite plants will be killed using a direct application of a clopyralid herbicide to each plant in late spring after leaf out. We will minimize soil disturbance and keep dead shrubs in place to avoid increasing gap size. Killing mesquite effectively reduces live plant cover with a direct effect on biotic processes. Because mesquite will not be removed, their mortality has no direct effect on gap size or transport by wind and water. Patch-scale manipulations (+WPa). Each bare soil interspace will be divided into 1 m2 grid cells, and a 50cm wide x 75cm tall obstruction (ConMods: Connectivity Modifiers) will be placed within each cell. ConMods effectively reduce the size of bare gaps, but because they are metal, they do not increase the cover of living plants and do not directly affect biotic processes. Previous studies have shown that gap sizes <= 0.5 m are sufficient to minimize erosional losses. Reducing bare gap size below this threshold will allow the accumulation of litter, seeds, and soil to modify the microclimate and stabilize the soil surface sufficiently to allow plant establishment and to initiate plant-soil feedbacks. Obstructions will be located in the focal gap for treatment plots. Repeat photos of each ConMod will be used to estimate fractional vegetation and litter cover using image processing techniques without removing material.

Aboveground ecosystem responses being collected include aboveground net primary production (ANPP), and cover by plant species and litter using line point intercept (LPI) methods from two 20-m long lines located 5 m apart that cross all three gaps in a plot. Biodiversity based on species richness will be obtained from the LPI data. All measurements will be identified as to their spatial location (upwind, focal, downwind gap). We will also measure height of 10 randomly selected shrubs and perennial grasses inside each plot to correlate with sediment movement by wind. Initial measurements will be obtained in fall 2010, and at peak growth (Sept.) each year. ANPP will be estimated from LPI using standard methods. Seedlings will be counted in sub-plots at the same time as LPI measurements. Surface soils (0-5cm) will be collected in year 3 from each plot, and placed in a greenhouse where seedlings will be counted by species. In collaboration with USDA, a patch mosaic UAV map in year 3 will be used to help interpret spatially-explicit responses in plots and to determine changes in gap size distribution. Landscape metrics including directional connectivity, and gap-size distribution will be calculated in 300m x 300m areas around each plot to account for the potential influence of broad-scale aeolian processes on vegetation dynamics. Quickbird imagery will be used to assess broad-scale changes in vegetation cover and gap size distribution. We submitted a proposal to the NSF Ecology Program to fund the water, wind, and nitrogen studies.

B. Simulation modeling. Another major integrative effort has been to combine the various simulation models.

2006-07
Peters, Parsons, Wainwright, and Herrick have been working to incorporate water redistribution models at fine to patch scales with ECOTONE, our vegetation dynamics model. Peters has also been working with Okin and Herrick to incorporate wind redistribution models at fine to landscape scales into ECOTONE. Fredrickson and Peters are working with an USDA ARS postdoc (Raul Peinetti) to develop an animal redistribution and energetics model to link with ECOTONE. The linked models, called ENSEMBLE, will be used to both understand historic patterns and to predict future dynamics under changing environmental conditions.

2007-09
We used a soil water dynamics simulation model to examine the effects of changes in vegetation from grasslands in 1858 to shrublands at present on seedling establishment of black grama, our historic dominant grass. We found that establishment in general declined with shrub dominance, and that thin, rocky soils dominated by creosotebush had larger declines than sandy soils dominated by mesquite. We also conducted simulations to examine the importance of changes in soil properties on seedling establishment. Our manuscript describing these results was recently accepted for publication in Journal of Arid Environments. Our next step is to simulate deposition or erosion of soil from the surface which will require dynamic soil layers, and will add a new complexity to the model.

2010- 2011
We continue to work with Raul Peinetti (Argentina) to develop an animal model to link with Ecotone. A manuscript describing a functional approach to modeling animal behavior that also integrates and synthesizes many of the livestock studies at the Jornada was published in Ecosphere in 2011.

Okin and Peters continue to work to combine the wind model (SWEMO) with the vegetation-water dynamics model. We are working on creating output files from each model that will be input files to the other model. In addition, Ecotone operates at a fine scale (1 m^2 plots) such that the results from many plots will need to be aggregated and the distribution of plants and bare soil interspaces can be used as input to SWEMO. Similarly, SWEMO output of wind erosion-deposition will need to be distributed spatially from 30m x 30m plots down to 1 m^2 plots in Ecotone.

C. Synthesis activities and products. We have been actively engaged in synthesis activities leading to major products. In addition to publishing our LTER Synthesis book and the EcoTrends book, we have led special issues in 5 different journals since 2006.

2006-07

(1) We published a special issue in 2006 in the ***Journal of Arid Environments*** based on our new conceptual framework. A total of 10 papers were published in this issue based on Jornada research.

(2) Our **LTER synthesis book** was published by Oxford University Press in June 2006. This book summarizes much of the work from LTER I-III, and provides an introduction to and justification for our new conceptual framework started in LTER IV.

(3) We coordinated a special issue ("Cross scale interactions and spatial heterogeneity: consequences for system dynamics") published in ***Ecosystems*** in late 2007 that extends the Jornada cross-scale framework to other sites and systems. This issue contains papers from two LTER sites (Virginia Coast Reserve [Young], Luquillo [Willig]), a paper from Australia (J. Ludwig), two fire-related papers (C. Allen, Falk), and a paper on animal metapopulations (Schooley).

(4) We led a special issue published in 2008 in ***Frontiers in Ecology and the Environment*** on continental-scale research that will draw heavily on LTER network-level science. This special issue consisted of the following 7 papers; each paper has at least one LTER scientist as an author:

Debra Peters, Peter Groffman, Knute Nadelhoffer, Nancy Grimm, Scott Collins, William Michener, and Michael Huston, "Living in an increasingly connected world: a framework for continental-scale environmental science"

John Marshall, John Blair, Al Rango, Mark Williams, Debra Peters, and Syndonia Bret-Harte. "Forecasting Ecosystem Responses to Climate Change and Variability at Regional-to-Continental Scales"

Todd Crowl, Bob Parmenter, and Tom Crist. "The Spread of Invasive Species and Infectious Disease as Drivers of Ecosystem Change Across Regional and Continental Gradients of Climate and Land Use"

Nancy Grimm, David Foster, Peter Groffman, Morgan Grove, Charles Hopkinson, Knute Nadelhoffer, Diane Pataki, and Deb Peters "Land Change: Ecosystem responses to urbanization and pollution"

Chuck Hopkinson Ariel Lugo, Merryl Alber. "Forecasting effects of sea level rise and catastrophic storms on coastal ecosystems"

Craig Williamson, Tim Kratz, Walter Dodds, Margaret Palmer. "Forecasting aquatic system dynamics at regional to continental-scales"

2007-08
The special issue was published in June 2008. Peters was interviewed by Ken Ferguson of Beyond the Frontier, a monthly podcast by ESA (http://www.eas.org/podcast); Dan Kulpinski of Earth and Sky, a radio podcast (http://www.earthsky.org); and Steve Barnett of the Paradise Parking Lot (http://www.prncomm.net).

(5) We have been leading the ***EcoTrends Project*** since its inception in 2004. EcoTrends currently includes long-term data (> 10 year record) from all 26 LTER sites and an additional 24 sites supported by other agencies (USDA-FS, USDA-ARS, DOE, USGS). After much deliberation, we decided to use the USDA ARS government publishing office for the EcoTrends book rather than Oxford University Press. This decision will: minimum the purchase cost of each book, allow free distribution and download of pdfs from the entire book or separate chapters, and maintain the creativity of the editors in putting together content. We have been actively populating the database as the revised datasets are returned from the PIs. We continue to work with the LNO to update the EcoTrends web site to improve its ease of use and accessibility by a broad range of users. The web site was open for public access with >20,000 long-term datasets prior to the All Scientists meeting in September 2009.

2010-2011
In May 2010, we submitted the EcoTrends book to the USDA ARS government publishing office. In addition, a paper was published in Trends in Ecology and Evolution that describes EcoTrends as a first step in developing a synthesis framework for cross-site comparisons.
We also worked to create science products with data in EcoTrends. In 2009, we received $25,000 in travel support from the LNO for 5 EcoTrends science groups to meet and work on cross-site products related to data in the database. One working group (Disturbance) published a cross-site synthesis paper in Ecosphere in 2011. A second working group on state changes recently submitted a cross-site synthesis manuscript to Ecosphere. In June 2011, the EcoTrends book was in the design and layout process at the USDA publishing office. The book has passed all approval stages for a USDA product. We are still hoping for a 2011 publication date. We recently moved the EcoTrends web site from the LNO to NMSU, and registered it under the Jornada LTER. Using supplemental funds from last year, we hired an R programmer (Katie Merth) to evaluate all of the R scripts used to check the datasets and to create the derived data products. Katie is working her way through the scripts to make them more efficient, and to provide detailed documentation of how the script works, the source dataset it is associated with, and the derived data products that it creates.

(6) We are also developing a ***web portal*** _____to allow easy access to information about ecological research sites globally and links to their web sites. This "network of networks" (Pole to Pole Ecological Research Lattice of Sites: pronounced pearls) will promote collaborative research across a range of scales, from regions to continents and the globe. We now have >600 research sites in our P2ERLS database. These sites span the globe and are not restricted to the US. Because the data required for a site to be added is few (latitude, longitude, mean annual precipitation, mean annual temperature, elevation, ecosystem type, land owner, and research program), we expect many more sites to be added through time. The search engine is complex because of the possible combinations of these relatively few variables, but is powerful in allowing users access to many sites globally.

(7) **Other synthesis activities**
2009-2010
Vivoni was the lead guest editor on a special issue to ***Journal of Arid Environments*** entitled Land Surface Ecohydrology of the North American Monsoon System (published May 2010, vol. 74, issue 5). Twelve papers and a preface were published and synthesized work at sites in Arizona (Santa Rita), New Mexico (Sevilleta, Jornada), Mexico (Rayon, Tesopaco) as well as the broader US/Mexico border area. This unique issue brought together ecologists, hydrologists and atmospheric scientists from the US and Mexico to discuss recent research results in the region.

2010-2011
We (B. Bestelmeyer, Havstad, Estell [USDA]) are leading a special issue to be published in the ***Rangeland Ecology and Management (REM) journal,*** entitled "Forum: 'Big questions' emerging from a century of rangeland science and management". In recognition of the 100th anniversary of the USDA Jornada Experimental Range and the 30th anniversary of the Jornada Basin LTER in 2012, the May 2012 issue of REM will be devoted to a set of invited forum papers that are conceptual in nature and provide an informative summary of contemporary topics or alternative views of contentious issues. Paper topics and authors were selected to address a body of interrelated and controversial questions at the interface of developments in rangeland science and changes observed in rangeland use and policies over the last century. The topics were selected to represent a range of critical issues/questions in different research areas. The collection of papers captures both the historical development of these questions and provides timely, forward-looking perspectives on the role of rangeland science (and its limitations) in resolving them. Such a collection of forum papers does not currently exist within the rangeland literature, yet would provide greater focus on key issues within the discipline. The collection of topics should also generate considerable interest both within and outside of the rangeland management community. The Issue includes 12-14 papers that reflect a set of interrelated, controversial ideas in modern rangeland management, with an introductory synthesis on the history of science approaches in rangeland management and a concluding synthetic reflection on the body of papers. Jornada scientists are either leading or co-authoring many of these papers.

II. Specific Activities

A. Vegetation dynamics

1. Spatio-temporal patterns of state transitions [B. Bestelmeyer, Archer]. Years of high rainfall may catalyze significant, long-term effects on the trajectory of arid ecosystems. In 2007, we initiated a new study to document the occurrence of perennial grass-dominated areas and establishment patterns of grasses and shrubs following the unprecedented rains of 2006 (in many cases 100% above average) and relatively wet spring of 2007. The landscape-wide inventory will be used to build statistical models of where recruitment did and did not occur as a function of soils, vegetation state, and landscape context. Selected plots will be used to monitor where recent recruitment events result in permanent, transient, or no change in vegetation structure. A rapid assessment of a large number of plots will be used to quantify the contributions of landscape variables to the characteristics and occurrence of vegetation states, and will serve as a basis for additional experiments. Long-term monitoring in selected plots will be used to test the hypothesis that establishment and community dynamics differ in distinct landscape contexts. Data collected at the plot scale will be coupled with analysis of high-resolution imagery of shrub and perennial grass patch structure. In addition, results from this pattern analysis will be used to assist in the location of future multi-scale connectivity experiments.

We are using a variety of geospatial data (landform, soils, geographic spread, road proximity) to select ca. 200 points spread across two geomorphic units at the Jornada (sand sheet, transition zone) where grass recruitment occurred. Samples were stratified according to soils, geomorphology, and climate heterogeneity estimated via changes in the Normalized Difference Vegetation Index based on MODIS imagery (September 2005 vs. September 2006). This analysis is being used to identify parts of the Jornada where production was relatively high vs. low due (largely) to the distribution of rainfall. Soil, landform, and vegetation-type maps will also be used to identify strata. Permanent plots will be 20 x 20 m. Vegetation cover and recruitment levels will be photographed and estimated using standardized ocular procedures or using line-point intercept procedures. Soils will be characterized to using a soil auger and field estimates (following National Cooperative Soil Survey protocols) to estimate A horizon texture, B horizon texture and carbonate accumulation, and calcic horizon development in lower B horizons. A horizon samples and samples with maximum clay accumulation will be further subjected to particle size analysis. Aerial photography gathered as part of the JORNEX project will be classified to vegetated and non-vegetated classes in Erdas Imagine, and used to extract landscape variables for each plot including bare ground connectivity, directional connectivity with respect to prevailing winds, and area of vegetation around each plot at several scales. Logistic regression and classification trees will be used to statistically evaluate effects of local and landscape variables on recruitment patterns and vegetation structure.

2007-08

About 150 plots were sampled in 2007, and resampled in 2008 for grass survival. Initial modeling will take place this fall coupled with repeat aerial photo processing. We are analyzing these data as part of Darroc Goolsby's PhD project. Darroc presented these results at the 2009 ESA meeting.

2008-09

In 2009, we mapped states and transitions across the study area from 1946 to 2003 to provide a broad-scale and long-term spatial context for the ground points. We also resampled vegetation cover on transects first sampled in 2002 and 2003 to evaluate changes in grass cover resulting from the 2006-2008 high rainfall years. We found that black grama cover increased over 3-fold in some shrubland sites where remnant grass cover remained. In other similar shrublands, black grama cover did not change but other perennials (largely Sporobolus bunchgrasses) increased instead. These measurements indicate that the high rainfall period caused at least temporary restoration of perennial grass cover in areas believed to be very close to an irreversible desertification threshold.

2009-2010

We added mapping data derived from 1974 aerial photographs to complement the 1946 to 2003 maps. These data provide evidence that transitions from grassland to mesquite dunes is contagious but not directional with regard to the prevailing winds**.** We also initiated historical reconstructions of NPP data gathered in different pastures to examine how historical threshold changes were related to utilization rates and rainfall. Data on NPP and utilization were collected from historical records from 1934-1970.

2010-2011

This year, we conducted data analyses relating the patterns of spread observed in the aerial photography to ground-based point data on soils and historical maps of vegetation. We are also establishing a new mechanistic study testing the causes of observed spatial patterns using studies being conducted by UA graduate student Nate Pierce. Demographic bottleneck models of savanna vegetation dynamics and woody plant encroachment propose that shrub proliferation is constrained by climatic variability and disturbances that inhibit shrub germination, establishment, or transition to a later life stage rather than post-disturbance resource competition with established neighbors. The objective of this experiment is to quantify the extent to which grasses and established shrubs influence germination and early establishment of mesquite (*Prosopis glandulosa*) seedlings. This objective will be addressed by testing the hypothesis that grass abundance or the density of established shrubs regulates recruitment of *P. glandulosa* seedlings. If this hypothesis is supported, then *P. glandulosa* recruitment should be greatest in bare zones (gaps) between grass patches and will decrease as gap size decreases and proximity to grass patches increases. Additionally, in areas where adult *P. glandulosa* plants occur, seedling recruitment will decrease with increases in the size/density of established shrubs. Known numbers of scarified *P. glandulosa* seeds will be placed within, next to, and between grass-dominated patches. The distance to and size of established *P. glandulosa* shrubs will be recorded. The structure of the grass patches (tiller density, height) and area of non-vegetated interstitial zones (gap size) will be quantified. Seeds will then be monitored for germination and subsequent seedling survival.

In July, 2010, mature *P. glandulosa* pods were collected from different areas on the JER. Approximately 25 kg of pods (dry weight) were harvested. Between May and August, 2011, seeds were manually extracted from some of the dried pods, and seed viability was evaluated. After 7 days, the number of germinated seeds was counted. A total of four repetitions of this process were carried out (total seeds tested = 200) to result in a 96% germination rate. Seeds will be disseminated into experimental plots in August/September 2011. Germination and mortality will be monitored daily for 7 days, every other day during days 8-21, and then less regularly over

subsequent weeks. Non-germinated seeds and established seedlings will continue to be monitored for the following two growing seasons (2012-13). The experiment will be replicated in time during summer 2012.

2. Mechanisms of state transitions and threshold dynamics [B. Bestelmeyer, Duniway]. The Threshold Experiment, initiated in 2010, is a new long-term experiment to test the mechanisms of threshold dynamics in Chihuahuan Desert grassland. Theory suggests that once vegetation patch mosaics become sufficiently fragmented by either reduced resource inputs (e.g., drought) or disturbance (e.g., grazing), the breakdown of positive feedbacks leads to collapse of the remaining vegetation patches. In particular, ecohydrological feedbacks are thought to drive aridland thresholds. Large, dense vegetation patches promote local infiltration and capture surface runoff from adjacent bare areas, resulting in sustained biomass production within the patch network. When such patches become fragmented at various spatial scales, reduced infiltration, loss of laterally-redistributed water, and erosion leads to reduced physiological performance and production of grasses, followed by further patch fragmentation. Other parallel feedback mechanisms may operate; fragmented patches may be more susceptible to herbivore disturbance, wind erosion rates increase leading to physical damage to plants, and microclimatic stress on adults and seedlings may increase due to elevated surface temperatures. Mechanistic tests of threshold-feedback theory in aridlands do not exist.

2010-2011

We established 36 measurement locations stratified among 4 experimental units that used grazing intensity to modify black grama cover and patch structure. The measurement locations were classified to microsites that were small patches (< 20 cm across; ES), medium patches (20-60 cm across; EM), and the interiors of large patches (>60 cm across; IL). At each measurement location, we gathered physiological measures of focal black grama plants (plant gas exchange and pre-dawn water potential) following three sizes of rain events: small (< 5 mm), medium (10-15 mm) and large (> 20 mm). We also established measurements of plant demography and soil water status at 180 locations, adding areas of open ground >20 cm from patches and the edges of large patches to the microsite categorization. On all microsites with focal plants, we monitored tiller length, including evidence of herbivory, on 5 tillers (or fewer for small plants). We tallied all stolons and ramets produced by each focal plant, including whether the ramets are rooted (established) or not. Reproduction by stolons is the primary mode of reproduction in black grama. Additionally, within a 25 cm radius from the center of each plant, we counted all stolons, ramets, and rooting events that may be due to the focal plant and adjacent individuals. Measurements were conducted twice per year, at the beginning (April) and end (October) of the growing season. For each focal plant, we also estimated the percentage of green biomass once each month throughout the growing season as an estimate of season-long photosynthetic activity. At each microsite measurement location, we initiated measurement of soil water content every ½ hour at a depth of ca. 5 to 10 cm using soil moisture sensors connected to a multiplexer and data logger.

2. Remediation of grasslands [Abbott]. Large-scale degradation has resulted in widespread conversion of Chihuahuan Desert grasslands to shrublands dominated by honey mesquite (*Prosopis glandulosa*) on sandy soils. Efforts to control mesquite and re-establish native grassland vegetation have had limited success, possibly because essential water and soil

resources are not retained in mesquite dune-dominated systems. Microcatchments may facilitate restoration of natural processes by reducing soil and water losses from the site. In 2003, we initiated an experiment to determine the integrated effects of vegetation manipulation treatments on mesquite control and grassland restoration at the Jornada. Treatments tested were herbicide application (Triclopyr and Clopyralid), and creation of microcatchments, followed by reseeding in June or August; the experiment was repeated in 2004 using a randomized complete block design. We continue to monitor plant cover and density annually, and soil movement every 3 months. By 2007-08, the vegetation manipulations produced patches with large and small interspace gaps suitable for studying aeolian sediment flux. We plan to sample aeolian sediment flux measurements in plots exhibiting different degrees of connectivity in the near future.

3. Spatial variation in ANPP [Herrick]. In 2007, we initiated a new study at each of the 15 NPP plots representing the 5 major plant communities on the Jornada. This study was designed to address three objectives. (1) Increase our understanding of variability in spatial pattern in the long-term NPP plots. We measured the size distribution of intercanopy gaps along 4 transects in each plot. We will also analyze spatial pattern on high resolution aerial photographs using e-cognition. The information on spatial pattern will be used to compare NPP plots with the plots established in the new connectivity study. (2) To compare vegetation measurement methods as a basis for comparing trends and patterns in the NPP data with other long-term datasets based on plant cover. We measured plant cover and composition using three commonly used field-based approaches: ocular estimates of $1m^2$ quadrats, quadrat point-frames, and a line-point intercept. We repeated these three methods using aerial photographs. (3) To compare among ground-based measurements, and between ground-based and air photo-based measurements to determine the most efficient sampling methods to address multiple objectives in desert environments.

<u>2010-2011</u>

We completed this study in 2008, and published comparisons among field methods in 2009 (Godinez et al. 2009) and between field and two different remote sensing analysis methods (Laliberte et al. 2010 and Duniway et al. 2011).

4. Precipitation controls of carbon and nitrogen cycles [Sala, Peters, Throop]. On a continental scale, a strong spatial correlation between precipitation and aboveground net primary production (ANPP) gives us great confidence that precipitation is the primary driver of ANPP in arid and semi-arid ecosystems. However, as a series of comparable long-term data sets have become available in recent years, the relationship has not held up in a temporal context — annual precipitation accounts for only 20-40% of the interannual variability of biomass production. This failure suggests that researchers are not accounting for key mechanisms that control the ability of arid ecosystems to track fluctuations in precipitation, yet increased fluctuations are a prominent feature of climate predictions in arid regions. Our project is organized around four hypotheses to explain observed lags in ecosystem response to changing precipitation and tests them by altering patterns of total precipitation and precipitation variability, with and without nitrogen manipulation. These manipulations, together with a model analysis, will help determine the cause and magnitude of lags and legacies in the ecosystem response to precipitation. A thorough understanding of the relationship between precipitation and ANPP in these ecosystems is critical to understanding the global carbon cycle, and to predicting changes with expected changes in

climate, which include altered precipitation amount, increased temperature, and increased interannual variability in climate.

We are addressing a question that is central to the dynamics of arid ecosystems: Is water availability truly the most important limiting factor on ecosystem functioning in arid and semiarid ecosystems? We hypothesize that it is, but that indirect mechanisms associated with meristem density, biogeochemical constraints and asymmetric responses of BNPP create lags that mask the production-precipitation relationship. Predicting the response of arid and semi-arid ecosystems to changing climate—and particularly increasing climate variability— requires an understanding of these indirect mechanisms. Four hypotheses guide our experiments: (1) meristem density constrains ANPP; (2) biogeochemical losses constrain ANPP; (3) asynchronous response of BNPP to water availability may offset ANPP variability; and (4) an asymmetric response of production to increases or decreases in precipitation produces unexpected legacies. We are testing these hypotheses with a combination of two manipulative experiments and a simulation modeling exercise, which will integrate experimental results and explore ecosystem responses beyond the spatial and temporal domain of the experiments. Our manipulative experiments is located in pasture 13, where we use passive rainout shelters and irrigation to manipulate incoming precipitation in a range from -80% to +80% of ambient. Nitrogen amendments on half the plots will tell us whether drought-mineralized N is captured by plants or lost from the system. The second experiment—in which we change precipitation variability, but not amount—will explore perhaps the most exciting implication of our hypotheses: that increased precipitation variability has the potential to increase long-term production.

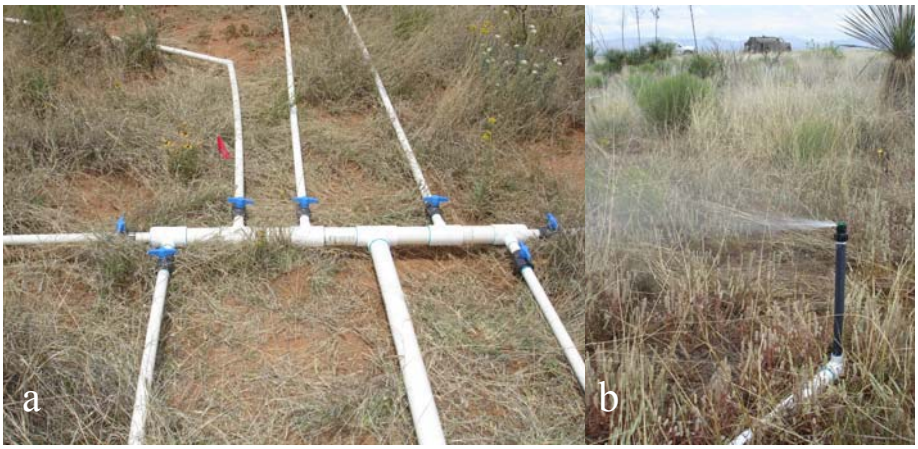
In 2006, plots were established within a 400 ha pasture co-dominated by *Bouteloua eriopoda* and *Prosopis glandulosa.* Three 1-ha exclosures constructed in 1998 are being used to allow replication of treatments, and to avoid effects of grazing and trampling as confounding factors on plant and soil responses. We manipulate nitrogen (N) soil availability (ambient N and increased N) and incoming precipitation ranging from -80% to +80% of controls (five levels of precipitation) using a combination of passive rainout shelters and irrigation. We are using 12 replicates (4 replicates/exclosure) in the water interception and water addition treatments per nutrient level, and 18 replicates (6 reps/ exclosure) in the control treatment per nutrient level, which produces a total of 132 2.5m x 2.5m experimental units.

The rainout shelter design consists of a metal structure that supports V-shape clear acrylic bands. The bands intercept a fraction of incoming precipitation that is then routed outside the plot by a gutter. Different levels of rainfall interception are achieved by modifying the number of bands. We are using two types of shelters that intercept 50% and 80% of the precipitation. To irrigate the plots, we installed a PVC irrigation system that pumps water from a water truck to the desired plot. Rain water is collected from the Jornada headquarters roof to a fiberglass tank that is then transported to the exclosures with a water truck. The shelters were operational starting in 2007.

In 2008, we completed two field seasons of measurements of aboveground measures (meristem density, plant density and cover by species). We reversed treatments in fall 2008 such that drought treatments become rain addition plots and vice versa to examine time lags and hysteresis in responses. Minirhyzotron tubes were installed in a subset of plots in 2007 to monitor root responses (growth, biomass, turnover) to treatments. In addition, we began collecting plant

physiological measurements (water potential, photosynthetic capacity, chlorophyll fluorescence) in response to major rain events.

Rainout shelter that intercepts 80% of the incoming precipitation. Constructed and installed in November of 2006.



Irrigation system made of PVC piping and valves that conducts water to each plot **(a)**. The plots have two sprinklers covering 6.25 m^2 **(b)**. The irrigation system was installed during spring of 2007.

2008-2009

We reversed treatments as planned, so plots that experienced drought in the last two years in 2009-10 now experience wet conditions and plots that had experienced wet conditions now experience drought. Reversing treatments required relocating watering pipes and rainout shelters. Preliminary results show a decoupling of carbon and nitrogen cycling with reduction of precipitation. Whereas, plant growth and N immobilization responded linearly to changes in water availability, N mineralization did not. This differential response to water availability resulted in an accumulation of nitrate in soils that had experienced drought. Analyses suggest there is a slight increase in total root area in the water addition plots relative to controls.

2009-2010

In order to continue with the experiment that studies lags in the response of NPP to changes in the availability of water and nitrogen, we installed root ingrowths cores in all the treatments to complement minirhyzotron measurements of belowground primary production (BNPP). Ingrowth cores and minirhyzotron measurements provided complementary data that assisted us

in testing hypotheses about the effect of previous year rainfall legacies, current year water availability, and N fertilization effect on BNPP. We also buried 4" PVC collars and measured soil respiration with a Licor 6400 through time and across all the treatments. These measurements allowed us to test hypotheses related to changes in soil respiration after a rain event, and also the effects of previous year rainfall legacies, current year precipitation, and N fertilization.

We installed a new large scale manipulative experiment to explore the effect of inter-annual variability of precipitation on primary productivity. In this new experiment, we installed the Automated Rainfall Manipulation System (ARMS) that consists of rainout shelters connected to an irrigation system powered by solar panels (Yahdjian and Sala 2002). The water collected in situ by the rainout shelters is stored temporally in 55 gallon barrels. When the water reaches a certain level, it pushes up a float switch that turns on a 12 volt water pump that starts the irrigation. Our design has three treatments: ambient precipitation, and either +50% or + 80% increased interannual variability. The +50% variability treatment in even years will receive half of the ambient precipitation, and in odd years will receive 150% of ambient precipitation. The +80% variability treatment will alternate years of +180% with years of -20% of ambient precipitation. We have ten replicates per treatment and we will monitor this experiment for 3 years. During spring 2010, we transformed the water and nitrogen interaction experiment into a long-term rainfall manipulation experiment. Long term manipulations include -80%, control and +80% ambient rainfall. Here, we changed the existing irrigation system to an ARMS. The automatic irrigation system will allow us to maintain this experiment with considerable less effort than the previous system where water was transported from headquarters. We also recalibrated soil moisture plots and installed minirhyzotron tubes in plots as part of the long term experiment. We continued with minirhyzotron image analysis of 2007-09 data. A dry monsoon season in 2009 prevented the collection of ecophysiological data since black grama did not green up until September. Analysis for the 2007-2008 ecophysiological data is complete and a manuscript was submitted.

2010-2011

We continued the long-term water manipulation experiment and the experiment designed to assess the effects of precipitation variability. These experiments were deployed in 2006 and 2009. We installed new soil moisture probes in all plots. We used Campbell probes linked to data loggers that provide hourly measurements of soil water. These probes replaced the Ecoprobes installed in 2006 that were measured manually. Soil water is a response variable that changes very rapidly so the new system that provides continuous estimates represents a major improvement in our ability to assess treatment effects on soil water dynamics. We also installed automatic rain gauges connected via radio frequency to headquarters. The new rain gauges represent an improvement because of the high spatial variability in this ecosystem. We monitored ANPP of grasses and shrubs, species richness, and species diversity (Shannon Index) in all plots. We installed flow meters in pipes connecting the shelters with irrigated plots to assess the efficiency of the ARMS. We also measured temperature, radiation, and wind speed inside and outside the shelters to quantify micro-environmental effects of the shelter design.

5. Remote sensing of ANPP and vegetation characteristics [Rango, Laliberte]. Satellite data from Landsat were purchased to study effectiveness of spectral vegetation indices to assess net

primary productivity. JORNEX campaigns were successfully conducted over CDDRC and JER study areas in September and May in every year possible since 2000. We also acquired Quickbird images and purchased two Unmanned Aerial Vehicles (UAVs) to obtain 5cm resolution aerial photography. Fine-scale UAV images are being used to measure gap and patch sizes as well as percent bare soil and vegetation ground cover. One meter resolution remote sensing data are being used to assess the pattern of ecological states while 15-30m resolution data are being used to delineate uniform landscape units.

In 2008, we successfully tested our UAVs in takeoffs, landings, and ability to fly prescribed routes. We also certified our ground crew with the FAA.

In 2009, we flew the UAV system in support of one LIDAR mission flown by NASA, and we also flew over areas at the JER to help in the site selection for flux towers and for disturbance experiments. Imagery was analyzed from prior year data acquisition in Idaho rangeland that showed that the UAV aerial photos produce data comparable to detailed line-point intercept surveys taken on the ground. Once 8 survey sites or plots are exceeded, the UAV data are much more cost effective than the ground measurements.

2009-2010

Based on the 2008 UAV flights in southern Idaho, we published a paper describing UAV-based image acquisition, processing, and analysis in the journal Photogrammetric Engineering and Remote Sensing. This has generated a considerable amount of interest in the UAV community, and Laliberte has been invited to contribute manuscripts to 2 journals running special issues on "UAVs for Remote Sensing" (Geocarto International, GIScience and Remote Sensing).
Image analysis from 2009 UAV flights over the Stressor 2 site has been completed. We collected a large number of field training samples to validate the image analysis. Data from this study and other UAV flights will be used to evaluate classification accuracies for species-level vegetation mapping, adapt field sampling for very high resolution imagery, refine methods for processing and analyzing very large image files, derive parameters for a deterministic hydrologic model (tRIBS), collect repetitive data for a Jornada phenology pilot project, assist in evaluation of disturbance experiments, and provide high resolution images for archeological or historical legacy analysis. In 2010, we purchased a 6-band multispectral camera, which is currently being integrated into the UAV. Laliberte conducted camera calibrations and has developed processing steps and workflows for converting the raw camera data into image formats suitable for further analysis. Test flights with the new camera will begin in late summer/fall of 2010. The narrow-band imagery from this camera will be highly suited for species discrimination.
The proposal for demonstration of UAV technology for rangeland remote sensing submitted by Laliberte in 2009 has been funded. The demo aimed at BLM, NRCS, NPS, and USGS is planned for late 2010/early 2011.

2010-2011

We are continuing to acquire UAV imagery over the Jornada for various projects, including the phenology project (PhenoMet) and evaluation of disturbance experiments. To date, we have acquired 30,000 images that have been processed into 100 image mosaic targeted at various projects. The 6-band multispectral camera (MCA) we purchased in 2010 has been integrated into the UAV and we now have the capability to simultaneously acquire RGB and multispectral

imagery. Multiple test flights have been conducted with the MCA, and we developed sequential processing steps and workflows for band-to-band alignment, conversion from raw to img image format, and radiometric correction. We have tested calibration targets and are comparing ground-based spectrometer measurements (collaboration with Dr. C. Steele) with image spectral measurements. Our work with unmanned aircraft is increasingly being recognized at the national and international level. Laliberte published 2 invited papers on UAVs for remote sensing (Geocarto International, GIScience and Remote Sensing), gave an invited talk at the TAAC UAS conference at Santa Ana Pueblo, and gave the keynote address at the British Remote Sensing and Photogrammetry Society UAV workshop in Durham, UK.

We are also acquiring UAV imagery pre- and post-burn to assess the recovery and fire impacts on black grama and the invasive grass, Lehmann's lovegrass. Image analysis and field validation approaches developed with previous UAV data sets will be applied. RGB and multispectral imagery will be acquired, and ground-based measures will include training samples for classification, estimates of cover and species composition, and ASD field spectrometer data. The multispectral UAV imagery will be radiometrically corrected, so that future imagery can be compared to a baseline. The imagery will also be used by Dr. Archer and his students to assess grass-shrub interactions. We plan to fly this site repeatedly in coming years to assess recovery after the burn.

Researchers at the Walnut Gulch Experimental Watershed (Tucson ARS) are also interested in evaluating spatial invasion patterns of Lehmann's lovegrass using UAV imagery. Members of the UAV team visited the Tucson site in 2010 and began planning for data acquisition. Laliberte obtained a Certificate of Authorization (COA) from the FAA to fly our UAV at Walnut Gulch in 2011 over the Kendall subwatershed. The objectives of the study are to: investigate spatial patterns of grasses, determine spectral separability of Lehmann's and native grasses, and validate the utility of deriving a fine resolution DEM from the UAV imagery. Multispectral and RGB imagery will be used to compare the utility of low-cost and more expensive radiometric targets.

6. Analysis of long-term data sets [Peters, Sala]. We are analyzing our long-term ANPP dataset collected since 1989 to determine if predictions about the relationship between ANPP and species richness found in more mesic grasslands hold true for arid systems.

In 2008-09, we re-examined several key assumptions associated with the conversion of volume to biomass and production that resulted in values that are too high relative to other sites with similar annual precipitation (e.g., the Sevilleta). Based on these analyses, we modified our equations in two ways: (1) we force the y-intercept through 0 in our biomass to volume conversions similar to the Sevilleta equations, and (2) we removed Yucca species from our analyses. Field observations indicate that Yucca species are often measured incorrectly because of their morphology. After modifying our analyses, our ANPP values are now more comparable to other sites with similar precipitation. Additional analyses were then conducted to examine relationships between ANPP and APPT for five vegetation states (grasslands and shrublands).

2009-2010
We continue to re-examine assumptions of the volumetric analysis which includes collection of additional biomass data and re-calibration of regression lines for certain species. Several manuscripts are being written using this long-term dataset.

In 2010-11, we published a paper comparing ANPP and species richness responses to long-term drought versus a sequence of wet years. We continue to collect biomass data by species three times a year to estimate ANPP and species richness.

7. Regional vegetation and landform mapping [Monger]. We are developing a landform map of the Chihuahuan Desert to provide a broad-scale understanding of desertification dynamics, and to place Jornada site results into a broader content. We are also using historic vegetation maps and climate records to examine changes in the geographic distribution of the Chihuahuan Desert boundary through time. We are collaborating with Juan Martinez-Rios (University of Durango) and Alfredo Granados-Olivas (University of Juarez) on these projects.

2010-2011
We completed the primary landform mapping of the entire Chihuahuan Desert, including the portions in Mexico, Texas, and Arizona. We are currently digitizing the polygons. The publication planned for this endeavor will be titled: The Landforms and Pluvial Lakes of the Chihuahuan Desert. We decided to highlight "Pluvial Lakes" in addition to landforms because of the large number of extinct lakes in Mexico that have prominent shorelines. This information will be particularly useful for paleoclimate studies. In addition, we hope this map will be useful for understanding vegetation-geomorphic relations at a broad scale. For example, vast areas of the southern Chihuahuan Desert in Mexico have banded vegetation. Other areas in Mexico are rapidly being developed for center-pivot irrigation. In addition to ecological studies, the map shows the landforms where human settlements have developed.

8. Regional scale patterns of vegetation dynamics [Bestelmeyer, Skaggs]. Within the public lands areas of the Chihuahuan Desert in New Mexico (Bureau of Land Management lands; BLM), we are (1) mapping areas based on ecosystem state, (2) inventory vegetation and soils in each state, (3) couple inventories and maps to GLO surveys, BLM adjudication maps (1937), and (4) using repeat aerial photography to assess recent changes in vegetation, soils, and state condition. We will use these datasets to understand the patterns and drivers of state change at a regional scale outside of the Jornada Experimental Range/CDRRC area. This work is being conducted in parallel with collection of human dimensions data within BLM grazing allotments.

In 2009, we continued development of a data set using BLM archival documents for individual BLM allotments in southwestern New Mexico. As of June 2009, we have characterized human dimension variables and built historical timelines for ~250 allotments. These data are being correlated to ecological site and state characteristics.

In 2010, we continued current vegetation state mapping and expanding the allotment dataset for public lands areas of the Chihuahuan Desert in New Mexico.

2010-2011
The historical vegetation map project was the subject of one research publication (Skaggs et al. 2011). Historical US Geological Survey maps of the greater JER region were obtained, scanned, and digitized (through NMSU SPARC) in order to have georeferenced historical data for the greater JER cultural landscape (maps are from the early 20th century).

9. Social-ecological structure of Chihuahuan Desert ecosystems [Skaggs, Bestelmeyer]. At the broader scale of the Chihuahuan Desert, we are addressing two key questions: (1) are there systematic relationships among soils, vegetation states, and human-dimension variables at a regional scale? (2) Are certain biophysical conditions more likely than others to produce a cycle of ranch failure and degradation characterized by high turnover rates, agency conflict, and accelerating loss of grassland? We are characterizing human dimension variables using BLM allotment data and correlating them to ecological site and state characteristics. We have several allotment clusters we are using that feature different soils and probably have different histories.

In 2009-2010, a dataset for key allotment events was created. These data are currently being analyzed to determine rates of ranch ownership and management turnover in the region and key variables which influence turnover (Skaggs). Bestelmeyer is using these data to analyze the relationship between ownership regimes and biophysical properties.

2010-2011
Preliminary analysis of the allotment event dataset was conducted. Postdoc Dawn Browning is assisting in this research. Spatial analysis of ranches relative to inter-family transfers, property sales, and financial stress (e.g., bankruptcies and foreclosures) was conducted using standard techniques which evaluate for statistically significant relationships. A manuscript based on this research is in preparation (authors: Skaggs, Bestelmeyer, Browning). The manuscript includes discussion of theoretical relationships between property rights, stewardship, and tenure uncertainty as applied to quasi-privatized rangelands.

A study entitled "Impermanence Factors and Rangeland Management in the Desert Southwest" was initiated by Skaggs and Parry. This study will be the subject of Parry's M.S. thesis. The goal of this research is to develop a better understanding of how various impermanence factors affect or do not affect public land ranchers' management decisionmaking and planning. Research on impermanence factors (e.g., urban encroachment, inter-generational transfer issues, regulatory environment, etc.) in agriculture has focused on crop land located in urban fringe areas. This research is the first that we are aware of that deals with impermanence factors in rangeland livestock production systems. Impermanence factors in crop land systems lead to disinvestment, reduced technical efficiency, increased costs, and reduced profitability. The results of this research will increase knowledge of factors and processes that control ecosystem dynamics and patterns in the Chihuahuan Desert.

10. Geomorphic influences on desertification and grass survival [Monger]. We initiated a new landscape-wide study to determine the landforms that have experienced the least vegetation change since 1858. We are using historic vegetation and soil maps with current landform maps to determine the influence of geomorphology on grassland resistance to shrub invasion. Fine-scale

landforms, such as alluvial fans, lake terraces, and playas, are being examined for the relative resistance of perennial grasses through time based on persistence. We are creating a "resistance map" for the Jornada that can be used when stratifying future experiments. The map will also be used to interpret vegetation dynamics within the context of spatially and temporally variable drivers (wind, rainfall) compared with landforms.

2010-2011

We developed a resistance index that compares the rate of vegetation change for each landform on the Jornada. In addition, we completed the analysis of vegetation-geomorphic relations for the eastern portion of the Jornada Basin and adjacent White Sands Missile Range. These results have been submitted for publication and are currently in review.

11. Development and testing of remote sensing tools for NRI Grazinglands CEAP [Laliberte, Herrick]. This is a continuing project and work is ongoing to complete the object-based image analysis of the digital aerial imagery acquired over several states (ID, PA, FL, NV, CA, NM) as part of the larger CEAP funded project. The objectives are to compare image- and ground-based measures of vegetation and soil cover and evaluate remote sensing based approaches for potential integration into the NRI. The analysis of the JER-based imagery over the NPP plots has been completed, and two papers describing the results have been published.

12. Livestock re-distribution of nutrients and propagules [Fredrickson]. Livestock have occupied Chihuahuan Desert grasslands for more than 400 years. During this time, the presence of livestock has promoted the reoccurrence of desert shrublands at the expense of grasslands. Efforts to model the effects of livestock on this transition may be affected by a shift in livestock breeds during the late 18th and early 19th centuries. Initially, aridland adapted breeds of cattle were used that were replaced by temperate breeds of increasingly larger body size throughout the last century. Our studies show that aridland adapted, Spanish criollo cattle use a greater diversity of habitat types, travel further, and remainat water less time than larger-sized, temperate breeds. Thus, models based on the behavior of modern breeds will underestimate the spatial extent of historic livestock impacts while overestimating patch degradation of sensitive grassland species. Furthermore, time spent at water would be greatly overestimated along with grazing influences on vegetation as a function of distance from water.

13. Hyperspatial object-based image analysis and field validation [Laliberte]. The results of the CEAP-funded project on integrating remote sensing tools showed that field-based training samples are required to obtain consistent species-level classification accuracies. In 2009, we obtained 6-cm resolution UltraCam L digital aerial imagery over the JER and collected concurrent field training samples to 1) evaluate accuracies of species-level classifications, 2) determine class separabilities, and 3) test several training sample collection approaches, all within the framework of object-based image analysis (OBIA). Results from this study were presented by Laliberte at the GEOBIA 2010 conference, and a manuscript is in preparation. The image analysis and field validation approaches are also tested on the UAV imagery, and will be integrated into the analysis of the new multispectral UAV imagery.

14. Terrain model extraction from UAV imagery [Laliberte]. The extraction of terrain models or digital surface models (DSM) from UAV imagery poses several challenges, including

the very high resolution imagery, large image files, and registration errors. We are currently experimenting with developing DSMs at cell sizes of 1-2 m down to 6 cm, and with fusing the optical imagery with the DSM. At the highest resolution, we will estimate vegetation heights with the UAV imagery. Data from these studies will be used as inputs for Enrique Vivoni's hydrology models.

2010-2011

We are continuing our research into extraction of 2D and 3D information from UAV imagery and data fusion for input into hydrologic models, a collaborative project between Vivoni and Dr. Srikanth Saripalli from Arizona State University. We acquired repeat UAV imagery at Tromble Weir throughout 2010 and 2011, and collected numerous field training samples for validation of the classification product. The DEM and image classification results from Laliberte were used in Dr. Vivoni's tRIBs model, and preliminary results are highly promising due to the high resolution of the data. Dr. Saripalli flew his autonomous helicopter at Tromble Weir and is developing DEM result that will be compared with Laliberte's data. We collected ground-based shrub heights for comparison with vegetation estimates from the fused classification/DEM data.

B. Animal population dynamics

1. Animal-animal interactions [Fredrickson]. In 2007, we initiated new studies on livestock-prairie dog interactions in an extensive area in northwestern Mexico with current flora and faunal assemblages similar to the Jornada Basin in the mid to late 1800's. We are examining: differences in breed habitat and foraging preferences, the importance of physical factors in affecting herd hierarchies and movements, and livestock – prairie dog interactions, including the possible formation of "grazing associations" that may prevent desertification by affecting prairie dog distribution and shrub establishment. We found strong seasonal associations between livestock and black-tailed prairie dogs that affect each species distribution. A successful eradication effort during the last century in New Mexico and Arizona is thought to be one factor leading to desertification in the northern Chihuahuan Desert. Our studies will elucidate mechanisms of livestock-prairie dog interactions that may have led to historic desertification patterns, and will provide information needed for the re-introduction of prairie dogs in the Southwestern US. We continued this study in 2008. Working with Mexican collaborators, we learned that livestock grazing has a positive influence on black-tailed prairie dog populations with the resulting interaction having a larger impact on ecosystem components than either species independently. While cattle grazing at recommended levels of forage utilization (40%) had little impact, the combination of cattle and prairie dogs altered plant species composition and structure that in turn altered arthropod, and small mammal populations. As a result, studies are currently being implemented to understand the interactive effects of fire, livestock grazing, and prairie dog dynamics on grassland heterogeneity and resilience at multiple scales. Included as response variables are grassland bird's use of a shifting mosaic of grassland seres, and the establishment and persistence of shrubs (ie. mesquite and Ephedra spp.) within each sere. We hypothesize that the combination of fire, livestock grazing, and prairie dogs maintain these grasslands and have favorable, long-term affects on livestock production and populations of grassland birds.

2. Animal studies evaluation.
Led by B. Bestelmeyer, we conducted a thorough evaluation of our ongoing animal population studies to determine which studies should be continued, and which ones should be modified, and the ones that should be discontinued. Many of our long-term animal monitoring studies were started in the 1980s, and data have been faithfully collected since that time. However, for several datasets, the data had not been examined for quality or suitability for publication or, in some cases, the scientific questions were missing, unknown, or forgotten when the original PI left the project. Because of limited resources, we decided it was time to conduct this evaluation. We plan on conducting a similar evaluation for our core plant datasets prior to LTERVI. Below is the document approved by the JRN Executive Committee on June 10 (2008) and approved at the PI mtg on July 14 (2008).

Changes to Jornada Basin LTER Animal Population studies

Submitted by Brandon Bestelmeyer, 1 May 2008; approved by the JRN Executive Committee June 10, 2008; approved by all PIs in attendance at PI mtg July 14, 2008

JRN LTER work will be refocused on the following studies, given existing resources and the involvement of PIs willing to oversee the studies and produce publications from them. Here are the new core studies:

1) Rodent population responses to spatio-temporal heterogeneity across ecotones associated with desertification (RES study). LTER techs trap 3 ecotones (9 sites) and measure NPP twice/year at those sites. This amounts to about 5 weeks of work. Gary Roemer and Brandon will, as often as possible, additionally trap the 2 other ecotones. This study already has 5 years of data. This can also serve as a platform for other studies in the future, including Jeremy Klass's work and was used by Leticia Rios to sample ants.

2) Population dynamics of lagomorphs in desertified and undesertified landscapes. This is the same as the ongoing study except changes in the design. This will take about 4 days of LTER time.

3) Bird population responses to desertification and exurban development. This study will be directed by Laura Burkett using help from whoever is available, and will involve point counts in and around the JER on the East Mesa. An M.S. student will be involved at the start. The amount of LTER time has not yet been determined.

4) Long-term monitoring of rodent-exclosures in grassland. This is the SMES study re-recorded on a 5 year interval, but only the grassland sites.

Below is the rationale for ending, modifying, and adding studies to the core JRN animal project.

Completion of studies
1. End the lizard monitoring study. Rationale: Discussions with past and present LTER techs, including Andrea Campanella, John Kuehner, Clayton (Clay) Crowder, as well as John Anderson indicates that the sampling design is flawed. Traps were allowed to collect sediment leading to

reduced capture rates of certain (especially large) species. Inspection of the data by Clay and Brandon confirmed this pattern. Further, the low overall capture rates seem to preclude an evaluation of habitat effects for most species. Brandon approached a graduate student of Blair Wolf (Biology, UNM) who had independently observed the trapping array and the student noted he would have no interest in the data given the design. Clay concluded that the data are essentially a study of population dynamics of a common, small, and easily-trapped generalist lizard Uta stansburiana. Furthermore, it is not clear what interesting patterns are evident in the data after 17 years (data summarized by Clay). The lack of a key question, specific rationale for a focus on this taxon, PI interest, and design problems limits the relative value of extending this data set. Furthermore, the data have not yet produced any significant insights or publications in 18 years. The traps have not been sampled for 1 year.

2. End the arthropod monitoring study. Rationale: This study has not produced any particularly interesting insights. Although the design appears not to be flawed, inspection of the data revealed that 1) for some reason, many more individuals were recorded in LTER II compared with LTER III (and most species have very low capture rates from 1996-2001) and 2) there appears to be a backlog of species identifications at UNM. The data on the tenebrionid beetles may be the best use of this data set, but the time investment, low capture rates, the need for species identifications, and the problems inherent in quality control of species designations that are "outsourced" reduces the utility of this data set. While a recent used some of these data, there is no interest by any local scientists in directing this study.

3. End maintenance of the creosotebush Small Mammal Exclusion Study (SMES) exclosures. Rationale: The location of the exclosures on an active alluvial fan has created high maintenance costs due to debris accumulation and erosion/deposition of sediment. Furthermore, the atypical nature of the Summerford bajada (most others are relict piedmont landforms with distinct parent materials and vegetation) limits the generality of inference that can be drawn to similar "creosotebush shrublands" elsewhere on the JER/CDRRC. The high maintenance costs associated with this treatment are not balanced by scientific insights that have been (or could be) generated relative to other projects.

4. End responsibility for SMES web sampling. Rationale: The primary rationale is limited resources; we need to free up tech time to sample rodents as part of the Rodent Ecotone Study (RES; see below). The loss of the SMES creosotebush exclosures negates the related need for background rodent abundances near those sites. There may still be a need for rodent abundances as explanatory variables for the SMES grassland sites, however. This could be achieved by using the grassland rodent grid from the nearby Pasture 9 ecotone to gauge yearly changes in abundance, and temporal overlap between SMES and RES sampling allows us to evaluate this option and calibrate future comparisons.

Modification of existing studies

1. Maintain black grama (Pasture 9) SMES exclosures and sampling on a 5 year basis. Rationale: The location of this treatment is adequate and the experiment addresses an important question regarding rodent effects on vegetation in an area of generally high rodent densities. There are, however, concerns about the design of this study as well. The 5 year cycle (as opposed to annual sampling) will maintain our ability to detect long-term directional changes in vegetation and free

up resources for other work. In order to justify further expenditure on this project by the JRN, however, the resulting data should be controlled directly by current JRN PIs.

2. Evaluate methods and potentially redesign lagomorph routes. Rationale: As noted above, the Summerford bajada does not adequately represent the shrubland types for us. Furthermore, detectability is very low so this route has been essentially producing a handful of recorded animals (John Kuehner). Consequently, the methods need to be re-evaluated and routes reconsidered. We should consider a new design that intersperses segments of shrubland and grassland that allows replication and blocks to control for rainfall heterogeneity. We also need more total routes to get higher numbers. Right now, it is not clear that we can ever publish the existing data.

New studies

1. Initiate LTER tech support for the Rodent Ecotone Study. Rationale: This study was initiated in 2002/2003 and has been run by Andrea Campanella as part of his doctoral research. Publications will be produced in 2008 and there is potential for us to test and publish on other, long-term hypotheses. Currently, 16 x 6 (10 m spacing) trapping grids are placed in 3 positions across grassland/middle/shrubland ecotone positions in 5 replicate ecotones. Productivity measurements are gathered in 32 1m2 quadrats/grid 2 times each year. The study directly addresses the consequences of desertification and shrub encroachment for rodent populations and, coupled to exclosure studies, to feedbacks on black grama dominance. If some of the ecotones are indeed dynamic in the future, we can test if the grassland grid converges with the shrubland portions in terms of species composition and energy flux. LTER techs will sample rodents in 3 ecotone grids with NPP measurements, requiring 3.5 weeks of field time in fall beginning and one week in spring beginning in 2008.

2. Initiate a new bird monitoring study: Rationale: Birds have experienced documented, interpretable, and significant changes in the Southwestern US, but a mechanistic understanding of the changes are lacking. The population and community responses of birds integrate ecological variables across a variety of scales, and most notably the broad scales of landscape-to-regional patterns and processes. Birds are uniquely positioned to provide information on the broad and diffuse impacts of regional vegetation change, climate change, and exurban development. Birds are widely used as indicators of the biotic consequences of land conversion and development, so data from the JRN would complement many such studies. We will design a study testing the combined consequences of desertification and suburban development by arraying a system of point count locations from the East Mesa into grassland and shrubland habitats (some of which will be coupled to the RES grids) on the JER. We would test the hypothesis that suburban development on the East Mesa in conjunction with climate change and desertification leads to increasing homogenization of the avifauna, and that suburbanization effects will extend away from the centers of development into adjacent wildlands. We can also take advantage of previous studies on JRN as older baseline data, dating to the IBP period (e.g., Raitt and Pimm 1976). While the sampling is relatively simple, the major challenge would be to train techs to recognize bird species. Fortunately, Laura Burkett is an expert birder and would direct this project in collaboration with other PIs, and a number of volunteers may be available.

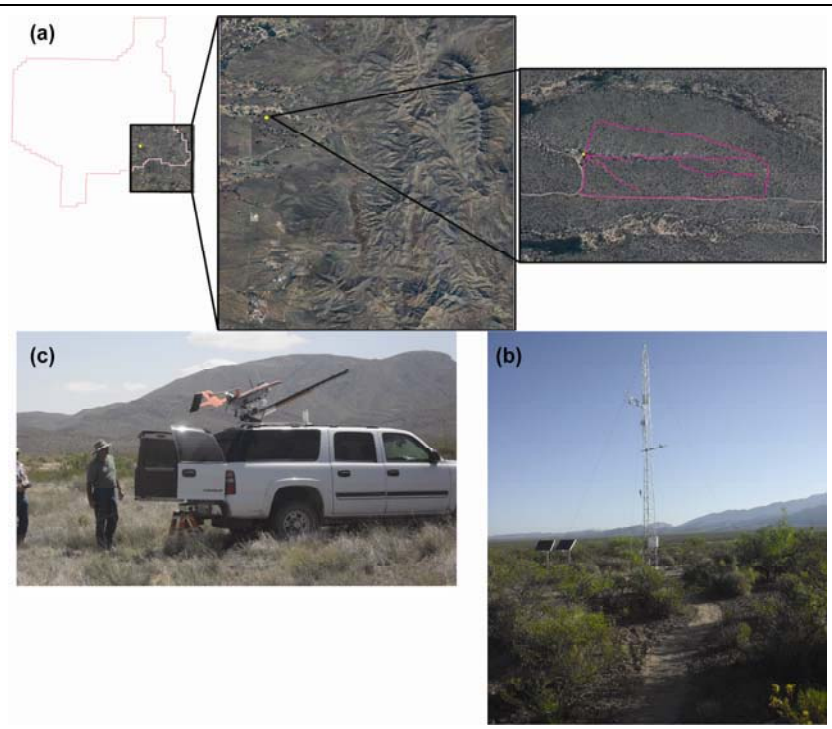
3. New in 2010-2011 [Bestelmeyer]
Over the past year, we initiated a major new study of bird and small mammal population responses to shrub control activities carried out by the Bureau of Land Management in areas surrounding the Jornada Basin LTER, supported by a USDA AFRI grant. Several long-term monitoring sites were added that will be continued after completion of the grant.

C. Transport processes, fluxes, and biogeochemistry

1. Hydrologic connectivity. We developed a conceptual and numerical model for emergent behavior of semi-arid vegetation based upon the concept of landscape connectivity and the role of water, wind and animals in exploiting connectivity to redistribute resources and propagules within the landscape. We also continue to collect water and sediment samples from the interrill and rill samples, stock ponds, and the North and South watershed.

2. Ecohydrological Fluxes, Characterization and Modeling of a Watershed [Vivoni]. We initiated a study in 2010 on the characterization, measurement, and modeling of ecohydrological fluxes in a small watershed in the Piedmont Slope (Bajada) region of the JRN LTER. The overall goals of the project are to: (1) quantify the spatial and temporal variability of water and carbon fluxes at the scale of the watershed, (2) to intercompare methods for estimating ET directly and through the water and energy balance, (3) to explore the impact of UAV observations on improved hydrological modeling, (4) to test a hydrological model of the watershed ecohydrological fluxes and (5) to synthesize across the observations and modeling so as to provide measures of water availability and erosion capacity in the piedmont slope.

<u>2010-2011</u>
We continued the characterization, measurement, and modeling of ecohydrological fluxes in this small watershed. An environmental sensor network consisting of an eddy covariance tower, 5 rain gauges, 3 miniflumes, 1 large flume, and 3 soil moisture transects (15 soil moisture profiles) was deployed in May 2010. Data have been collected and analyzed until present (>1 year) to illustrate water, carbon, and energy fluxes and states



(a) Regional domain of first order basin in Chihuahuan desert shrubland from aircraft imagery. (b) Eddy covariance tower site that is part of environmental sensor network with 4 flumes, 5 rain gauges and 15 soil moisture profiles. (c) Launching of vehicle-mounted UAV for high resolution vegetation cover imagery (6-cm) over first order basin.

throughout the sensor network. A new telemetry system was deployed on May 2011 that collects real-time data from all sensors and transmits it to JRN Headquarters and to the Internet. A new datalogger will be installed at the large flume (August 2011) to allow incorporation of this long-term data into the telemetry system.

Field characterization of soils, channel network locations, and vegetation cover have been completed using a soil sampling protocol, a differential global positioning system (GPS) and line-intercept vegetation transects. In collaboration with Rango and Laliberte, a sequence of 8 UAV images of the watershed have been collected since June 2010 to present covering a sequence of different vegetation conditions. One additional UAV flight (in collaboration with Sri Saripalli, ASU) with a helicopter was carried out with optical and stereo observations of the watershed (September 2010), with future flights planned using the helicopter and a small LIDAR (light detection and ranging) sensor.

A hydrological model, the Triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator (tRIBS) has been setup and tested against the site observations at the eddy covariance tower. Model setup for the entire watershed has commenced using the high resolution digital elevation model (DEM) at 1 m obtained from the UAV aircraft imagery (Laliberte). Terrain analysis of this project has yielded a description of the basin elevation, slopes, aspects, curvature and upslope contributing areas. A high resolution vegetation species map derived by Laliberte has been aggregated for use in the model. An M.S. thesis (Templeton) and manuscript will be completed on this project by December 2011.

3. Soil water dynamics in the profile [Duniway, Herrick]. Soil profiles were characterized at each of the 15 NPP sites and soil texture data were collected in association with the neutron probe access tube locations. These data were publicly released in 2008 together with a separate calibration study relating neutron moisture meter (NMM) probe counts to volumetric and plant available water that can be used to interpret long-term NPP soil water data.

In 2010-2011, NMSU MS student Crossland successfully defended his thesis documenting the results of the NMM calibration study. Results of the calibration study have improved the accuracy of the NMM measurements and will allow us to back correct past data. Additionally, new neutron count standards are now routinely collected along with monthly measurements to help improve data reliability. Duniway presented the long-term soil water dynamics measured at the NPP sites at the Soil Science Society of America meeting in 2010 and the Ecological Society of America meeting in 2011. A manuscript is currently in preparation synthesizing new insights into long-term arid land vadose zone dynamics.

4. Soil carbon dynamics [Monger, Throop]. In 2007, we initiated a new study using carbon isotopes to compare C_4/C_3 vegetation changes in the arid vs semiarid regions of the Jornada Basin. We are also developing methods for measuring $CaCO_3$ formation/dissolution and its isotopic composition for recording relative abundances of C_3 vs C_4 plants. Through an REU student in 2007 (Ebbs), we assessed spatial patterns of soil organic carbon (SOC) distribution on mesquite coppice dunes. We performed fine-scale soil sampling on dunes of different sizes to determine the influence of dune size on SOC distribution. Additional data collection and analyses are being conducted in 2008. This works parallels work in Sonoran Desert grasslands that suggests sub-canopy SOC pools are strongly a function of shrub size and sub-canopy location. This work will increase our ability to generate landscape-scale estimates of shrub

encroachment impacts on C sequestration. Ebbs will write an honors thesis on this work in 2008-09, and we expect to submit a manuscript for publication in spring 2009.

In 2008-09, Ebbs wrote an honors thesis on this work. Laboratory experiments demonstrated that unglazed ceramic tiles containing Ca(OH)2 are the best method for measuring CaCO3 formation/dissolution. In addition, Ca-isotopic studies are underway to identify the source of Ca in pedogenic carbonate in order to assess carbon sequestration in desert soils. Ebbs submitted this work as an undergraduate thesis in the NMSU Biology Department in Spring 09.

2010-2011

We explored patterns of soil organic carbon sources and stability in a remnant grassland and shrub-encroached former grassland by combining density fraction and stable isotope analyses. We are currently establishing a multi-site comparative study of soil organic carbon spatio-temporal patterns and stability in response to woody encroachment. This project is funded by the NSF CAREER program (see H. Associated Grants below).

Ceramic tiles have been installed to measure short-term carbonate dynamics in a tobosa grassland, linear sand dune, and bare region at the SCAN site near Taylor Well. We are comparing soil carbonate accumulation in control tiles with tiles containing calcium hydroxide and spiked calcium carbonate. We will also put tiles in a mesquite dune field, black grama grassland, and creosotebush shurbland. We completed a study of microbial precipitation of carbonate that was presented at ESA 2011 and will be submitted for publication this fall.

5. Atmospheric deposition [Anderson]. Atmospheric deposition collection devices of the same design as used by the US Geological Survey in its deposition sampling program in the Mojave were installed at the 15 NPP sites in March 2001. After a rusting problem was identified by LTER personnel, the collectors were retro-fitted with stainless steel connectors to correct the problem. The intent is to enable quantitative measurement of dust deposition at each site, and eventual analysis of the chemical composition of that dust, to facilitate the estimation of basin-level biogeochemical budgets. Collections of atmospheric (wet and dry) deposition continue to be monitored seasonally. These measurements will provide (coupled with emission data) a measure of the net loss/deposition of soil nutrients by wind in the Jornada.

6. Wind redistribution of litter [Throop, Archer]. In 2008, we initiated an experiment to test the rate of redistribution and decomposition of mesquite leaf litter by wind in landscape positions that differ in vegetation patch structure and connectivity. We hypothesize that decomposition rates will be greatest in areas where flux rates are greatest. Litterbags were deployed in 2007; data collection on the first phase of this 4-year project was completed in May 2008. We are currently preparing a manuscript for publication. A related project funded by NSF in spring 2008 (see H. Associated Grants below) is exploring how interactions between solar radiation and soil transport influence decomposition rates. As part of this project, we are conducting a series of laboratory incubations exploring the mechanisms by which soil-litter mixing affects decomposition. Another related projected was recently funded through a Los Alamos National Lab-NMSU collaborative grant (see H. Associated Grants below). This project uses stable isotopes to explore the drivers of C loss from decomposition.

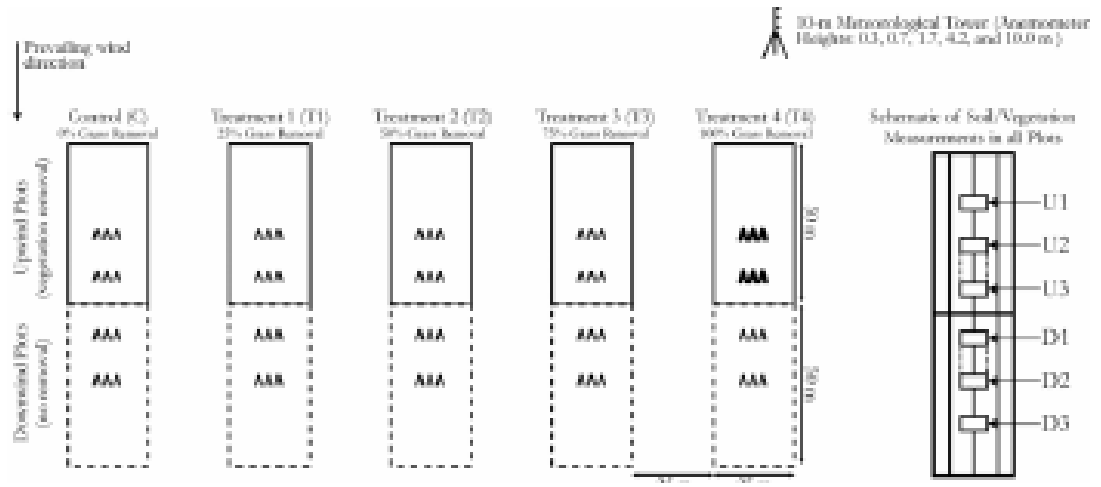
In 2009-2010, we completed the first two years of data collection on the vegetation structure and decomposition study. The data show a positive relationship between soil-litter mixing and rate of decomposition. One of the interesting observations was the formation of stable soil aggregates within the litterbags. We initiated a study to explicitly explore the nature and rate of formation of these stable aggregates. We completed several controlled environment studies exploring the mechanisms by which soil-litter mixing enhances decomposition rates. We are incubating litter-soil mixtures under controlled temperature and moisture conditions, and quantifying rates of microbial respiration, litter mass loss, and changes in litter and soil chemistry in response to changes in soil moisture and soil-litter mixing.

2010-2011

We completed the first year of the soil film/stable aggregate study and are working on novel methods to quantify the soil film area and composition using scanning electron and confocal microscopy. We characterized changes in soil aggregate sizes over time, and are working with collaborators to characterize the chemical composition, biological community, and stability of these aggregates. We combined findings from field and laboratory incubations studies on photodegradation and soil-litter mixing, and developed a new conceptual model to show that the controlling drivers of dryland decomposition switch over time from photodegradation to biological decomposition. A manuscript describing the data and conceptual model is currently in review. To further explore how woody encroachment affects soil-litter mixing and subsequent decomposition, we established a new decomposition experiment across a shrub encroachment/coppice dune gradient. We expanded our laboratory incubations to explore trace gas fluxes under a variety of abiotic conditions. These studies have yielded novel data on efflux during decomposition of both C-based trace gases and H2. We currently have two manuscripts in review describing the gas flux data.

7. Wind interactions with vegetation [Okin]. We continue to collect data from a large-scale wind erosion experiment established at the JER in 2003. To our knowledge, this experiment is the *only* vegetation manipulation in existence 1) aimed at investigating feedbacks between aeolian processes and vegetation, 2) of a large size, and 3) in natural vegetation. The study was initially funded as an NSF award to Okin (DEB 0316320); the LTER is now assisting with plot maintenance and data collection. The wind erosion experiment consists of three blocks (replicates). Each block consists of four treatments and a control oriented perpendicular to the direction of the prevailing wind. Each treatment consists of an upwind portion where vegetation has been manipulated and a downwind portion where no vegetation manipulations have occurred. Vegetation manipulation on the upwind portion of the treatments consisted of removal of 25%, 50%, 75%, and 100% of the grasses, forbs and small shrubs such as *Gutierrezia sarothrae* in an area of 25 m x 50 m. Shrub cover (*P. glandulosa*) was low in the sites at the beginning of the experiment and was not removed. No vegetation was removed in the control. Because annuals are typically dead by the beginning of the windy season, annual cover is ignored, although each March we determine whether any removal of annuals is necessary. Maintenance (vegetation removal) on the site was last done in March, 2007 and 2008 following significant establishment in summer, 2006. Several recent papers have resulted from this study (Li et al. 2007, 2008) with additional manuscripts being prepared for submission.

In 2010-2011, we concentrated on analysis of vegetation from these plots. In one study (Alvarez et al. 2011), we used high-precision surveying equipment to map vegetation distributions and in a second study (Alvarez et al. submitted), we report on the measured impacts of increased aeolian flux in the downwind areas on vegetation community structure. Additionally, a high-resolution ground-looking LIDAR was deployed at some of these plots to observe changes in soil microtopography. These plots also served as important calibration sites for Okin's wind erosion model (WEMO). Validation/calibration of this model was a major activity for 2010-2011. Soil/litter mixing studies continue to be carried out on these plots, and new measurement of vegetation cover on the plots, in response to the recent drought and readily observed impacts of wind-blown material on vegetation, have been initiated.



Schematic of an individual block in the wind erosion experiment. BSNE collectors are indicated by ^^^. Meteorological stations are installed in Blocks 1 and 3. The right figure shows the layout of sampling locations in each treatment. There are a total of six 5 x 10m soil sampling plots (U1, U2, U3 upwind and D1, D2, D3 downwind). There are six 50-m line-intercept transects for vegetation monitoring (3 upwind, 3 downwind). There are also 10m x 20m plots upwind and downwind where the location of every plant > 2 cm wide has been mapped.

8. Dune formation [Monger].
<u>In 2010-2011</u>, we completed a study of the timing and mechanism of scarplet formation and associated arculate dune formation. The results reveal that the sand began accumulating in the Medieval Warm Period (about 1000 years ago) after which erosion and sedimentation ceased and soil formation occurred during the Little Ice age (ca. 1500 to 1850 C.E.). A period of renewed erosion and sand deposition began after 1850 and has continued since that time. These findings have been submitted for publication and are currently in review.

9. Fire effects on biogeochemistry [Throop and Whitford]. We initiated a study in 2008 on the effects of fire on soil processes as part of a new grant funded by the International Arid Lands Consortium (see H. Associated Grants, below). This study is taking place in historical management burns conducted in the San Andres Mountains (in the area of overlapping ownership of San Andres National Wildlife Refuge and Jornada Experimental Range). We are working in burned and unburned patches to assess how fire affect vegetation dynamics, litter decomposition, nutrient availability, and soil biota. In 2009, we completed one year of litter

decomposition, soil nutrient availability, and soil biota studies in response to management burns. We are in the process of data analysis, and our MS student (Majd Abu-Salem) is preparing her MS thesis with these data.

2010-2011

We completed all data collection and analyses on this project. MS student Majd Abu-Salem will defend her thesis in fall 2011. We will begin work on a manuscript following her defense.

D. Linked socio-economic-natural systems

1. Adjudication maps [Skaggs, Wright]. In 2008, we started working with the BLM to digitize the 1930s Las Cruces District allotment adjudication maps that were only available in paper format. There are ca. 230 double-sided 18" x 24" original map documents in generally good condition that we are digitizing and creating an accurate key. BLM personnel in the Las Cruces Office know of at least two retired former BLM employees who can likely provide insight into the map key development; we will consult these individuals as required. The NMSU Geography Department Geospatial Lab supervised by Jack Wright and Mr. Quinn Korbulic is responsible for scanning and digitizing the maps, and developing the map key.

2. Relationships between Socio-Economic & Ecological Processes in Rangeland Landscapes [Skaggs, Bestelmeyer] In 2008, we started compiling socio-economic data from BLM allotment files in order to link to LULLC data. Previous surveys of individuals involved in cattle production throughout the US point to significant variation in motivations, objectives, and cattle management practices. However, previous research has not explored the linkages between this variation and variation in the land they use for livestock production. Furthermore, previous socio-economic research has been aspatial in nature and fixed in time. Thus, while we have some sense of the types of ranchers throughout the country, we have little knowledge of the dynamic spatial and temporal relationships between ranchers' socio-economic characteristics and biophysical data. Individual BLM grazing allotment records contain data which provide insight into the human agents which control and manage rangelands management, decision making, and outcomes. We recently began building a data set to characterize socio-economic variables and processes for allotments located in Southern New Mexico. Some of the data pertain to the individuals and households which have managed spatially distinct rangeland units since the 1930s. The human agent behavior and characteristics data are linked to spatial data (i.e., grazing allotments). Other data are a function of broad scale trends, events, and shocks which have affected the region's rangelands as well as the people who live and work on them. Some allotments and households have been directly affected by these events (e.g., transfer of land to military reservations during WWII), while other allotments and households may have been indirectly affected as a result of impermanence fears.

Our first step in data collection has been to develop timelines of major events in the "life" of an allotment. These data show differences in allotments which may have had significant effects on LULCC and ecological conditions. The management and ownership differences are qualitative, and also have a temporal dimension. Data collection for BLM rangeland allotments in the study region currently involves establishment of a timeline since the late 1930s for each allotment, development of a brief narrative describing significant socio-economic processes which have impacted the allotment over time, the creation of binary variables to indicate the

socio-economic processes. Examples of binary variables being developed include: active manager vs. absentee permittee; agency assessment of permittee management of allotment; commercial rancher vs. hobby rancher; high vs. low ownership turnover; orderly vs. messy transfers or turnovers; evidence or lack of evidence of permittee financial stress; contentious vs. non-contentious relationship between permittee and agency; presence or absence of impermanence factors such as urban area proximity, vandalism, Wilderness Study Area, endangered species, actual or potential military takeover, etc.; presence or absence of significant recreation use; and presence or absence of actual or potential transportation corridors.

Clearly, the data being developed to characterize the georeferenced socio-economic processes on BLM rangeland allotments in the study area involve a certain degree of expert judgment. When the data are complete they will be linked with biophysical data, and provide previously unavailable insight into the relationships between socio-economic and ecological processes in rangeland landscapes.

3. Landuse-land cover change in Dona Ana County [Wright, Skaggs]. Maps are being used to evaluate historic and potential future changes in the number and distribution of residences, and spatial variation in these changes. Results of the modeling exercise are being used to predict the spatial distribution of residences and population density in the future.

2010-2011

We worked with the ULTRA-Ex project. Wright assisted with development of an open space typology for application to the Phoenix, Albuquerque, and Las Cruces metro areas. Buenemann and Hestir completed research on land cover/land use change in the greater JER region. This research was the subject of Hestir's thesis. Some of this research was also published in an article by Buenemann and Wright (2010).

E. Cross-site research (ongoing)

1. Small mammal impacts on recruitment of perennial grasses [Bestelmeyer]. We continue to sample vegetation responses in plots set up in 2000 to study the role of small animals on grass recruitment across a climatic gradient that includes three sites in the Chihuahuan desert. The sites range from the Sevilleta National Wildlife Refuge LTER site in central New Mexico to the Jornada Basin and Range LTER in southern New Mexico to Big Bend National Park in southwestern Texas. Three locations were selected at each site, consisting of an ecotone between black grama grassland and an alternative dominant species, either creosotebush (SEV), honey mesquite (JRN) or chino grama (Big Bend). Cages were installed in 2001, and response variables have been measured annually during peak plant growth. We are monitoring black grama basal diameters and assessing plant growth and colonization of all species within each plot. We also monitor small mammal abundance along these ecotones using mark and recapture trapping procedures. Rabbit population studies were conducted by an REU student in 2004.

2. Small mammal exclosure study: Field work and analysis continue for the cross-site project examining the role of small mammals in desert grassland shrubland at three Chihuahuan desert sites (Sevilleta, Jornada, and Mapimi Biosphere Reserve in Mexico). Rodents are trapped outside the exclosure, and vegetation, grasshoppers, and soil surface characteristics are assessed in the exclosure treatments. Annual vegetation responses were completed in 2004, although we plan on

sampling vegetation every 5 years into the future. Rodent trapping has occurred yearly as part of our animal monitoring studies. This study was initiated by D. Lightfoot (UNM) and is now part of our core studies with management by B. Bestelmeyer and J. Anderson.

3. Monitoring manual [Herrick]. The "Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems" published in 2005 continues to be used in training workshops held throughout the western US, Mexico, and more recently in Mongolia. This document integrates much of the LTER research and applies it to indicator selection and interpretation. A number of US agencies have adopted these methods, including the NRCS, USGS, BLM, and The Nature Conservancy.

4. Hydrology [Parsons, Wainwright]. In 2004-2005, we initiated hydrology studies at the Sevilleta LTER to coordinate cross-site comparisons. Fieldwork at the Sevilleta is being conducted by a graduate student who is sampling spatial characteristics of the physical and chemical properties of soils.

5. Ecotone studies [Peters]. Field work continues to compare grass-shrub ecotones at the JRN and Sevilleta. This research started in 1995 and integrates long-term removal plots at the Sevilleta with the ecotone studies started at the JRN in 2001 (E.1) and the recent connectivity – drought pilot study being initiated.

6. [New Hydrology in 2010-2011] Vivoni began a cross-site intercomparison study at two small instrumented watersheds in the JRN LTER and the Santa Rita Experimental Range in southern Arizona. Similar environmental sensor networks have been deployed at each site with supplemental basin characterization studies following similar protocols. High resolution topographic and vegetation imagery is being obtained at each site from UAV (JRN LTER) or manned aircraft (Santa Rita) platforms. The numerical model tRIBS will be applied at each site at the point scale (eddy covariance tower location) and within the watershed.

F. Network-related activities

2006-07
We continue to remain active at the network level. We initiated the EcoTrends project in 2004 and continue to lead this effort (Peters, Laney, Ramsey). We participated in the LTER GIS survey and the Remote Sensing survey that resulted in articles in Databits (Nolen). We attended the annual LTER Information Managers meeting in San Jose (Nolen, Ramsey, Laney). We co-chair the Network Information Systems Advisory Committee (Peters) and have another member on this committee (Ramsey). We attended a course on "Sensing Technology for the Soil Environment" held at the Center for Embedded Networked Sensing, Riverside, CA and the workshop " Phenology Across the LTER Network" sponsored by LTER Network Office at Sevilleta, NM (Anderson). In addition, Peters was on the LTER Executive Committee until her term expired this spring.

2007-08
We continue to lead the EcoTrends and P2ERLS Projects (see I. Synthesis activities). We submitted a proposal to the Advances in Biological Informatics Program at NSF to expand

EcoTrends and P2ERLS in three ways: (1) to include more sites and databases through an automated procedure, (2) to allow statistical analyses of the long-term data combined with spatial databases, and (3) to allow visualization of original data and derived data products in time and space.

We collaborated with four LTER grassland sites (CAP, SEV, SGS, KNZ) to submit a coordinated LTER social sciences supplement that was funded in 2008. This supplement will allow cross-site social science studies to be conducted and will further develop the JRN social science database. In addition, we are using these ideas to develop a coordinated effort towards a regional ULTRA submission that would include Phoenix, Albuquerque, and Las Cruces.

We participated in the cross-site grassland symposium held at the University of New Mexico July 11-12. We had a total of 18 attendees (8 PIs, 4 staff, 6 graduate students and postdocs) with two presentations (Peters, Monger), and 11 posters. One of the working groups at the meeting discussed the upcoming ULTRA competition, and links among sites in their social sciences research.

2008-09

We continue to lead the EcoTrends and P2ERLS Projects (see I. Synthesis activities). We submitted a proposal to the Advances in Biological Informatics Program at NSF to expand EcoTrends and P2ERLS in three ways: (1) to allow statistical analyses of the long-term data combined with spatial databases, (2) to allow visualization and animation of original data and derived data products in time and space, and (3) to allow simulation models to interact with the database through access of model parameters, and visualization of model output.

We (Sala) collaborated on the development of a network proposal to study the importance of rainfall variability on ecosystem functioning. We propose to use the rainout shelters currently being used at our study site along continental precipitation and temperature gradients to test hypotheses regarding differential ecosystem sensitivity to climate change.

We (Wright, Nolen) participated in the Socioecological Gradients and Land-use Fragmentation: A Cross-site Comparison Analysis workshop held at the Global Institute of Sustainability at Arizona State University (CAP) in Phoenix April 20-21. As a result of the workshop, each participating site (CAP, JRN, KNZ, SEV, SGS) produced a recoded structure for NLCD Land-Use Classification for their site and submitted it to our Fragmentation Google site. The initial fragmentation analysis across sites will be presented at ASM 2009 and we have scheduled a workshop at ASM titled A Cross-site Comparative Analysis of Land Fragmentation.

We (Peters, Wright, Nolen, Ramsey) participated in producing the ULTRA proposal that was submitted in July 2009. The principal question of this proposal is to understand how decision makers respond to and make land and water use decisions based on measured and preferred ecosystem services on the wildland-rural-urban fringe in the arid southwest. We participated in the cross-site grassland symposium held at the University of New Mexico in 2008. We had a total of 18 attendees (8 PIs, 4 staff, 6 graduate students and postdocs) with two presentations (Peters, Monger), and 11 posters.

2009-2010
We presented 17 posters and organized 5 work groups plus assisted in organizing an additional four work groups for the EcoTrends project at the 2009 All Scientists Meeting in Estes Park, CO.

We (Nolen, Ramsey) attended the Annual Information Managers Committee Meeting held in Estes Park, CO,

We (Nolen, Sayre) continued work on the MALS project, a cross-site LTER comparative study of land-cover and land-use change with spatial analysis and local ecological.

We (Nolen, Skaggs, Wright) continued work on the cross-site group paper on socio-ecological gradients and land-use fragmentation. This paper was published as York et al. 2011.

We (all JRN students, PIs, and staff) prepared for and hosted NSF LTER mid-term site review in 2009.

Ramsey attended and participated in an EML Best Practices Workshop held at LNO in Albuquerque, NM.

We (Peters, Laney, Yao, Tummalapalli, Ramsey) participated in the EcoTrends project to complete the EcoTrends book and make changes to the EcoTrends administration and public website.

2010-2011
S. Bestelmeyer participated in surveys and interviews about existing site K-12 education programs in summer 2010 with Jennifer Witers (The Learning Partnership, Ohio).

Sala is a member of the LTER National Advisory Board.

Sala participated of the LTER cross-site activity on Climate Change. This activity involved meetings in Colorado, and Connecticut and resulted in a proposal that was submitted to the Macroecology Competition.

Sala participated in the LTER Science Council meeting in Plum Island, MA as the JRN LTER site representative.

The EcoTrends website was successfully migrated from the LTER Network Office to the Jornada. We migrated EcoTrends from Ubuntu Linux to Windows Server 2003 Server. Java was also updated to version 1.6 during the deployment. The source data and metadata files that used to be linked to the Jornada website from EcoTrends were migrated to the new EcoTrends server so all data and associated metadata, including source and derived, now reside on the EcoTrends server. The EcoTrends server is now deployed as a virtual machine using Citrix XenServer 5.6.

We integrated Tomcat and Apache so that Tomcat delivers the dynamic content of the website and Apache delivers the static content. In order to complete the Tomcat/Apache integration, we modified he EcoTrends source code so that EcoTrends is now the default Tomcat application.

Rewrite rules were implemented to redirect users from the /EcoTrends context to the default context (/). This will allow URLs to EcoTrends that were previously bookmarked or advertised in publications to still work. The EcoTrends website is now accessible from http://www.ecotrends.info or http://www.ecotrends.info/EcoTrends. New SSL certificates were purchased and implemented on both the LNO and Jornada EcoTrends websites as the old certificates and domain registration were expiring in June.

During the process of deploying the website to Jornada, we updated website content. We updated website URLs for the 6 EcoTrends sites and ClimDB that had changed over time. We updated the ClimDB metadata report PDF files and site description PDF files. The EcoTrends bibliography was also updated to include recent EcoTrends related publications. We corrected an issue that caused station metadata for 8 LUQ LTER datasets from being incorporated into the EcoTrends metadata and EML. We also corrected a Santee Experimental Forest dataset so that the PostgreSQL table is now created. All 15,403 EcoTrends datasets and associated metadata is now as complete and accurate as possible.

We (Ramsey) attended the Annual LTER Information Managers Meeting in Kalamazoo, MI.

We (Brown, Peters, Ramsey, Skaggs, et al) attended and participated in 2 USDA Climate-Rangelands Connections planning workshops. The first workshop was held in Tucson, AZ and we hosted the second workshop in Las Cruces, NM.

We (Ramsey) continue to participate in several LTER Network Information System (NIS) development Tiger Teams; Metadata Management, Data Management, and Data Portal.

We (Nolen, Ramsey, Skaggs, Wright) participated in an ULTRA-Ex planning workshop in Phoenix,AZ.

We (Ramsey) continue to participate in regular LTER Information Managers Committee video conferences.

We (Jensen, Ramsey) participated in a workshop at the Palmer LTER site offices in San Diego, CA to integrate the LTER Unit Registry web services with the Jornada Information Management System workshop.

We (Buenemann, Nolen, Sayre) attended and participated at the Bonanza Creek LTER in Fairbanks, AK as part of a workshop to continue work on the Maps and Locals project (MALS). The overall objectives of MALS are to 1) use spatial representation of land cover and land use to identify patterns of landscape change in regions in and around LTER sites and 2) integrate local ecological knowledge and other existing social data into theories and models of ecological change and their implications for human livelihoods. At the workshop we shared our individual and collective experiences integrating local knowledge with spatial analysis, and initiated our cross-site comparative analysis. Products of the workshop will include two or more synthesis papers for submission to scientific journals.

We (Nolen) attended and participated in an LTERMapS workshop at the H.J. Andrews LTER research site in Oregon that focused on creating EML from GIS metadata. The LTERMapS project has been developing a common interactive map for the LTER Network (http://www.lternet.edu/map). More recently, the LTERMapS project has been working on developing best practices and procedures for generating EML metadata to describe LTER site GIS layers.

We (Nolen, Sayre) attended and participated in a 2nd MALS workshop at the H.J. Andrews LTER research site in Oregon. At the workshop we developed new methods, new questions and a new framework. There are plans in place to pursue social science supplemental funds. A book on MALS is planned.

G. Information Management

1. Ongoing Activities

We continue to perform ongoing tasks of data documentation, collection, archive, and backup for all research data archived within the Jornada Information Management System (JIMS). We continue planning how to effectively integrate geographic information system (GIS) data layers and research site locations with research data and associated metadata to enhance the quality and availability of all JRN data and to generate more detailed and precise EML documentation. We also continue to provide GPS of research site locations and production of new GIS layers, to provide GIS and GPS support to researchers and students including training and map production. We continue to administer NMSU site licenses for GIS and remote sensing software (Nolen). We continue to populate the JIMS database with research project and associated dataset metadata to support EML generation and the data catalog for all Jornada Basin LTER (JRN) datasets. The Jornada Basin LTER website URL was changed to http://jornada.nmsu.edu/lter in 2011.

2. Servers

2006-2007

The USDA ARS Jornada Experimental Range (JER) purchased a new database server and the JIMS' databases and Trends administrative databases have been migrated to the new server, which required upgrading from Microsoft SQL Server 2000 to 2005. During this process we discovered that Xanthoria (CAP LTER product) would not work on SQL Server 2005. This required that we develop a customized EML creation solution from metadata stored with JIMS. New style sheets have been developed that generate EML level 3 from the JIMS database.

2007-2008

JRN is purchasing a new file server using the LTER site supplement this year. The operating system for the new server will be Novell Open Enterprise Server on SUSE Linux Enterprise Server. Upgrading the operating system from Netware 6.5 will give us the capability to organize our data easier as our volume size limit will be increased from 2TB to 16 TB per volume; e.g., our image archive is currently spread out over 6 volumes on the old file server.

2008-2009

The JRN purchased a new file server this year. The data and imagery were migrated from the ISCSI volumes on the old file server to the new file server SAN volumes. Data and imagery

volumes were consolidated and reorganized using a consistent naming and organizational structure conventions to allow ease of access to and backup of data and imagery hosted on the file server. Backup performance has increased from a new fiber channel tape backup library and performing backups across the SAN instead of the LAN.

2009-2010
JER purchased 2 new Dell PowerEdge R710 servers this year; web server, virtualization server. The new web server was clustered to the file server purchased last year for high availability and multiple FTP sites and websites were migrated from the old web server. The other server was configured as a virtual host running free Citrix XenServer 5.5 software. XenServer allows high availability and load balancing and makes server migration easier using graphical or command line virtualization tools.

Jornada plans to purchase a new Dell PowerEdge R710 server and 3 high availability licenses for XenServer using this year's NSF site supplement. The new server will be added to the production pool and the 3 XenServer Essentials licenses will be applied to the production pool to provide high availability (24x7x365) and load balancing for the production pool running on 3 physical R710 servers. The old file server will be used as a data store for load balancing the production resource pool as well as a backup and development database server.

Upgrades, Migration, and Virtualization of Servers
All Jornada servers were virtualized within a production resource pool using Citrix XenServer this year, with the exception of 1 physical Active Directory server. The following upgrades (including system and application patches) and migrations were performed during the virtualization process.

- Services, imagery, data, network shares, and permissions were migrated from Novell OES2 to Windows Server 2008 R2
- Operating systems were migrated from 32-bit to 64-bit along with appropriate software applications
- Databases were upgraded from Microsoft SQL Server 2005 to 2008 R2
- All Windows servers were upgraded from Windows Server 2003 to 2008 R2 during virtualization
- 2 Active directory servers (physical, virtual) were updated from Windows Server 2003 to 2008 R2
- The mail server was upgraded from Novell GroupWise 7 to 8 and the operating system was migrated from NetWare 6.5 to Windows Server 2003 and mail accounts were migrated

Novell cluster services (NCS) were leveraged to allow the websites and FTP sites to failover and be hosted by the file server while the web server was added to the production resource pool and the web and FTP sites were virtualized.

The GIS server was configured as virtual host server to support a new development resource pool. The development resource pool contains virtual machines running Windows Server 2008 R2. The virtual servers that were created within the development resource pool support active directory, GIS, database, file, image, and web services needed to support software integration

and development and prototyping within a separate environment from our production environment. The Jornada can now quickly clone and export virtual servers from the development resource pool to the production resource pool without impacting services running in either pool. As we complete migration of data from the file server, it will be added to the development resource pool. The development resource pool will not be licensed for high availability. Older servers will be used to support development efforts and science projects until ready for deployment in the production resource pool. The file server will be added to the development pool to provide manual failover capability for the development pool.

2010-2011

A new server was purchased using LTER site supplement funding. The server was integrated into the production server pool. All hypervisor servers in the production (3) and development (2) resource pools were upgraded to XenServer 5.6. The LTER site supplement also supported the purchase of 5 XenServer high availability and dynamic workload balancing licenses for the production and development server pools. The new production web server and the development web server were integrated with Microsoft Active Directory 2008 R2 using LDAPS and SAMBA. This allows Active Directory to serve as the root certificate authority to provide authentication and authorization (using groups) for access to the CentOS 5.6 Linux file systems and hosted web applications (Drupal 6).

We (Lenz) have added virtual machine snapshots to our backup strategy. By snapshotting the virtual machines (servers) prior to upgrades we are able to quickly recover the server to the point immediately prior to the upgrade in the event that the server becomes unstable or inaccessible during the upgrade process. We are evaluating mechanisms to automate the snapshot process to allow regular snapshots of all virtual machines in the development and production pools.

3. GIS/Image Archives and Services Integration

2006-2007

The GIS metadata in xml will be used to generate EML documentation for all JRN GIS layers stored within JIMS, which includes geographic bounding coordinates within EML documents describing research datasets.

JRN purchased a new server to support ESRI ArcGIS Server and ArcGIS Image Server software to allow JRN researchers to query and access the JRN data, GIS layers, and imagery. We also attended the Annual ESRI International User Conference in San Diego, CA to gather technical information necessary to develop and serve the GIS services on the new GIS Server. The new GIS Server will support the following GIS Services:

- query and access to aerial photograph archive
- access research site locations (Intranet)
- online shapefile production to support research site location selection and approval
- Jornada Interactive Map (2D) on website
- Jornada Interactive Map (3D) using ArcGIS Explorer

Deployment of ESRI ArcGIS Explorer is being evaluated to support interaction with the globe services and research site locations and their associated data and metadata as well as GIS thematic layers such as vegetation, soils, and base maps.

2007-2008
We are working closely with JRN users of imagery to improve organization of and access to JRN GIS and remote sensing (RS) data. With the growing quantity of imagery at the Jornada, consistent organization, use of naming conventions, processes for adding and acquiring GIS and RS data, and search interfaces and map services for gaining access to the image archives is critical. We are also exploring new methods for backup of imagery to minimize the backup window and reduce impacts on the local area network (LAN). We are preparing to connect 2 imagery users to the SAN to demonstrate the speed and performance of the SAN versus traditional local disk storage to our imagery users. Backup of the SAN is much faster than LAN-based backups of desktop computers and does not impact LAN performance. We deployed ESRI ArcGIS Server for Java and ArcGIS Image Server on the new GIS server and have begun to develop and deliver map services and web mapping applications for research projects. We attended the Annual ESRI International User Conference in San Diego, CA again this year to gather more detailed technical information necessary to develop search interfaces for the aerial photographs (> 5,000) and other image archives and to stay current on advances in ESRI software.

2008-09
We have redesigned the geodatabase archive and it is currently being updated. The geodatabase supports the Jornada base map and research site locations. The interactive map (http://jornada-gis.nmsu.edu:8399/JornadaBaseMap) has been updated and is now hosted on the GIS server. We now create and host map services and web applications (maps) to support Jornada research and ranch management efforts. Barbara Nolen attended the Annual ESRI International User Conference in San Diego, CA again this year to stay current on software advances and analytical approaches.

2009-10
Virtualized database server and migrated the relational databases from SQL Server 2005 32-bit to 2008 64-bit during that process. The geodatabase was also upgraded from ESRI ArcSDE 9.3 to 9.3.1 SP1. Updated data sources for online interactive map (http://jornada-gis.nmsu.edu:8399/JornadaBaseMap) to use the new virtual database server.

Developed and tested a process to deliver map and image services for use by scientists, GIS users, and web services. Tested connection of GIS layers of research site locations to research projects and dataset documentation stored within SQL Server within an MXD map document. The MXD document was used to develop initial mapping web services using the geodatabase and metadata database to increase data and metadata access and availability. The next step will be to populate Jornada research data into the relational database and relate the data to existing GIS and metadata databases. Relating GIS research site locations, people, research projects, and research datasets will provide the basis for the new Jornada Information Management System and interactive maps similar to those under development by the LTERMaps working group.

Nolen attended the Annual ESRI International Users Conference in San Diego to stay current on ArcGIS software updates and enhancements to better understand upgrading our GIS system to ArcGIS 10 and to keep current on new analytical tools. Nolen continues to work on potential LIDAR data acquisition for Jornada.

2010-2011

We have moved from a planning phase into an implementation phase in integrating our GIS data layers (research site locations and map products) with our data and associated metadata. We have begun to populate all Jornada long-term data into the relational database (SQL Server 2008) that also stores the metadata describing those data. Research study numbers from the research request forms and research project identifiers have been associated in the database. This allows research site locations in the GIS to be associated to metadata and data stored within the JIMS databases.

SAS programs were developed to parse tabular research data files into relational database tables for all long-term datasets. We are now working to link these programs with the metadata in the database to provide a semi-automated mechanism for loading and synchronizing data in the database from source ASCII text files. We plan on migrating our current fixed format text data files to comma-separated value text files to make the automation easier and to provide CSV files from our data catalog. This should make it easier for users of Jornada data to import and use since CSV file formats are supported by most analytical and database software.

So far, we have populated the database with the Jornada NPP and climate datasets. We plan to populate all remaining long-term datasets into the database by the end of the year. Having the Jornada research data stored in a relational database will allow us to integrate the data with web interfaces and tools (EcoTrends) being developed in house as well as to support geospatial and statistical analysis from a common data repository.
Barbara Nolen has created a new geodatabase model that will make it easier to administer, access, and use Jornada GIS layers. The model uses feature datasets to thematically group GIS layers. Barbara has also implemented procedures for generating EML metadata from the metadata stored in the new geodatabase. Barbara has also changed the structure and system for creating map services and web-based interactive maps. We plan on completing population of GIS metadata and subsequently generating EML for all Jornada research site locations in the coming year.

The interactive map was redesigned and deployed to use the new geodatabase model and to provide the ability to print maps. The newly designed interactive map has been integrated into the new Drupal website.

Barbara Nolen and Curtis Monger continue working on the Chihuahuan Desert landform mapping project which should be completed this year.

Scott Schrader is currently evaluating the ESRI open source GeoPortal to provide access to Jornada map and image services as well as web services from other data holders and agencies. We plan on implementing the GeoPortal and integrating it with Drupal in the coming year.

Barbara Nolen, Scott Schrader, and Jin Yao attended the Annual ESRI International Users Conference in San Diego, CA to stay current on ArcGIS software and systems enhancements. This is extremely critical this year as we are actively implementing an enterprise GIS system.

Another critical aspect of the success of our GIS, JIMS databases, and Drupal integration efforts has been holding regular monthly data management meetings that coincide with the monthly combined website meetings. These meeting have been instrumental in keeping our efforts coordinated and productive.

4. Jornada Website
2006-2007
The new web server (purchased by JRN) has been installed and configured to support the new Jornada website currently in beta testing. The new website will include a new XML-based data catalog and data cart that will enforce the JRN data access policy by requiring user registration and authentication prior to download of JRN data. Users that download data will be required to supply an intended use statement upon download. Users will provide contact information, affiliation, and acknowledgement of the JRN data policies when they register with JIMS. When the beta testing of the new website is completed, the new server will be renamed and replace the web server that currently serves the Jornada website.

2007-08
The new web server has been deployed. The new data cart will be deployed soon and will enforce the JRN data access policy by requiring user registration and authentication prior to download of JRN data. We will be phasing in the data cart in a prioritized manner; ongoing, long-term dataset first, followed by climate and all remaining datasets. Prior to deployment of the new server, the website was updated. The new website has the familiar look and feel of the old website, but under the hood, site authentication now uses the JRN LDAP directory and XML configuration files for dynamic web page creation. The LDAP integration also supports the new user registration and data cart systems.

2008-09
The Jornada Experimental Range (JER) purchased a new web server this year. The web and FTP sites were deployed on the new web server using mirrored and clustered volumes as a member of a 2 node cluster running Novell Open Enterprise Server 2 and SUSE Linux Enterprise Server 10. This allows the web sites and file services to have higher availability when maintenance or updates are being performed. Web, FTP, and file services automatically fail over to the other cluster node on the file server.

The JRN development web site has been migrated from the old development server to the new clustered web server on a different port available within the Jornada Intranet. The interactive map (http://jornada-gis.nmsu.edu:8399/JornadaBaseMap) was migrated from ArcIMS to an ArcGIS web application hosted on the GIS server. The Jornada searchable bibliography has been migrated from Reference Web Poster to Reference Manager 12 Web Publisher hosted on the GIS server (http://jornada-gis.nmsu.edu:81/rmwp). We also modified our web page according to the LTER Network wide guidelines for web site design and content.

2009-10
A virtual EcoTrends development server was deployed at the Jornada to allow testing of EcoTrends website development prior to updating functionality to the production EcoTrends server at LNO. Jornada also deployed a virtual Subversion server running on a virtual Novell SLES server. The source code repository is being used to support the EcoTrends software development efforts at the Jornada.

The web and FTP sites were migrated twice this year. First, the sites were migrated to the new web server running Novell SLES and NCS. The second migration was from Novell SLES to CentOS as part of the server virtualization process. Following the virtualization process, the websites (Jornada LTER, Jornada Experimental Range, Jornada LTER development, and Other websites) previously hosted by 1 physical server running Novell SLES are now hosted on 4 individual virtual servers running CentOS. The Other websites include P2ERLS, Western Snow Conference, 2009 SRM Meeting, and EcoTrends Database Administration. The FTP sites and permissions were migrated from Novell to Windows file and directory systems.

2010-2011
The Jornada has developed a new combined website (http://jornada.nmsu.edu) based on the open source Drupal content management system. The combined website serves as a portal to access information and data for all Jornada collaborations. This allows common tools to be developed and deployed to serve multiple research projects and initiatives. A key component to our success has been monthly combined website meetings. A Drupal development and production server was deployed to support the new website development.

We are currently working to implement the Drupal Environmental Information Management System (DEIMS) developed by several LTER sites and the University of Michigan. The DEIMS will serve as a dynamic data catalog with capabilities to search for data products by person, abstract, and data categories (LTER core area, Jornada data categories) and provides the capability of ingesting or generating EML for data described within DEIMS.

The Jornada email system was migrated to a new email domain (jornada-vmail.nmsu.edu) to free up the jornada.nmsu.edu domain for the new website. The new Jornada Basin LTER website (http://jornada.nmsu.edu/lter) is currently under construction and will be deployed this year. The newly updated interactive map has been added to the new combined website and all content from the old LTER website has been migrated to the new website. We are now working to update the content as well as the look and feel of the Jornada Basin LTER website.

The combined website was setup using LDAPS to provide authentication and authorization (using groups) for Drupal. This will allow new users to register within Drupal and use LDAP for authentication if their user account exists in Active Directory. Otherwise, Drupal is used for authentication. The Jornada bibliography and personnel directory have been migrated to Drupal where the content is now maintained. DEIMS allows people, research data, and publications to be related. The Jornada plans on enhancing DEIMS to provide an additional association of related research site locations stored with GIS. We also intend to integrate DEIMS with developing web services to access data, metadata, map, and image services such as those being developed (LTER NIS, LTERMapS, and a Jornada GeoPortal).

5. Storage Area Network
2007-2008
The Jornada Experimental Range (JER) purchased a new storage area network (SAN), a fiber channel switch, network attached storage (NAS) server, and fiber channel tape library. This storage solution gives JRN nearly 24 TB of storage capacity with the ability to add 28 TB by adding 1 TB hard drives.

2008-2009
An additional 6 TB of storage capacity was added to the SAN this year. Currently, full backups of all Jornada workstations and servers consume 10-11 LTO4 tapes per week, with a total capacity of up to 17.6 TB.

2009-10
JER purchased a new partially populated Xyratex TE444 SAN storage enclosure with 24 TB of storage, doubling storage capacity of SAN. This leaves 24 slots for future expansion in both TE444 SAN enclosures for growth of the SAN. JER purchased a new SAN switch that allowed the 2 SAN switches to be connected redundantly and provide additional ports to connect select desktop computers to the SAN using fiber channel.

2010-2011
JRN purchased and deployed 18 new hard drives to populate the older TE444 storage area network enclosure using LTER site supplement funding. This provides an additional 18 TB of storage capacity to our server pools. The initial data migration to the new storage has been completed.

6. Wooton Hall Network
2008-2009
Three new gigabit network switches were purchased (1 by JRN, 2 by JER) and installed to replace the server switches (inside, DMZ) and to allow connection of scientists' and staff computers to the servers at gigabit speeds. This increase in bandwidth from the desktop computers and laptops increases the performance of image analysis and GIS software to the central storage system and reducing data backup windows for client and server computers. All servers were moved to the DMZ subnet to provide improved security, higher availability (clustering the web and file servers), and to minimize network problems from affecting servers, desktop computers, and wide area network (field station) performance simultaneously.

2009-10
JER purchased and deployed new gigabit Ethernet switches within Wooton Hall to (1) increase available server ports, (2) allow redundant, load balanced interconnectivity of Jornada servers (virtual and physical), and (3) increase bandwidth (100 MB to 1 GB) between desktop computers and Jornada servers for 'power' data users (imagery and GIS users).

7. Field Station and Wireless Networks
2008-2009
Two 10/100 MB network switches (gigabit backbone) were installed at the JER Ranch Headquarters facilities to improve performance of computers and IP phones as well as to prepare for higher speed bandwidth, planned expansion of facilities, and to support the expansion of the wireless coverage across to research sites. We anticipate increasing bandwidth from the field station to the NMSU campus from 1.54 MB to 50 MB, in the coming year to support data and video streaming, remote education (K-12), IP phones, and video conferencing.

2009-10
Increasing bandwidth from the field station to the NMSU campus using Qwest Metro Optical Ethernet was found to be cost prohibitive. We are now exploring options to increase bandwidth to the field station using high speed point-to-point or multi-point wireless repeaters with little or no recurring costs.

H. Education and Outreach

1. K-12 Education [S. Bestelmeyer].

The Jornada Basin sLTER is run through a unique collaboration that links the Jornada Basin LTER, the USDA-ARS Jornada Experimental Range, and the nonprofit Asombro Institute for Science Education (home of the Chihuahuan Desert Nature Park). Since its inception in 1998, the program has become a model used by regional school districts (El Paso Independent School District), other NSF-funded programs (e.g., GK12 program at the University of Texas El Paso), and statewide initiatives (New Mexico's NSF EPSCoR). The program's success highlights the need for inquiry-based science education opportunities for underrepresented students in this border region where approximately 70% of the students are Hispanic.

During the 2007/08 year, staff continued and/or improved all four components of the program. In doing so, staff directly reached more than 12,000 individuals (8,923 students, 80 teachers, and 3,078 other adults) in southern New Mexico and western Texas. Specific accomplishments for each project component are listed below.

Field trips – 2,735 kindergarten through 12th grade students attended 38 day-long field trips where they participated in hands-on activity stations to learn about LTER scientists' latest research. Teachers used pre- and post-field trip activities available through the Asombro Institute for Science Education's web site (www.asombro.org) to prepare students for the field trip and then extend the learning back into the classroom.

Classroom programs and schoolyard studies – Asombro Institute staff members brought exciting, hands-on science programs into classrooms as well. Staff gave 162 hour-long classroom programs to 3,751 students. Most of the activities for these classroom programs come from the Jornada Basin Schoolyard LTER's 400-page handbook containing 35 inquiry-based activities that are done in the schoolyard and/or classroom. Activities are divided into seven categories that overlap with LTER research: weather, microclimates, soil, water, vegetation, arthropods, and vertebrates. Each activity includes teacher instructions, background information, sample graphs, reproducible student pages in English and Spanish, and alignment with state standards. Each topic area (e.g., weather, arthropods) has an associated Science Investigation Kit containing all

of the equipment and consumable supplies needed to do the activities. Teachers borrowed these kits for use in their classrooms throughout the 2007/08 school year.

Teacher workshops – During the project year, staff presented nine daylong teacher workshops for 80 teachers from three school districts. During workshops, teachers learned and practiced the schoolyard activities.

Programs for the general public – Focus was also placed on increasing science learning opportunities for the general public through the presentation of 52 public programs attended by 2,437 students and 3,078 adults. Programs took place at the Asombro Institute's 960-acre Chihuahuan Desert Nature Park as well as at other venues throughout the region.

While maintaining the components above, staff also added two new classroom programs (one for elementary students and one for middle school students). These programs were specifically designed for teachers with limited science backgrounds; handouts allow teachers to use project activities and borrowed equipment to continue data collection and analysis with their students following the programs given by Asombro Institute staff members.

Finally, project staff began working with a program evaluator from the University of Texas at El Paso to develop evaluation instruments that can assess students' and teachers' gains in understanding following participation in sLTER programs. Instruments are being pilot tested during the fall of 2008.

During the 2008-09 year, staff continued to provide field trips, classroom programs, schoolyard studies, teacher workshops, and programs for the general public. A new project for middle school students, the Real World – Real Science Project, was also implemented in spring 2009 (described below). In total, these efforts provided up-to-date, locally relevant science information to more than 14,000 individuals (11647 K-12 students, 81 K-12 teachers, and 2844 members of the general public). Specific activities are described below.

Field trips – Staff and volunteers ran 57 day-long field trips for 3,829 K-12 students. Trips took place at the USDA-ARS Jornada Experimental Range and/or the Asombro Institute for Science Education's Chihuahuan Desert Nature Park (located directly south of the Jornada Experimental Range). Teachers chose from a menu of activity stations designed for four grade levels (K-2nd, 3rd-5th, 6th-8th, and 9th-12th). All stations allowed students to collect data and learn about current research being conducted by LTER scientists. Each station is also aligned with New Mexico and Texas state science standards.

Classroom programs and schoolyard studies – 7,818 students participated in 331 one-hour classroom and/or schoolyard programs delivered by Asombro Institute for Science Education staff members. Most of the activities in these programs once again came from the Jornada Basin LTER's 400-page handbook on inquiry-based activities that are based on LTER research.

Teacher workshops – 81 teachers participated in six workshops hosted by program staff. Workshops ranged in length from one day to ten days. The 10-day advanced ecology workshop for high school science teachers was part of a NSF-EHR grant which involves scientists and educators at five LTER sites (JRN, HJA, SGS, LUQ, and CAP).

Programs for the general public – 2,844 people took part in 24 public education programs during the 2008/09 year. Programs covered diverse science topics (e.g. archaeology, entomology ecology) in a variety of locations throughout southern New Mexico and the El Paso, Texas region. All programs were designed to expose visitors to current, ongoing research taking place

in the region. In addition to continuing the existing program components listed above, program staff also designed and implemented a new program using sLTER supplement funds as well as other funding. The Real World – Real Science Program exposed 1,182 students and nine teachers from five middle schools to environmental science research. Teachers participated in a one-day workshop and chose a module (topics included arthropods, vertebrates, global climate change, and soil) to continue with their students. During the 2008/09 school year, students completed pre-field trip activities, attended a one-day field trip with LTER staff, and completed post-field trip activities in their classrooms. This model improved the traditional one-day field trip model, allowing teachers to adequately prepare students for the field trips and extend the learning back into the classroom. The project was a great success, with teachers reporting tremendous increases in students' knowledge of and enthusiasm for ecology.

During the 2009-2010 year, more than 60,000 kindergarten through 12th grade students and 1,000 teachers have participated in the Jornada Basin Schoolyard LTER Program (sLTER) since its inception in 1998. Three partners collaborate to run the program: (1) the nonprofit Asombro Institute for Science Education (which manages a science education facility – the Chihuahuan Desert Nature Park), (2) the USDA/ARS Jornada Experimental Range, and (3) the Jornada Basin LTER. The most recent Jornada Basin LTER site review by NSF in September 2009 praised the program's focus and reach: "The school yard LTER program is very strong and the numbers of K-12 students and teachers that have been reached are impressive. The relationship with the Chihuahuan Desert Nature Park and the Asombro Institute for Science Education is a definite strength of the sLTER outreach and education program and the focus on teacher training and curriculum development is laudable."

The Jornada Basin sLTER provides multiple opportunities for teachers and students to engage in inquiry-based activities as a method of learning about the desert ecosystem and local research. All Jornada Basin sLTER programs are tied directly to research on the environmental causes and consequences of desertification in semi-arid Chihuahuan Desert ecosystems, the main research focus of the Jornada Basin LTER. Key components of the program are:

- Schoolyard Science Studies (Schoolyard Desert Discovery Program) – Asombro Institute for Science Education staff have worked with LTER scientists to develop 31 hands-on activities that can be completed in the schoolyard and/or classroom. These activities mirror active research conducted by LTER scientists, with appropriate modifications for the schoolyard setting. Activities are divided into seven modules: weather, microclimates, water, soil, vegetation, arthropods, and vertebrates. Each module has an associated Science Investigation Kit containing all of the materials and consumable supplies needed to do any activity within that module. Teachers borrow the kits from the Asombro Institute for use in their classrooms. A 400-page handbook containing all 31 activities is given to teachers who attend project workshops. Each activity's write-up includes background material, teacher instructions, tips for completing the project with the entire class, sample tables and graphs, reproducible student pages in English and Spanish, and alignment with New Mexico and Texas science and math standards (the Jornada Basin sLTER serves the NM/TX border region).
- Field Trips – Students attend day-long field trips to the Jornada Experimental Range and/or the Chihuahuan Desert Nature Park. They rotate through four hands-on activity stations that have been chosen by their teachers from a menu of 38 stations in four grade levels (K-2nd,

3rd-5th, 6th-8th, and 9th-12th). Stations have been developed with the assistance of LTER scientists, and they are delivered by Asombro Institute staff members and trained volunteers.

- Classroom Programs – Asombro Institute for Science Education staff members visit classrooms to present one-hour, inquiry-based science programs. These programs have become extremely popular over the past few years with increases in bus costs and other barriers that often prevent field trips.
- Teacher Workshops – Teachers attend workshops ranging in length from one day to two weeks to learn about current ecological research being conducted in the region. During longer workshops, teachers conduct a full research project themselves and later share the results with their students.
- Family Education Events – Science education events are held at the Chihuahuan Desert Nature Park to encourage families to get outside, interact with scientists, and learn about the ecosystem where they live. In October 2009, we used sLTER funds to host a Saturday event about the desert. Eighty-five participants (54 adults and 31 children) participated in hands-on activity stations to learn about the geology, soil, plants, and animals of the desert.

Demographic Information on Participating Students

The majority of the Jornada Basin sLTER participants come from the Las Cruces Public School District and the Gadsden Independent School District, both in southern New Mexico. These districts serve a high percentage of students considered "economically disadvantaged" (Las Cruces 90% and Gadsden 92%) and a high percentage of Hispanic students (Las Cruces 71% and Gadsden 96%). Jornada Basin sLTER programs therefore provide enriching opportunities to groups traditionally underrepresented in STEM fields.

In 2010-2011, we continued to support and improve the five major activities listed above. The year's highlights for each activity included:

- Schoolyard Science Studies (Schoolyard Desert Discovery Program) – program staff added: (1) a new biodiversity topic with six activities to bring the total number of topic areas covered to eight (weather, microclimates, water, soil, vegetation, arthropods, vertebrates, and biodiversity), (2) an activity on phenology, and (3) a data website where teachers and students can enter their data and/or download data collected by other students (www.schoolyarddesertdiscovery.org).
- Field Trips – 1648 students attended 23 day-long field trips to the Jornada Experimental Range and/or the Chihuahuan Desert Nature Park. They rotated through four hands-on activity stations chosen by their teachers from a menu of 38 stations in four grade levels (K-2nd, 3rd-5th, 6th-8th, and 9th-12th). Stations have all been developed with the assistance of LTER scientists.
- Classroom Programs – Asombro Institute for Science Education staff members delivered 325 one-hour programs to 8,745 K-12 students in the 2010/11 school year. Programs took place in classrooms and schoolyards using the activities developed by education staff for the Schoolyard Desert Discovery Program at the Jornada Basin LTER.
- Teacher Workshops – Eight one to two day workshops were hosted by LTER education staff for 178 teachers. Attendees learned about current ecological research being conducted in the region and received training on use of Schoolyard Desert Discovery activities at their schools.

- Family Education Events – We hosted six science education events at the Chihuahuan Desert Nature Park to encourage families to get outside, interact with scientists, and learn about the ecosystem where they live. A total of 1,478 people attended these events.

2. Graduate Education

2009-2010

Throop ran a graduate seminar in spring 2009 (BIOL 550: Chihuahuan Desert Ecology). The Jornada synthesis volume served as the central text, supplemented by recent and historical papers from the Jornada. The course was greatly enhanced by very active involvement from Jornada scientists; ten scientists from JER and NMSU attended class one or more times to participate in discussions. The course was highly interdisciplinary; the ten students enrolled were from four different departments (Biology, Animal and Range Sciences, Plant and Environmental Sciences, Fisheries and Wildlife). However, all students were involved in field research in the Chihuahuan Desert as part of their graduate research. As a service learning component of the course, graduate students took 101 undergraduate biology students to local field sites for desert natural history excursions. The course included a a one day field trip for graduate students to the LTER.

Vivoni taught a graduate class at ASU (GLG 598: Ecohydrology of Semiarid Landscapes) in spring 2010. The class consisted of an interdisciplinary group of 12 MS and PhD students from Geology, Geography, Engineering, Life Sciences and Sustainability. A one-day field trip was conducted to JRN LTER during spring break to visit research field sites (watershed study area, SCAN site) and meet with JRN LTER scientists (Rango, Peters, Anderson). Material from the JRN LTER synthesis book and other publications was used during the field visit and for class readings and homework exercises, including long-term data analyses. The course was well received by the participating students.

2010-2011

Sala and Ferrán García-Pichel taught an ASU course for first-year PhD students in Environmental Life Science. As part of this course, students and faculty visited the Jornada LTER and spent two nights at the headquarters. Curtis Monger and John Anderson gave lectures in the field that complemented the ecosystem and microbial viewpoints.

Vivoni taught a graduate class at ASU (GLG 598: Advanced Watershed Hydrology) in spring 2011. The class consisted of an interdisciplinary group of 18 MS and PhD students from Geology, Engineering, Life Sciences and Sustainability. Material from JRN LTER publications was used for class readings and homework exercises, including long-term data analyses. One of the class term projects focused on the application of the KINEROS2 hydrology and erosion model to the small instrumented watershed in the JRN. The course was well received by the participating students.

3. Outreach: local to national

In an effort to develop and maintain contact with a cross-section of clients and stakeholders, a Jornada Advisory Committee was established in 1995. This group meets periodically to review aspects of our research, and provides input on content, future directions, and potential for new collaborations. Membership on this committee includes representation from the environmental

community (Sierra Club), the agricultural community (New Mexico Cattle Growers, New Mexico Association of Conservation Districts), land management agencies (NM Department of State Lands, USDA: Natural Resources Conservation Service, USDI: Bureau of Land Management), non-government organizations (World Wildlife Fund, The Nature Conservancy) , and scientists (NMSU). This group has been restructured and our interaction are more organized through ~ two dozen collaborative research agreements with these partners.

An additional component of our outreach program has been targeted interactions with resource management practitioners. This is accomplished in a variety of ways, including workshops, seminars, and service on various boards of directors. We also contribute to a multitude of different training, workshop, and symposia events developed for public and managers agency personnel and private individuals. Topics of these events include rangeland health evaluations, the National Resource Inventory, and development of ecological site descriptions. Each year, Jornada staff devote hundreds of hours to these types of outreach activities. We specifically target individuals and groups that have expressed interest in information and technologies based on current research. An added benefit to the Jornada Basin LTER is the co-location of three resource specialists/scientists with the Natural Resource Conservation Service in our building. These specialists have been invaluable in providing input and content to our outreach activities.

Two of our primary mechanisms for science audience outreach continue to be our annual research symposium and our annual newsletter. The Jornada Basin symposium is scheduled for the second Thursday each July, and has attracted a growing audience during its first 19 years. We now employ a web based simulcast to reach additional interested individuals off site, and provide Spanish translations when large numbers of participants are from Mexico. Our newsletter is locally produced and reaches a variety of research, administrators, and land managers across the United States with a mailing list of > 350. It is also available on the Jornada Basin LTER web site (http://jornada-www.nmsu.edu).

Selected local to national outreach examples are below.

2006-2007

Based on a synthesis of our research results together with other studies and in cooperation with the NRCS, we developed a protocol for improving ecological site and ecological site. The NRCS is now promoting the national adoption of this protocol. We also served with an interagency team (USGS, BLM and NRCS) to provide three week-long workshops to over 150 land managers on an ecological process-based rangeland assessment protocol in Colorado, Oregon and Wyoming. This protocol, much of which is supported by Jornada LTER research, is already being nationally applied by NRCS and BLM. Participants in the 2006-2007 workshops including a number of USFS and DoD managers.

2007-08

In addition to numerous oral and poster presentations at local to national meetings, we highlight the following invited talks:

Herrick presented the invited talk "Prioritizing responses to desertification" at the United Nations Commission on Sustainable Development (CSD-16) in May 2008 in New York, NY.

Sala presented the talk "Sustainability without stability: new goals for a world in flux" at the American Association for the Advancement of Science annual meeting in Boston, MA.

Monger hosted the Soil Geomorphology Institute, March 4-20, 2008. The workshop consisted of 35 participants mainly from the NRCS with others from BLM and USDA-APHIS. The objective was to provide training to soil scientists on pedology and geomorphology using a combined classroom and field training approach.

Monger chaired two symposia (Geology and Biomineralogy; Human Influences on the Stratigraphic Record) at the joint 2008 meeting of the Geological Society of America and Soil Science Society of America meetings.

Rango established formal links with the Physical Science Lab at NMSU for the JRN to become part of their UAV facility.

Peters will give the key note talk at the annual meeting of the New Mexico Native Plant Society on 26 September 2008 in Las Cruces, NM. Her talk, entitled "The past as a lens to the future: crossroads in time and space" will feature JRN LTER research results.

Peters was elected to the Board of Directors of NEON as a member representative. She attends three NEON board meetings each year as part of her duties in her 3-year term.

2008-09

Archer attended Agency Heads briefing, USDA Strategic Plan for Climate Change, Washington, DC, Sep. 15-16, 2008 as part of a 6 member briefing team.

Archer presented "Grasslands in Transition: Emerging Issues and Challenges in the Western US". In: Symposium on "Assessing the Multi-Functionality of Grasslands—Future Research Priorities to Address Global Change". SA-CSSA–SSSA Annual Meetings, Houston, Texas (Oct 5-9, 2008)

Parsons and Wainwright with coauthors L. Larsen, J. Wheaton, C. Gibbens, G. Okin, and E. Mueller presented a talk at the American Geophysical Union Fall Meeting, San Francisco in the special session on "Multiscale Feedbacks in Ecogeomorphology" Dec. 2008.

Wainwright and Parsons presented following papers at the American Geophysical Union meeting: "Dynamics and Resilience of Desert Ecosystems under Changing Climate"; "Do Changes in Connectivity Explain Desertification?" 'A "Turing" Test for Landscape Evolution Models'; "Particle movement by interrill erosion and 137Cs loss based on the transport distance model. 2008.

2009-2010
Archer with co-authors KW Davies, TE Fulbright, K McDaniel, and BP Wilcox presented "Brush Management and Conservation: New Perspectives on an Old Problem" In: Conservation Effects Assessment Project (CEAP) Rangeland Literature Synthesis: An Initial Report Symposium. Society for Range Management Annual Meetings, Albuquerque, NM. (Feb. 2009).

Archer presented "Grassland Conservation and Management: Emerging Issues and Challenges" in Leaders in Agriculture Lecture, Sul Ross State University, Alpine, TX (2009).

Sala presented talks describing results of his work at JER at Arizona State University, Texas A&M, and University of Connecticut.

Sala, Bestelmeyer, Rango, and Wright were elected to the Desert Southwest Domain Science and Education Coordinating Committee for NEON

2010-2011
Archer presented an invited seminar entitled "Ecosystem state transitions in grasslands: shrubs gone wild" to the NSF Division of Environmental Biology on 24 May 2010 in Washington, DC

Throop presented talks describing results of her work at JRN at Kansas State University, Oregon State University, and New Mexico State University.

Herrick with many co-authors presented "How international research cooperation in Africa, Asia and Latin America is benefiting U.S. efforts to address land use change and management" at the Soil and Water Conservation Society "Fellows Forum" in Washington, DC (July 2011).

Herrick presented "Resilience-based management" at the Agricultural Landscapes Forum in Washington, DC (April, 2011).

Vivoni offered an invited talk at the American Geophysical Union, Fall Conference on the JRN LTER research activities: "The Challenge of Fully-Predictive Hydrologic Models Supported by Observations: Recent Experiences and Prospects in Semiarid Systems." Templeton (with co-authors Vivoni, Rango, Laliberte) presented a poster at the same conference entitled: "Emerging Technologies for Ecohydrological Studies during the North American Monsoon in a Chihuahuan Desert Watershed". Templeton (with co-authors Vivoni, Rango and Laliberte) also presented the 24th Annual Arizona Hydrological Society conference on: "Redesigning the small catchment study: Distributed model evaluation in a Chihuahuan Desert basin and the impact of model coarsening."

3. Outreach: international.

International Connections - We also have extensive experience working in other parts of the world undergoing similar aridland or desertification processes. We are collaborating with researchers on all seven continents, including South America (Sala, Herrick, Bestelmeyer), Antarctica (Peters, Sala), Australia (Bestelmeyer), Europe (Herrick, Bestelmeyer, Peters), and

Africa (Herrick). Here we highlight work in Central America (Mexico), China, and Mongolia as examples of this collaborative research.

Mexico: With support from an LTER supplement, we initiated the development of a network of sites in Mexico designed to examine the role of extreme events in Chihuahuan Desert dynamics [Herrick]. A workshop held in Zacatecas, Mexico (April, 2005) resulted in the development of a set of standardized site characterization protocols that were subsequently applied at 18 locations distributed among 7 sites in Mexico. As part of this pilot project, over 20 Mexican scientists and students were trained during workshops in 2006. A database was developed to facilitate the characterization of additional sites for extreme events and other long-term research. The database was transferred to the GRACILIS network based in San Luis Potosi.This effort contributed to the eventual participation of the new Mexican LTER. We are also involved in efforts to form a biosphere reserve in the Janos grasslands and working with the Sta. Elena Protected area [Fredrickson]. We have active research projects in Chihuahua, Mexico on prairie dog-cattle-vegetation interactions, and mentor graduate students from the Universidad de Chihuahua and the Universidad Nacional de Mexico. Soil-geomorphic studies were conducted at Janos by Monger in conjunction with Herrick and Fredrickson.

China: We are actively involved in training researchers in monitoring techniques developed and tested at the Jornada. We led a week long "Interpreting and Measuring Indicators of Rangeland Health" workshop in Xilinhot, Inner Mongolia, China (June 2008; 60 participants) [Bestelmeyer]. We also led a group of two students and two other professors to Inner Mongolia (Sept 2008) to discuss future collaboration on soil-geomorphology and grassland ecology [Monger]. The trip was funded by the Jornada LTER Supplement (2008).

Mongolia: Jornada scientists have active collaborations in Mongolia that include training, research, and scientist exchange programs [Havstad, Herrick, Bestelmeyer]. Jornada scientists visited Mongolia in Oct. (2006) at the invitation of the Green Gold Pasture Ecosystem Project supported through the Swiss Agency for Development and Cooperation (SDC) and the Research Institute of Animal Husbandry (RIAH) in Ulaanbaatar, Mongolia. This visit had two objectives: 1) to provide US and Mongolian scientists and land management agency personnel the opportunity to share views and exchange expertise on issues of pasture monitoring and health assessment, and 2) to review the process of land assessment being used in Mongolia in terms of overall state of conduct, methodology, indicators, and synthesis. These objectives were addressed by initiating discussions for furthering collaborations, by providing two days of training of Mongolian personnel in interpreting indicators of rangeland health followed by educating Jornada scientists on ecological and socioeconomic characteristics of Mongolian rangelands. These collaborations continued in 2007 with meetings on long-term data needs funded in part by the LTER Network office. In 2008, we conducted a five week training program for young Mongolian scientists at the Jornada. In 2008 and 2009, we contributed to the modernization of Mongolia's national rangeland monitoring program by training local technical personnel in updated data collection and quality control protocols, and reviewing monitoring site selection during a series of meetings and a 3 week field campaign.

Selected international outreach examples are below:

2006-07

Herrick: With support from an international supplement, we initiated the development of a network of sites in Mexico designed to examine the role of extreme events in Chihuahuan Desert dynamics. A workshop was held in Zacatecas, Mexico in April, 2005. The workshop resulted in the development of a set of standardized site characterization protocols. These protocols were subsequently applied at 18 locations distributed among 7 sites in Mexico. As part of this pilot project, over 20 Mexican scientists and students were trained in the protocols during workshops held in 2006. A database was developed that will facilitate the characterization of additional sites that can be used in the future for extreme events and other long-term research. The database was transferred to the GRACILIS network, which is part of the new Mexican LTER network and is based in San Luis Potosi.

Monger: We hosted the Desert Project Soil-Geomorphology Tour, May 21-25, 2007. This tour brought together geomorphologists, soil scientists, ecologists, and archaeologists from 15 states, Washington DC, Nepal, Puerto Rico, and India. The tour had an attendance of 85 participants from 16 university, 5 federal agencies, and 6 consulting companies.

2007-08

Herrick co-led one week long "Interpreting and Measuring Indicators of Rangeland Health" workshops in Las Cruces (May 2008; 45 participants), Worland, WY (June 2008; 35 participants), and Xilinhot, Inner Mongolia, China (June 2008; 60 participants). Workshop participants in the US included representatives from BLM, NRCS, DoD, NM State Lands, TNC, university faculty, and consultants. This internationally applied protocol is based on our LTER research.

Bestelmeyer presented the invited talk "The regional ecology of alternative states and thresholds: strategies for ecological site descriptions" at the International Rangeland Congress in Hohhot, Inner Mongolia, China.

Bestelmeyer presented the invited talk "Thresholds in rangelands: the scales of social-biophysical interactions" at CSIRO Rangelands and Savannas stations on Alice Springs, Darwin, Townsville, and Canberra, Australia.

Fredrickson will participate in the Sister Park Meeting between White Sands National Monument and Cuatrocienegas Protected Area in Mexico 3-5 September 2008. Ed will lead a tour of the Jornada and will discuss JRN LTER approaches to understanding and remediating arid and semi-arid landscapes. He has extensive experience working in Mexico, and is involved in efforts to form a biosphere reserve in the Janos grasslands and is working with the Sta. Elena Protected area. He also has active research projects in Chihuahua, Mexico on prairie dog-cattle-vegetation interactions, and is mentoring graduate students from the Universidad de Chihuahua and the Universidad Nacional de Mexico.

2008-09

Herrick led several sessions in a workshop on soil quality monitoring in Latvia at the invitation of the Food and Agriculture Organization (FAO) in September (2008). The 20 participants represented agricultural development workers, government scientists and academics from Latvia and the surrounding region.

Herrick led a workshop on the development of monitoring indicators for Kenyan rangelands at the Mpala Research Center near Nanyuki, Kenya at the invitation of the US Agency for International Development and CARE International. The 20 participants represented ranchers, scientists and consultants from several non-profit conservation and development organizations in Kenya.

Herrick and Bestelmeyer led a one-week international workshop on rangeland inventory, assessment and monitoring in association with the International Rangeland Congress in Hohhot, Inner Mongolia, China in June, 2008. The workshop included over 20 participants globally.

Monger led a group of two students and two other professors to Inner Mongolia (Sept 2008) to discuss future collaboration on soil-geomorphology and grassland ecology. The trip was funded by the Jornada LTER Supplement grant (2008). While there, he and another professor and the two students gave lectures at the Inner Mongolian Agricultural University.

Monger hosted the National Cooperative Soil Survey Conference at NMSU (May 9-14) that focused on ecological relationships and soil change. The conference brought together 172 participants from 34 universities and 7 federal agencies from 41 states, Washington DC, Puerto Rico, Mexico, Hungary, and Australia. Tours to the Jornada Experimental Range were led by Brandon Bestelmeyer, Arlene Tugel, and Mike Duniway. Kris Havstad gave the keynote address at the banquet.

2009-2010

Throop and NMSU doctoral student Jane G. Smith traveled to western New South Wales, Australia in November-December 2009 with funding from the International Supplement. to the JRN They worked with David Eldridge of University of New South Wales to assess the impacts of grazing management strategies and feral animals on soil carbon pools, organic matter dynamics, and litter redistribution patterns. Eldridge visited JRN in July 2010 to collaborate on data analyses, manuscript preparation, and plan for additional related studies.

Throop traveled to Israel and Jordan to meet with students and faculty at Bar Ilan University, Tel Aviv University, Ben Gurion University of the Negev, and Jordan University of Science and Technology and to discuss collaborative work on litter decomposition, nitrogen cycling, and organic matter dynamics.

Monger gave a keynote address at the 19th World Congress of Soil Science (Brisbane, Australia) August 1-6, 2010 on "Soil morphology adaptations to global warming in arid and semiarid ecosystems".

2010-2011

Archer presented the R.D. Watt Centenary Lecture at the University of Sydney in March 2011. The title of his presentation was "Woody plant imperialism: new perspectives and current challenges"

Archer presented an invited lecture to the Faculty of Agriculture, Food and Natural Resources at the University of Sydney in March 2011. The title of his lecture was "Shrubs gone wild: the ecology of brush management". During a week-long visit, he met with a variety of faculty and research scientists about the ecology and management grasslands, savannas and woodlands and reviewed their on-going programs; and he met with the Executive Director of Victoria Forests and Parks and personnel in their Department of Sustainability and Environment regarding approaches for managing fuel and and wildfire risk in Victoria's high country and National Parks using strategic cattle grazing

Herrick worked with scientists at the Mpala Research Center in Kenya to develop a simplified ecosystem monitoring system that is sensitive to changes in connectivity. This system is now being applied, and a new project was initiated to characterize spatial variability in plant community dynamics as a function of soils using an ecological site-based approach.

In April, Bestelmeyer and Herrick led three separate workshops in Argentina on ecological site-related concepts and applications for arid and semi-arid environments. These workshops were associated with the International Rangeland Congress, where Herrick gave a plenary presentation, “Are we ready for the (range)land revolution?”.

Herrick gave an invited presentation, “Land use planning for limiting drought impacts and promoting recovery” at the International US-Mexico Forum for Drought Mitigation and Early Warning Systems in Zacatecas, Mexico (August 11-12).

Herrick represented the United States on science-related issues at the UNCCD Commission on Science and Technology meeting in Bonn, Germany in February.

Herrick initiated work with Mongolian and Canadian collaborators to establish an ecological monitoring system for a large US-Mongolian development project designed to support the development of more sustainable livestock production systems in several peri-urban areas in Mongolia. This work included a 10-day field visit in June.

Laliberte gave the keynote address and presented another paper on UAV remote sensing at the British Remote Sensing and Photogrammetry Society UAV workshop in Durham, UK, July 6-8, 2011. The workshop explored development of new sensors for UAVs and will lead to future international collaborations in UAV remote sensing.

Sala is part of the selection committee of the Ramón Margalef award, which is given annually to an outstanding ecologist and carries a 100,000 Euro prize. The committee meets annually in Barcelona and selects the winner among a distinguished group of nominees.

Vivoni offered a seminar in Cagliari, Sardinia, Italy where he discussed work at the JRN LTER under the title of: "Distributed hydrologic modeling supported by observations: How do we provide predictions for a range of hydrologic applications?"

I. Associated Funded Grants

2007-2008

Bhattacharya, A., Cook, J., Bailey, D., Jeffery, C., **Peters, D**. CRI: Infrastructure for networked sensor information technology. NSF. Division of Computer and Network Systems. Program for Computing Research Infrastructure. $498,000. 2006-2009.

Peters, D. LTER V. Site Supplement. NSF. $72,150. 2007.

Peters, D. LTER V. EcoTrends Supplement. NSF. $149,800. 2007.

Peters, D. LTER V. Supplement. NSF. $206,707. 2008.

Bestelmeyer, B. and **Archer, S**. A hierarchical, geospatial approach to predicting and mitigating shrub invasion in the southwestern US. USDA-NRI Biology of Weed and Invasive Species in Agroecosystems. $400,000. 2008-2011.

Archer, S. and **Throop, H.** (collaborative with D. Breshears, P. Barnes, R. McCulley). Decomposition in drylands: soil erosion and UV interactions. NSF Ecosystem Science Cluster. $1,108,000. 2008-2012.

Barger, N., Miller, M, **Herrick, J**. Development of a science-based decision making model for restoration of pinyon-juniper ecosystems. USDA-NRI Forest and Rangeland Ecosystems. $499,650. 2008-2011.

Dougherty, L., **Peters, D**., and **Havstad, K**. Construction of a multi-user facility at the Jornada Experimental Range Field Station. NSF. Division of Biological Infrastructure. Field Station Program. $238,000. 2008-2010.

Peters, D.P.C., and W. Sheldon. Workshop to promote synthesis products from the EcoTrends project. LTER Network Working Group Proposal. $24,500. 2008-09.

2009-2010

Sala, O., Peters, D., and Bestelmeyer S. Precipitation controls of carbon and nitrogen cycles in semi-arid ecosystems. NSF. Division of Environmental Biology. Ecological Biology Cluster. $799,441. 2009-2012.

Peters, DPC. LTER V. Supplement. NSF. $70,250. 2009.

Peters, DPC. LTER V. Supplement. NSF. $214, 200. 2010.

Schooley, R., Kelly, J. F., **Bestelmeyer, B.T**., Brawn, J.D., and **Bestelmeyer, S.V**. Targeting restoration of desert grasslands to maximize biodiversity at landscape scales. USDA-AFRI Managed Ecosystems. $499,776. 2010-2012.

Throop HL. Soil organic carbon dynamics in response to long-term ecological changes in drylands: an integrated program for carbon cycle research and enhancing climate change literacy. National Science Foundation, CAREER Program, Ecosystem Science Cluster. $858,614. 2010-2015.

Laliberte AS. Demonstration of Unmanned Aircraft Systems (UAS) technology for rangeland remote sensing. New Mexico View, AmericaView, Inc. $11,072. 2010.

2010-2011

Bestelmeyer, S.V. Gen M Project – A catalytic collaboration of 5 southern New Mexico nonprofits to engage middle school youth in the creativity of science, Wal-Mart Foundation. $110,000. 2011. (L. Burns et al. collaborators at Community Foundation of Southern New Mexico.

Bestelmeyer, S.V. Young science leaders project, Wolslager Foundation. $20,000. 2011.

Boeken, B.R., **J.E. Herrick and G. Okin.** The role of herbaceous plants in the maintenance of shrub patches. $85,000. International Arid Lands Consortium**.**

Laliberte AS. State-View program development for the State of New Mexico: demonstration of UAV technology for rangeland remote sensing, database server, remote sensing short course, AmericaView, Inc. $23,800, 2011-2012

Monger, H.C., A. Unc, M. Lucero. $117,500 National Park Service. Inventory of Carbon Sequestration Organisms and Biomineralization at White Sands National Monument and Guadalupe Mountains National Park

Monger, H.C., A. Unc, M. Lucero. $120,496 National Park Service. Inventory of Soil Microbial and other Soil Faunal Ecosystem Components at the White Sands National Monument and Guadalupe Mountains National Park

Peters, D.P.C. LTER V. Supplement. NSF. $24,000 (Part 1) and $71,000 (Part 2). 2011

Peters, D.P.C. Collaborative Research: Processes and patterns in the North American monsoon macrosystem. NSF (Macrosystems). $400,000 [2011-2015] (R. Munson et al. collaborators at UA)

Throop, H.L. Research Experience for Undergraduates Supplement to NSF CAREER grant. $7500.

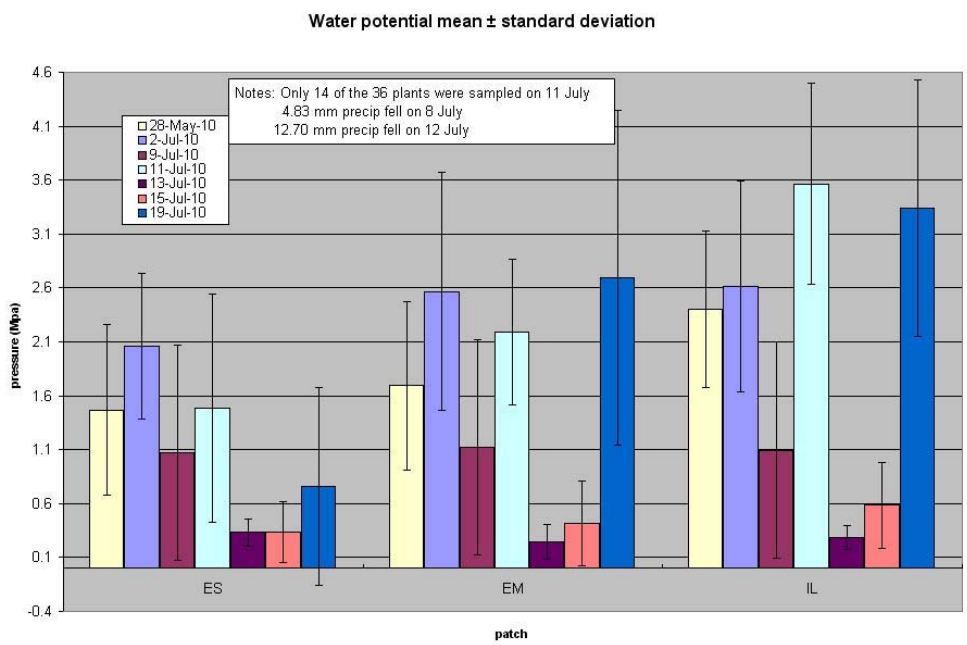
JORNADA BASIN LTER FINDINGS: 2010-2011

(1) Ecosystem indicators and vegetation dynamics

(a) Mechanisms of state transitions and threshold dynamics [Bestelmeyer, Duniway, Laliberte, Havstad]

The Threshold Experiment, initiated in 2010, is a new long-term experiment to test the mechanisms of threshold dynamics in Chihuahuan Desert grasslands. Theory suggests that once vegetation patch mosaics become sufficiently fragmented by either reduced resource inputs (e.g., drought) or disturbance (e.g., grazing), the breakdown of positive feedbacks leads to collapse of the remaining vegetation patches. In particular, ecohydrological feedbacks are thought to drive aridland thresholds. Large, dense vegetation patches promote local infiltration and capture surface runoff from adjacent bare areas, resulting in sustained biomass production within the patch network. When such patches become fragmented at various spatial scales, reduced infiltration, loss of laterally-redistributed water, and erosion lead to reduced physiological performance and production of grasses, followed by further patch fragmentation. Other parallel feedback mechanisms may operate; fragmented patches may be more susceptible to herbivore disturbance, wind erosion rates increase leading to physical damage to plants, and microclimatic stress on adults and seedlings may increase due to elevated surface temperatures. Mechanistic tests of threshold-feedback theory in aridlands do not exist.

Following from the theory that increased patch size promotes conditions and feedbacks that promote patch persistence and site-level resilience, we predicted that microsites associated with large patch interiors and edges would be associated with indicators of greater grass fitness and lower stress than other microhabitat types, as measured by: 1) relatively high levels of tiller and stolon production, 2) relatively low pre-dawn leaf-water potentials, 3)

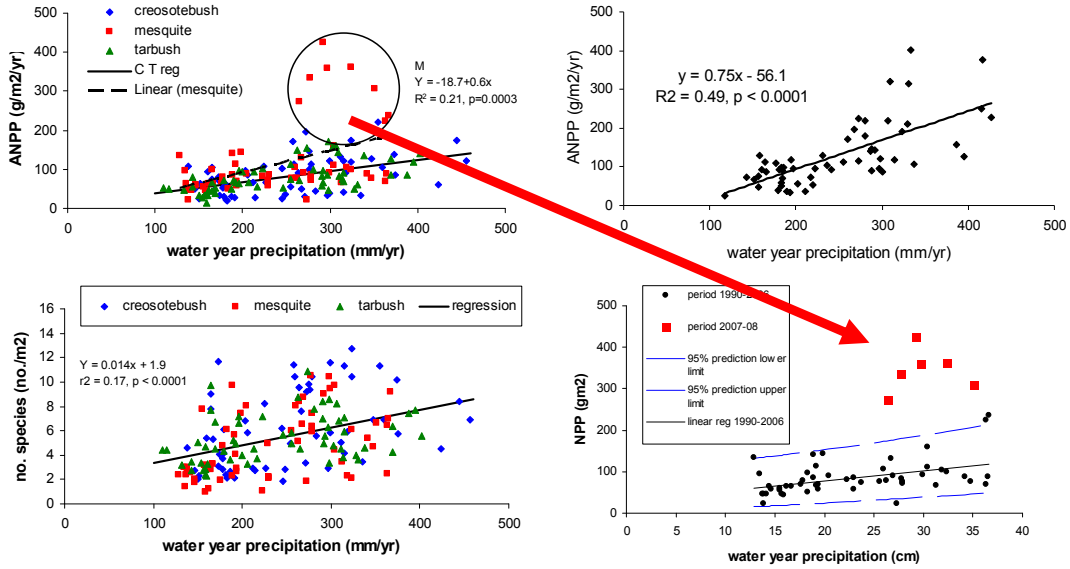


Pre-dawn leaf water potentials of focal black grama plants located in small patches (< 20 cm across; ES), medium patches (20-60 cm across; EM), and the interiors of large patches (>60 cm across; IL).

relatively high rates of carbon assimilation. These plant measurements will be related to soil water measurements associated with each plant. Our measurements over the past year indicate that there is no clear physiological benefit for a black grama plant to be associated with a large grass patch across a range of rainfall event sizes, providing initial evidence supporting an alternative to threshold-feedback theory.

(b) Spatial and temporal variation in aboveground net primary production [Peters, Yao, Sala, Anderson].

We used our long-term vegetation maps combined with long-term sampling of ANPP to determine if directional climate change provides an opportunity to reverse grassland to shrubland conversions in the Chihuahuan Desert. Although warming is predicted globally, there is uncertainty in both the magnitude and direction of change in precipitation for dryland regions. We compared historical dynamics based on 140 years of landscape change (1858-1998) with 19 years (1990-2008) of detailed ecosystem responses under a variable climate to predict future responses under either a directional increase or decrease in rainfall (Peters et al. 2011. GCB). Our data show that upland grasslands have higher ANPP and more species than shrublands. Production, and not richness, is related to water year precipitation for all vegetation types. The unusually large values of ANPP in upland grasslands and mesquite shrublands in 2006-08 following a sequence of 5 wet years suggest the importance of plant-soil feedbacks affecting the vegetation response. Thus, our data suggest that a multi-year increase in precipitation may act to convert degraded shrublands to savannas containing mixtures of shrubs and grasses, and potentially a return to grasslands in the future. Because this regime shift reversal is not predicted based on historical drivers, assumptions about ecosystem dynamics in the face of global change need to be re-examined, and new strategies need to be developed to take advantage of opportunities provided by future climates.



ANPP (1989-2006) is related to water year precipitation for all sites. Note the unusually high values of production in mesquite shrublands (circled) that occurred in 2006-08 suggesting the importance of plant-soil feedbacks in the vegetation response. These points are outside the 95% confidence interval of the regression line. Similar results were obtained for upland grasslands and tarbush shrublands (not shown).

(c) PHENO-MET: Integrating vegetation phenology, meteorology and soil moisture observations [Browning, Rango]

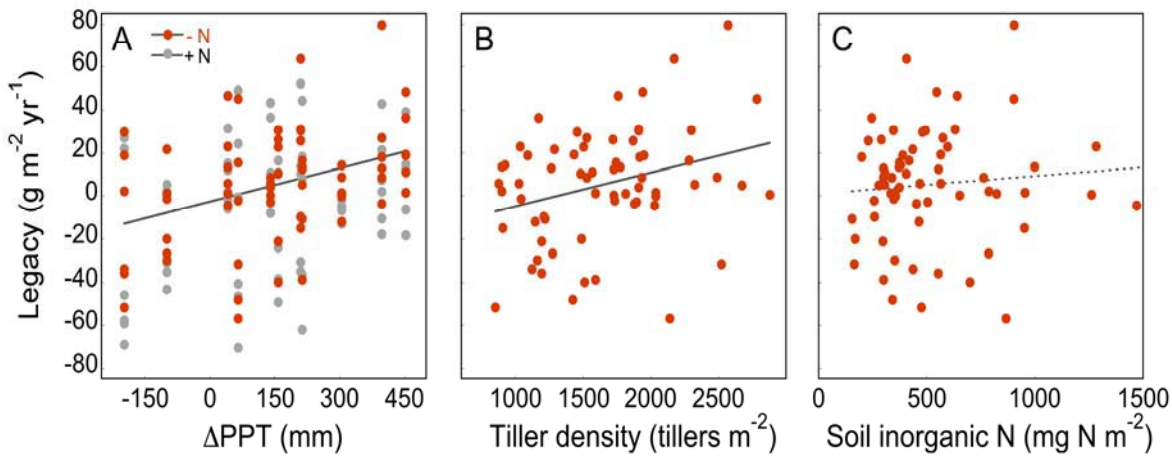
We have maintained weekly observations of 116 individuals across six perennial grass, five deciduous shrub, one evergreen shrub, and one succulent species. In 2010, we added one study site at an instrumented watershed to encompass five instrumented sites ranging from the creosote-dominated eastern bajada to black-grama dominated alluvial plain. As of 15 Aug 2011, we have compiled 73 sets of weekly observations and built the database for the hourly and daily data from the meteorological stations. We have openly collaborated with the National Coordinating Office of the National Phenology Network to fine-tune monitoring protocols for plants occurring in arid environments. At the end of the 2010 growing season, we will engage in the analysis of abiotic variables (e.g., soil moisture and temperature, air temperature, rainfall, relative humidity, and wind speed and direction) to identify those variables associated with plant phenophase transitions. These data complement our long-term monthly phenology observations for key species collected from each of the 15 NPP sites since 1989.

(d) Precipitation legacies explain inter-annual variability in grassland primary production through previous-year tiller density [Sala, Reichmann, Peters]

In arid to mesic ecosystems, a strong spatial relationship has been observed between mean annual precipitation and mean aboveground net primary production (ANPP) for different regions across precipitation gradients. Similar relationships have been documented from North to South America and from China to Africa with precipitation (PPT) accounting for 55 to 94 % of the ANPP variability in space. Temporal ANPP-PPT relationships for individual sites are far weaker than spatial relationships, and account for only 20 to 40% of the interannual ANPP variability. Lags in ecosystem response to changes in water availability may explain the low predictive power of annual precipitation and the difference between the spatial and temporal models relating ANPP and PPT. Legacies of previous-year precipitation may reduce production when previous year is drier than current and may enhance it when previous year is wetter. Here, we examined two possible mechanisms for the existence of legacies, nitrogen limitation and vegetation structure. Our hypotheses are that: 1) legacies would be a function of the difference between previous-year precipitation and current-year precipitation, and 2) legacies would result from changes in tiller density (grass leaf-bearing units) and/or biogeochemical phenomena.

We tested our hypotheses with a replicated experiment of precipitation and nitrogen manipulation in a desert grassland at the Jornada LTER. We experimentally generated wet-to-dry and dry-to-wet transitions in annual precipitation. Our approach consisted in looking at the relationship between the response variable legacy, defined as the difference between observed and expected ANPP deduced from a long-term precipitation-production relationship for this site, and three potential explanatory variables (precipitation transitions, tiller density, nitrogen availability). We subjected 132 2.5 x 2.5 m plots to one of five levels of water input (ranging from -80% of ambient to + 80% of ambient) during two growing seasons after which we switched treatments to reproduce either a wet year or a dry year. Ammonium nitrate fertilizer was applied to half of the plots throughout the study. We examined the differential effect of dry-to-wet and wet-to-dry precipitation transitions on the magnitude of the legacies, and we assessed

whether available nitrogen and/or tiller density explained legacy variability.
Our results support the hypothesis that legacies in ANPP increased linearly with the difference between previous and current precipitation (□PPT) (panel A). Negative legacies resulted from dry-to-wet PPT transitions, where drought-preceding plots produced less than expected from current-year PPT alone. Wet-to-dry PPT transitions had positive legacies resulting in higher production than expected. The magnitude of the legacies represents ~20% of the 3-year average productivity of ambient PPT treatments. Legacies in ANPP were positively related to the number of tillers at the end of previous-year growing season, which explained ca. 40% of legacy variability (panel B). Previous-year precipitation affected plant capacity of replacing tiller populations, constraining ANPP following dry years and enhancing ANPP following wet years. We rejected the hypothesis of the biogeochemical mechanism of legacies because legacies did not differ between fertilized and unfertilized treatments (panel A), showing that fertilization did not erase the presence of legacies. Although changes in water availability affected soil inorganic nitrogen, PPT legacies were not related to available nitrogen at the beginning of the growing season (panel C).

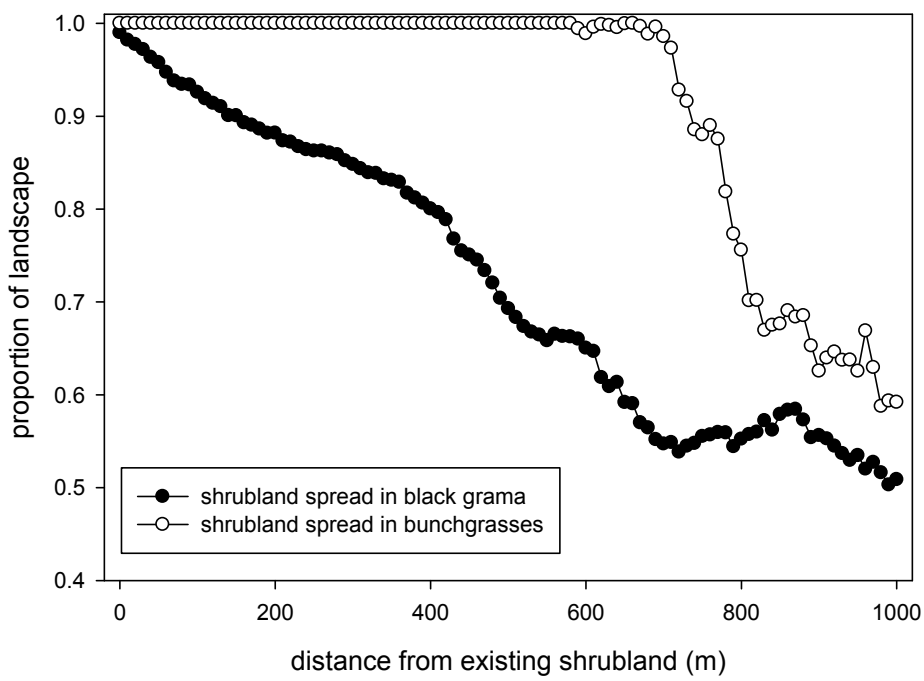


Precipitation legacies in primary production as a function of difference between current and previous-year precipitation (ΔPPT) (A), previous-year tiller density (B) and soil inorganic nitrogen (NO-3 + NH+4) at the beginning of current-year growing season (C). Legacies are the differences between observed and expected ANPP. Legacies were proportional to the difference between previous and current-year PPT, and previous-year tiller density. Legacy = -2.71 + 0.05 * ΔPPT, n = 132, R2 = 0.42; Legacy = -25.61 + 0.019 * previous-year tiller density, n = 66, R2=0.37. The effect of inorganic N on legacies was not significant. Dots represent results for individual plots in unfertilized (orange) and fertilized (grey) treatments.

(e) Landscape pattern of grassland-shrubland transition and recovery [Bestelmeyer]

Most evaluations of grassland-shrubland transitions are historical and point-based, often solely from photographs. We initiated two efforts to provide a deeper understanding of landscape change. First, we are mapping state-transitions across the study area from 1946 to 2003 to provide a broad-scale and long-term spatial context for the ground points. Second, we are monitoring contemporary change across grassland-shrub ecotones located in the same areas

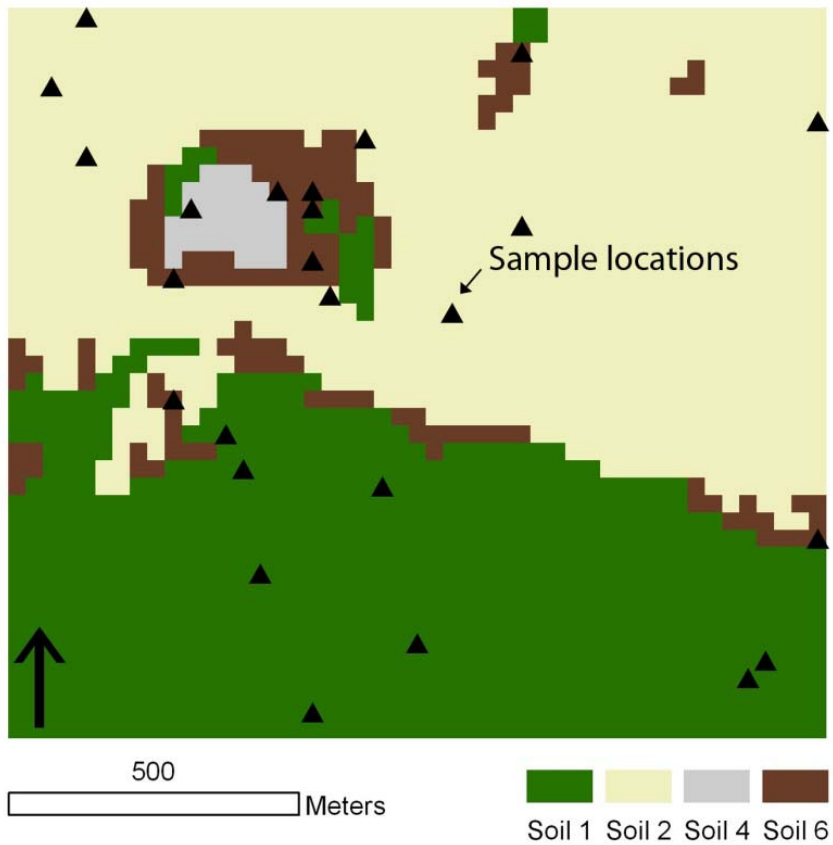
using line-point intercept transects. We combined our aerial photography based analysis of shrubland spread with other historical vegetation maps to show that the spread of shrubland occurred earlier and has been most extensive into grasslands that were dominated by bunchgrasses in 1928, the time period of vegetation mapping prior to the window of our aerial photography analyses. This suggests that bunchgrass grassland is either less resilient to shrubland invasion or occupies soils that are less resilient.



Spread of mesquite shrubland into vegetation dominated by either black grama or bunchgrasses in 1928.

(f) Patch and landscape vegetation dynamics over 71 years: Soil rainfall interactions in a Chihuahuan desert ecosystem [Browning, Duniway, Laliberte, Rango]

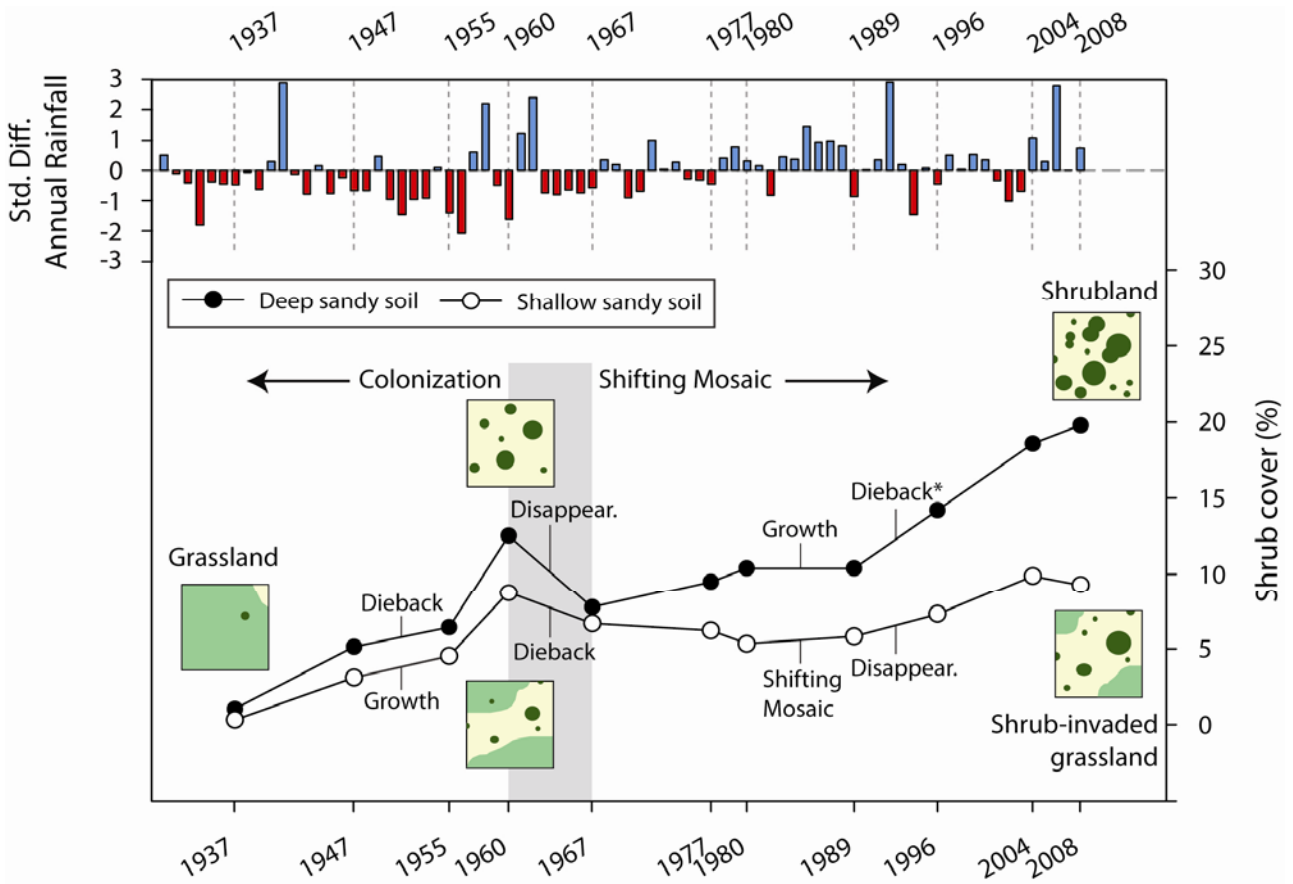
Variation in plant community resilience to climate and land-use drivers can often be attributed to spatial heterogeneity in the soil-geomorphic template. In water limited systems, soil properties associated with water redistribution and capture are thought to govern plant community resilience. To understand how vegetation dynamics are influenced by spatial variation in the soil-geomorphic template, we employed a novel technique to map key soil properties known to control plant water availability in the same study area where we previously quantified long-term vegetation dynamics. Spatially explicit information on key soil properties along with long-term landscape- and patch-scale shrub dynamics allowed us to elucidate the effect of soils on plant community resilience and ecological potential over 71 years. Soils in the 150 ha study were mapped using a novel digital soil mapping technique that used Landsat ETM+ imagery and 5m terrain (IFSAR) data to map soil classes in the absence of a priori field training data. We then characterized soil classes mapped using this semi-automated technique. The method distinguished spectrally distinct soil classes that differed primarily in subsurface water holding characteristics (from Browning and Duniway 2011).



Supervised classification representing soil classes for the 150 ha study area on the Chihuahuan Desert Rangeland Research Center in southern New Mexico. Spectral classes were derived in an automated fashion using the Transformed Divergence feature in ERDAS Imagine. A field assessment of 24 points (black triangles) was conducted by generating a stratified random sample to characterize soils within mapped classes.

(g) For the coupled soil-vegetation dynamic analysis (Browning et al. In Review Ecological Applications), we focused on two soil types that dominated the study area: a sandy soil (soil 2) with a shallow petrocalcic horizon (< 1 m) and a deep sandy soil (soil 1) with little horizon development. Effects of annual precipitation on patch dynamics on two soils revealed strong

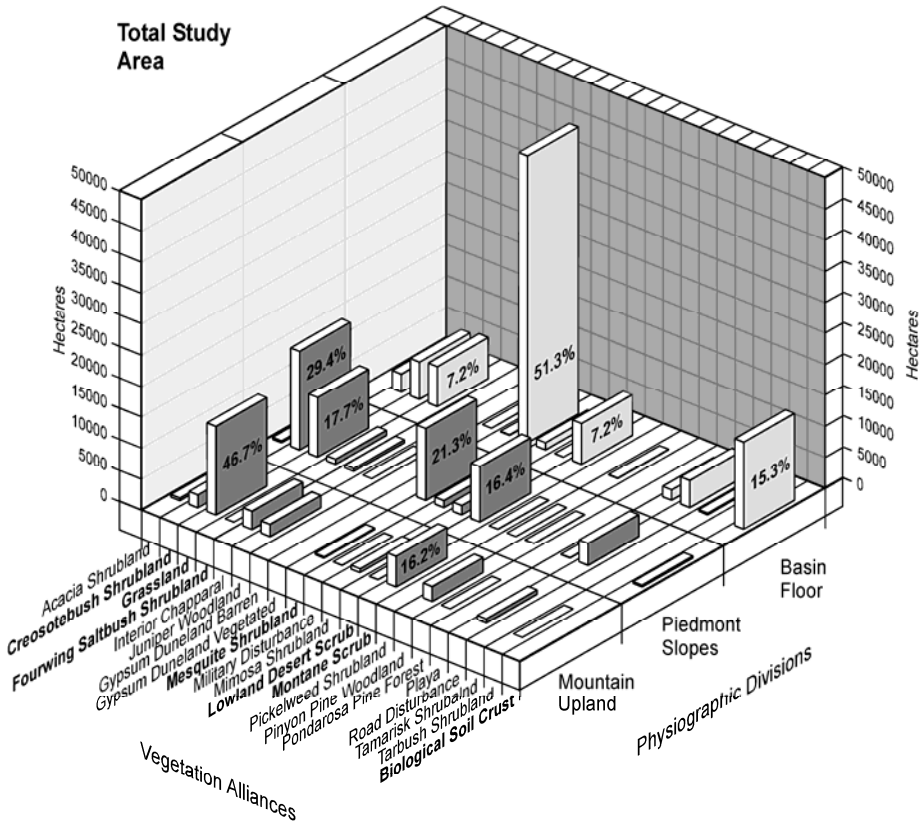
correlations between shrub growth on deep sandy soils (soil 1) and above-average rainfall years ($r = 0.671$, $p = 0.034$) and shrub colonization and below-average rainfall years on shallow sandy soils (soil 2; $r = 0.705$, $p = 0.023$). Patch-level analysis of demographic patterns revealed significant differences between patches on deep and shallow sandy soils during periods of above and below-average rainfall. At the landscape scale, both deep and shallow sandy soils exhibited low mean (standard deviation) shrub cover in 1937 [1.0 (2.3)% and 0.3 (1.3)%, respectively] and were characterized by colonization of new shrub patches until 1960. However, different demographic responses to the cessation of severe drought on the two soils and increased frequency of wet years after 1960 resulted in very different endpoints. A shrubland occupied the deep sandy soils with mean cover in 2008 at 19.8 (9.1)% while a shrub-dominated grassland



Conceptual synthesis of shrub patch-level dynamics and landscape depictions of shrub cover on two sandy soils over 71 years. Shrub patch demographics demonstrate a high degree of dynamism during periods with no net change in cover, highlighting the need for multi-scale observations. Shallow and deep sandy soils exhibited low shrub cover in 1937 with edaphic constraints governing two different endpoints. Shrub dynamics were characterized by colonization or appearance of new patches until 1960 (i.e., Colonization stage). Patch dynamics post-1960 represent a shifting mosaic whereby shrub patches at different stages of development co-occurred on shallow and deep sandy landscapes. The climatic context for shrub dynamics is provided as annual deviations from long-term average rainfall which were calculated by subtracting the long-term (1930 to 2008) average and dividing by the standard deviation. Red bars denote below- while blue denotes above-average annual rainfall. Patch demographic responses on soils with different water holding capacities to the end of severe drought followed by the increased frequency of wet years (after 1960) manifest as different trajectories.

occurred on the shallow sandy soils 9.3 (7.2)%. Present-day shrub vegetation constitutes a shifting mosaic marked by the coexistence of patches at different stages of development. Management implications of this long-term multi-scale assessment of vegetation dynamics support the notion that efforts to remediate grasslands on sandy soils should be focused on sites characterized by near-surface water holding capacity as those lacking available water holding capacity in the shallow root-zone pose challenges to grass recovery and survival.

(h) Vegetation-geomorphic relationships [Monger]. The physical landscape has long been recognized to influence vegetation patterns in arid regions. To better understand geomorphic-vegetation relationships, we developed a geopedological classification that organizes the landscape into five categories from broad scale to fine scale: (1) *physiographic divisions* which describe regional topographic configuration, such as mountains and basin floors; (2) *deposit types* which describe the mode in which sediments move across the landscape; (3) *parent materials* which describe lithology; (4) *landforms* which provide local descriptions of topographic shapes; and (5) *soil texture,* a fine-scale variable important for infiltration, erodibility, aeration, and available water holding capacity. This method was applied to a 1753



Geomorphic-vegetation relations at the broadest scale shown by plotting vegetation alliances against physiographic divisions for the total study area (i.e., basin floor, piedmont slopes, and mountain upland). Percentages shown on bar graphs represent the area of each vegetation alliance occupying a physiographic division. Vegetation alliances shown in bold are major vegetation types. Figure from Michaud, Monger, and Anderson: Geomorphic-Vegetation Relationships Using A Geopedological Classification System, Northern Chihuahuan Desert, USA (In Review, Journal of Arid Environments)

km^2 study area in the Chihuahuan Desert of southern New Mexico (USA) at the Jornada Experimental Range and adjacent White Sands Missile Range. The major geomorphic-vegetative relationships using this technique are the domination of (1) mesquite on sandy non-gypsiferous soils of the basin floor, (2) biological soil crusts (i.e., cryptobiotic crusts) on gypsum soils of the basin floor, (3) creosotebush on rocky soils of the piedmont slopes, and (4) grasslands on desert mountain uplands. This method provides a way of organizing knowledge beyond ecology-soil relationships to ecology-geology relationships.

(i) Regional controls on the spatial distribution of ecosystem states [Bestelmeyer].

We are conducting studies that link the occurrence of grassland, savanna, and shrubland states to soil, geomorphic, and climate properties as well as management history across the Chihuahuan Desert region of southwestern New Mexico. Our goal is to understand the factors that determine resilience and that may cause variation in ecological potential for grassland and shrubland vegetation. A key part of this effort is a regional inventory of current plant-soil profile

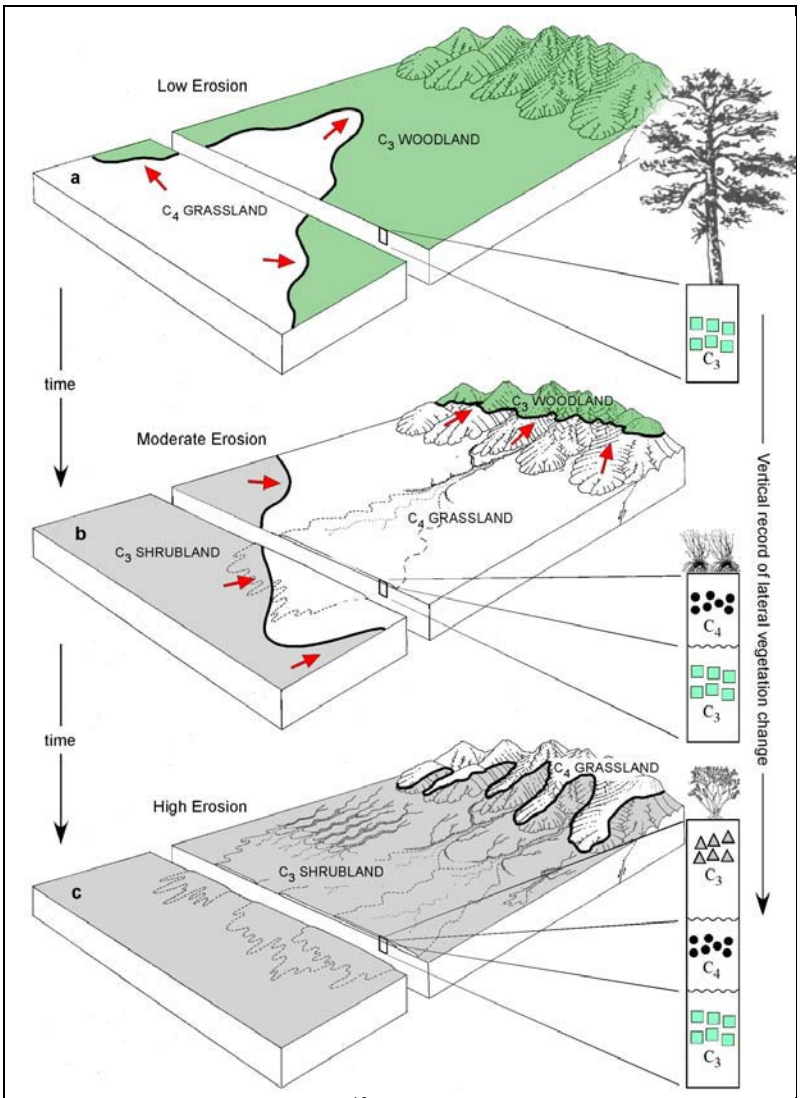
Soil properties measured in soil pits in locations that were stable grasslands from the early 1970s to 2005, were stable communities of mixed grass and shrub life forms, or transitioned from grassland to mixed life forms.

	Stable grass			Stable grass-shrub mix 1970s-2005			1970s grass transitioning to 2005 grass-shrub mix		
	N	Mean	Std Error	N	Mean	Std Error	N	Mean	Std Error
Depth of A	15	6.8	0.6	20	6.9	0.4	18	6.5	0.4
A texture class		Sandy Loam			Loamy Sand			Loamy Sand	
A % sand	15	76.7	4.1	20	85.9	1.0	18	84.4	1.4
A % silt	15	14.3	3.1	20	7.9	0.6	18	9.1	0.9
A % clay	15	9.0	1.3	20	6.2	0.7	18	6.4	0.8
Depth to argillic	15	36.7	6.5	20	36.9	4.7	18	46.8	5.0
Thickness of argillic	15	32.5	7.7	20	43.5	3.3	18	41.3	5.1
Argillic texture class		Sandy Clay Loam			Sandy Loam			Sandy Loam	
Argillic % sand	15	61.2	5.6	20	71.9	2.9	18	68.9	2.2
Argillic % silt	14	18.1	3.8	19	11.2	1.6	16	13.2	1.0
Argillic % clay	14	22.3	3.3	19	17.4	1.9	16	17.1	1.8
Depth to stage III calcic	7	58.1	7.3	14	82.9	7.8	14	76.6	5.2
Thickness of stage III	7	46.0	13.0	14	31.2	5.9	14	36.4	6.2
Depth to stage IV calcic	6	60.2	10.9	7	89.3	10.9	8	89.4	12.8

relationships. This year we focused on patterns in sandy soils and linked our soil sampling-based analyses to points referenced to the aerial photography-based assessments of vegetation change described in "Landscape pattern of grassland-shrubland transition and recovery" described above. We found that stable grasslands tend to have finer textured soils and a shallower depth to stage III calcic horizons than shrub invaded areas. Higher clay and silt content in grassland A horizons may be due to reduced erosion rates. Stable grass-shrub mixes and recently invaded areas had similar soils.

(j) Paleoecology and soil memory [Monger]. Paleoecology provides a long-term context for understanding modern changes of vegetation and climate. In the Chihuahuan Desert many soil profiles carry information about past climates by their physical and geochemical properties, such as pedogenic carbonate, profile depth, degree of chemical weathering, and isotopic composition. This source of information can metaphorically be thought of as soil memory. In particular for the Chihuahuan Desert, the $^{13}C/^{12}C$ ratio in pedogenic carbonate is a significant tool for investigating C_4 biomes of the past.

Like soils, some landscapes are more sensitive to climate change than others. A semiarid grassland on sandy soil, for example, is more susceptible to a slight change in climate than a densely vegetated peneplain in the center of a tropical rainforest. Landscapes and soils are connected to each other, to the aboveground ecosystem, and to climate as a complex adaptive system. A perturbation to the system can leave its mark as both soil memory and as vertical sedimentary records (i.e., lithomemory). A systematic examination of soil memory and landscape sensitivity to climate change can be used as a prospecting method for finding informative paleosols. Some of the best paleosol records, for example, are on landscapes sensitive to climate change where pedomemory develops during periods of landscape stability and lithomemory develops during alternate periods of landscape instability characterized by high erosion and sedimentation rates.

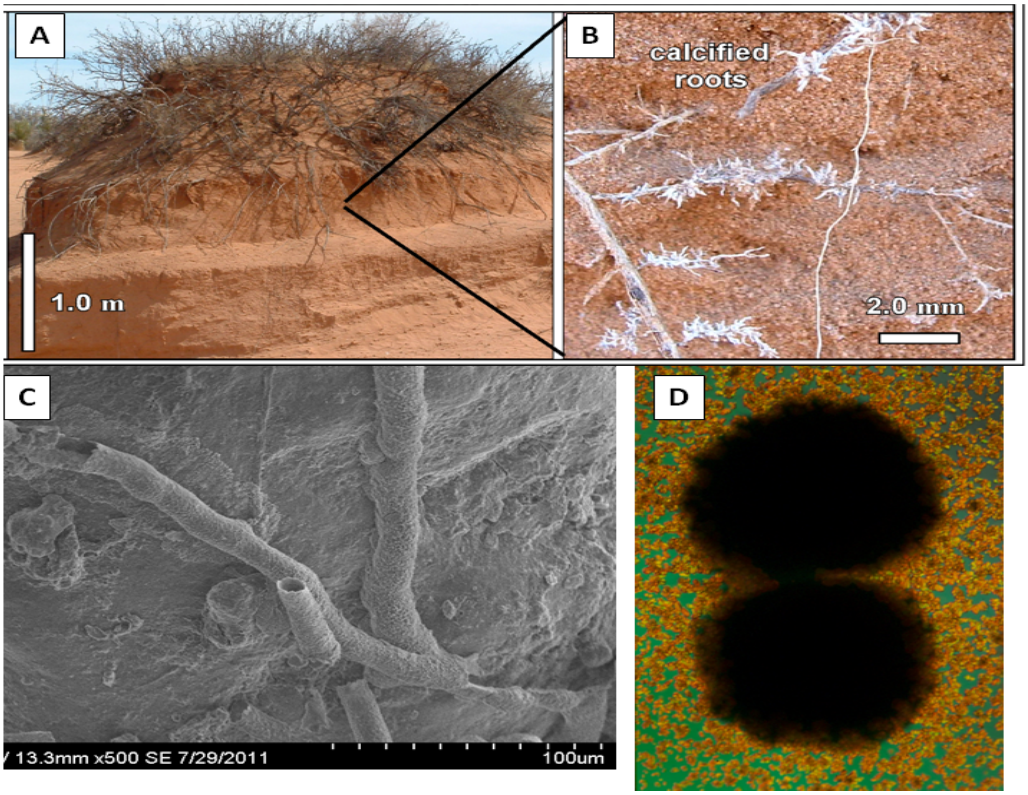


Development of a vertical $\delta^{13}C$ record of lateral vegetation change. (a) Low erosion, or stable landscape, associated with abundant vegetative cover in which a C_3 woodland is recorded by $\delta^{13}C$ in pedogenic carbonate. (b) Moderately eroding landscape resulting from increased aridity and reduced vegetative cover in which a C_4 grassland is recorded by $\delta^{13}C$ in pedogenic carbonate formed in new, aggrading deposits. (c) Actively eroding landscape resulting from bare ground between shrubs in which a C_3 shrubland is recorded by $\delta^{13}C$ in the youngest soil mantle. Figure from Monger, H.C., D.R. Cole, B.J. Buck, and R.A. Gallegos. 2009. Scale and the isotopic record of C_4 plants in pedogenic carbonate: from the biome to the rhizosphere. Ecology 90:1498-1511.

(2) Carbon and nitrogen dynamics

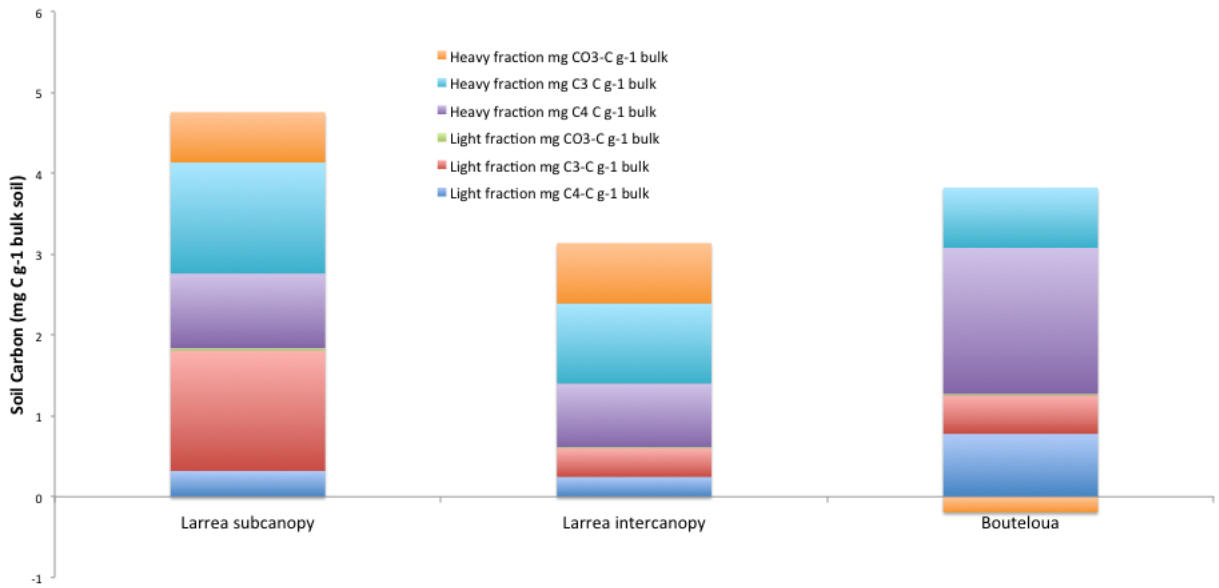
(a) Carbon sequestration as microbial soil carbonate [Monger]. Soil carbonate is ecological in origin because its formation is, in part, linked to the aboveground ecosystem. However, ecologists seldom research its formation. Geologists research its formation, but from a physicochemical rather than a biological standpoint. Our current studies on carbon sequestration at the Jornada Basin LTER focus on understanding the magnitude of carbon sequestration by biogenic mechanisms. This involves microscopy of calcified root hairs, fungal hyphae, and bacteria in native soils. It also involves lab studies that grow calcifying soil microbes in culture and in soil column experiments. To identify calcifying microbes in situ we have most recently initiated a series of field experiments that use buried microscope slides and fungal traps irrigated with liquid culturing media.

The result of these studies show that scanning electron microscopy can readily detect calcified soil microorganisms in all soils investigated thus far . In lab studies, numerous microbes form calcite in culture (Panel D). These microbial cultures are being isolated for DNA sequencing. In column studies, soils sterilized by autoclaving do not form calcite in contrast to soils that do contain microbes. Buried microscope slides and fungal traps reveal that microorganisms can form calcite as fast as a few days to weeks. Because soil calcite is biogenic in part, the vast reservoir of soil carbonate in arid and semiarid regions must be viewed as being a potential sink or source of CO_2 rather than an inert reservoir.



Images providing evidence that soil microorganisms precipitate calcite and sequester carbon as soil inorganic carbon. (A and B) Calcite formed on the roots of mesquite. (C) Calcified root hairs in which the organic matter has decomposed leaving a shell of carbonate that preserves the original morphology. (D) Soil bacterial colonies forming calcite crystals in a petri dish after a few of days of growth.

(b) Soil organic carbon sources and stability in response to woody encroachment (Throop)
The degree of biological, physical, and chemical protection of carbon and hence soil organic carbon (SOC) stability is not well understood in dryland systems. However, this information is crucial for predicting long-term C sequestration rates in dryland soils. This information is particularly important in the context of encroachment by woody plants, where SOC pools may be affected by both changes in carbon inputs and the stability of these inputs in the soil. Currently available data on SOC stabilization in drylands, using density separation methods or a combination of particle size and density separations, provide conflicting results. We density fractionated Aridisols from sites encroached by *Larrea tridentata* (subcanopy and intercanopy locations) and remnant *Bouteloua eriopoda* grasslands. Density fractions were analyzed for C content and ^{13}C to assess source and stability of SOC. Total SOC pools declined from remnant grasslands to *Larrea* intercanopy areas, but were enhanced under *Larrea* canopies. Surprisingly, enhanced subcanopy SOC included not only substantial C_3-derived material in the light fraction pool, but also a large amount of heavy fraction C_3-derived material. Losses of SOC with woody encroachment were driven primarily by losses from the heavy fraction C_4-derived pool.

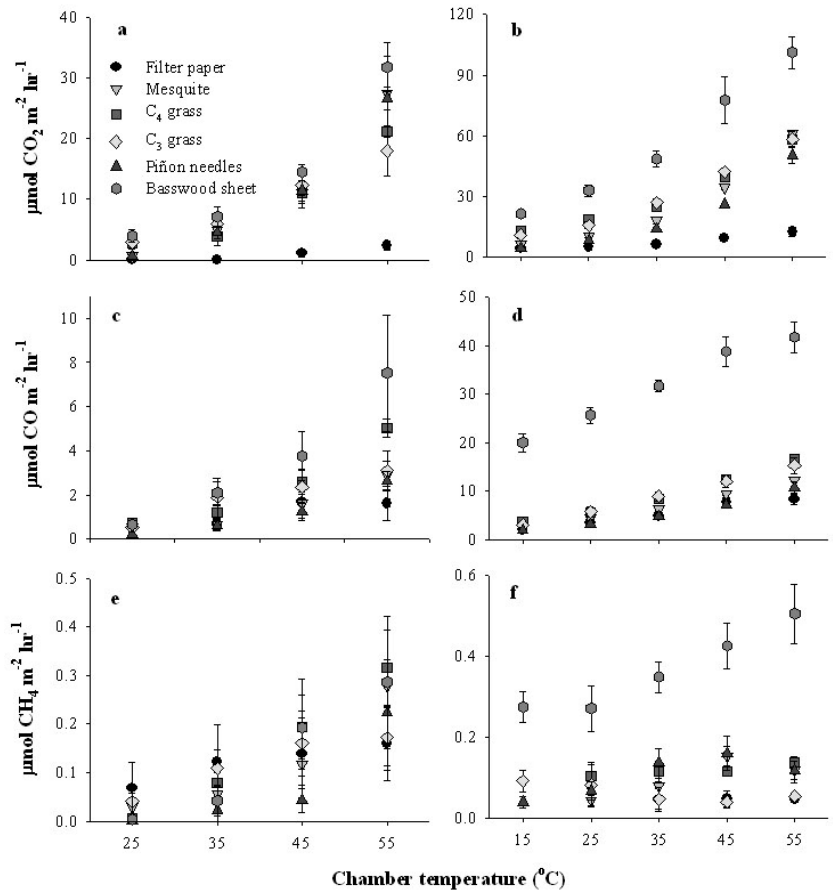


Soil carbon pools from soils collected in remnant *Bouteloua* grassland and an area encroached by *Larrea.* Total carbon pools are divided into light (less stable) and heavy (more stable) pools by density fractionation and carbon source (C_3, C_4, $CaCO_3$) was determined by acid fumigation and isotope mixing models.

(3) Decomposition

(a) Accounting of C-based trace gases from abiotic litter degradation (Throop)

Photochemical breakdown (photodegradation) of plant material accounts for a large portion of litter decomposition in ecosystems with high solar radiation and low precipitation. The release of numerous trace gases during photodegradation of organic matter in terrestrial systems suggests that the photodegradation process may be more complicated than traditionally studied, microbially-mediated decomposition pathways. Understanding the correlations between emission rates of different gases during photodegradation of plant litter may provide mechanistic insight into photodegradation and will help to quantify the effects of abiotic litter decomposition on atmospheric chemistry. We performed a simultaneous C accounting of CO_2, CO, and CH_4 produced as a byproduct of abiotic litter degradation and found that the rate of photodegradation increased exponentially with temperature. We demonstrated that a significant portion of gas was produced from low temperature (< 100ºC) thermal degradation of litter in the absence of solar radiation, which was also exponentially correlated to temperature. In addition, all these gases were produced, although at lower rates, in the absence of O_2, implying that the mechanism formerly accepted as photo-oxidation may only be part of the

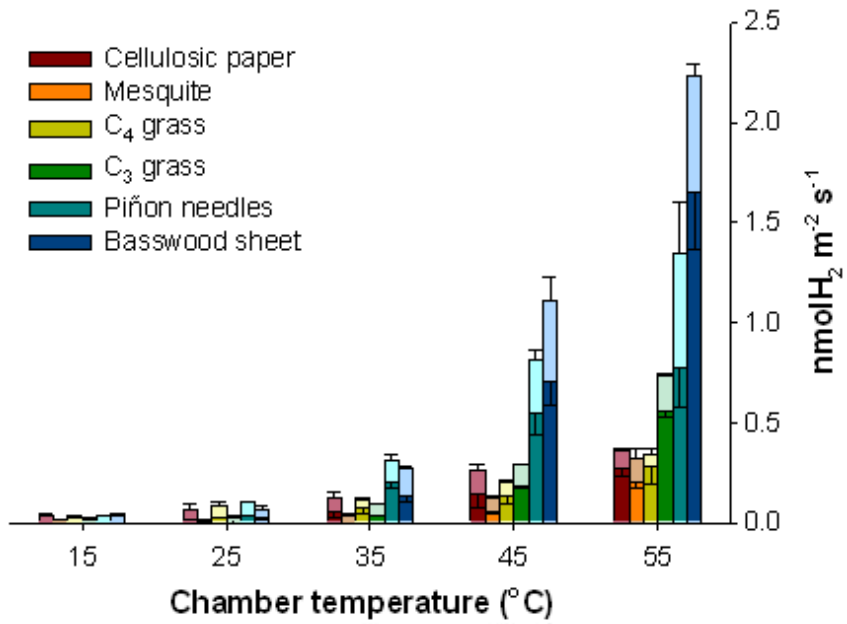


The rate of CO_2 (a and b), CO (c and d), and CH_4 (e and f) production from thermal degradation (closed symbols, a, c, and e) and photodegradation (open symbols, b, d, and f) among the six plant litter types under changes in chamber temperature. Thermal degradation represents the rate of gas release in the absence of solar radiation and photodegradation represents the rate of gas release in the presence of solar radiation subtracted by thermal degradation. Error bars indicate standard errors (n = 4).

abiotic decomposition process and direct breakdown of chemical groups such as carboxyl or carbonyl groups may produce CO and CO_2. Gas flux responses to the presence and absence of solar radiation and O_2 differed considerably among the six plant materials we used, suggesting that litter chemical composition affects rates of abiotic decomposition. Our rough estimation of global abiotic production of CO_2, CO, and CH_4 shows that approximately 133 Tg C yr^{-1} (86.2 Tg CO_2-C yr^{-1}, 45.9 Tg CO-C yr^{-1}, and 0.8 Tg CH_4-C yr^{-1}) may be released from abiotic degradation of plant litter.

(b) Decomposing litter as a novel source of atmospheric hydrogen (Throop)

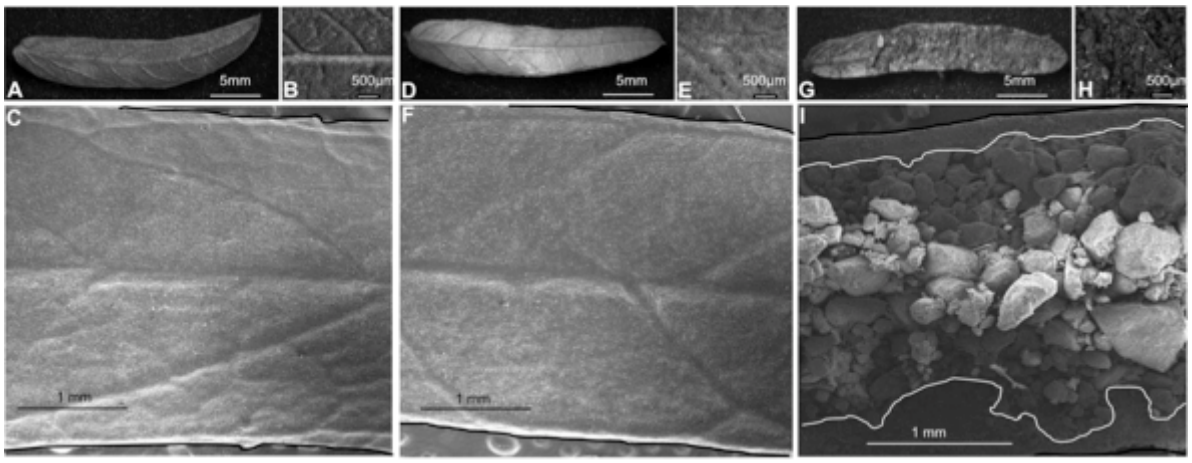
Molecular hydrogen (H_2) in the atmosphere plays an important role in atmospheric chemistry by competing for reactions with the hydroxyl radical ($OH^{\cdot}$) and thus potentially influencing the budget of H_2O in the stratosphere. However, the terrestrial source/sink dynamics of H_2 in the global H_2 budget are still uncertain. We found that abiotic degradation of plant litter is a previously unrecognized, but potentially important, terrestrial source of H_2. We quantified H_2 flux and found that more H_2 was produced under low temperature thermal degradation of plant litter in the absence of solar radiation than photodegradation alone. In addition, we observed significant release of H_2 during abiotic degradation of plant litter even in the absence of O_2. Our results suggest that release of H_2 during abiotic degradation of plant litter is a ubiquitous process and is a unique source of atmospheric H_2 from terrestrial system. When combined with likely production of H_2 from soil organic matter and standing dead biomass, these previously unidentified sources with increase the uncertainty in estimates of the terrestrial H_2 sources and sinks. Furthermore, because these processes occur at the soil/atmosphere interface, the H_2 produced may provide an additional proximal source of H_2 for the microbial community and confounds interpretation of direct measurements of atmospheric uptake that are important for constraining the global H_2 budget.



The rate of H_2 production from low temperature thermal degradation (dark colors) and thermally enhanced photodegradation (light colors) among the six plant litter types under changes in chamber temperature. Error bars indicate standard errors (n = 3).

(c) Rapidly developing soil film covers dryland plant litter and negates UV photodegradation (Throop, Archer)

Litter decomposition is a central focus of ecosystem science because of its importance to biogeochemical pools and cycling, but predicting dryland decomposition dynamics is problematic. Recent studies indicate photodegradation by ultraviolet (UV) radiation can be a significant driver of dryland decomposition; however, other studies suggest soil-litter mixing controls decomposition. To test the influence of soil coverage on UV photodegradation of litter, we conducted a laboratory experiment in a controlled-environment chamber with *Prosopis* leaf litter experiencing two levels of UV radiation and three levels of soil coverage. Additionally, we quantified rates of litter surface coverage by soil films under field conditions. In the laboratory, decomposition over 224 days was enhanced by UV, but increasing soil coverage strongly and linearly diminished these effects. The importance of soil coverage was underscored by field results, where after 180 days nearly half of shrub leaf litter surface area was covered by a tightly-adhering film composed of soil particles and fungal hyphae. Together, these results suggest 1) soil deposition can ameliorate the direct effects of UV photodegradation in drylands and 2) predictions of C losses based solely on UV effects will overestimate the importance of this process in the C cycle. An improved understanding of how development of the soil-litter matrix mediates the shift from abiotic (photodegradation) to biotic (microbial) drivers is necessary to predict how ongoing changes in land cover and climate will influence biogeochemistry in globally-extensive drylands.



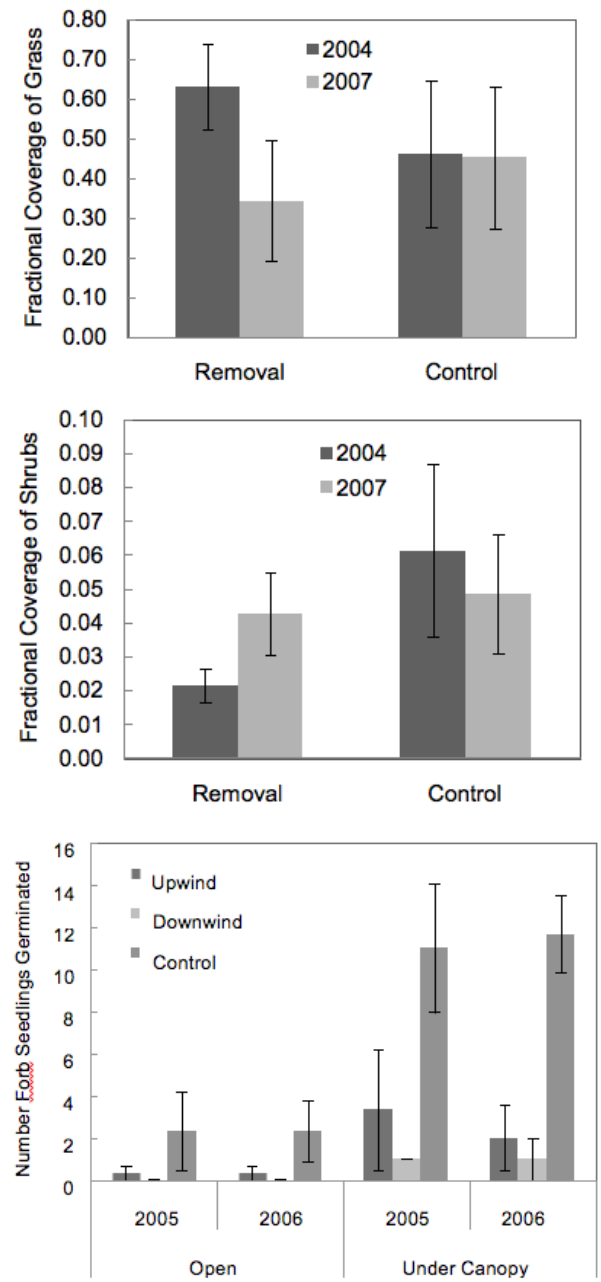
Development of soils films on field-deployed litter over time (0, 30, and 180 days in A-C, D-F, and G-I, respectively) illustrated by low magnification (1.6x) stereo micrographs showing entire leaflets (A, D, G), high magnification (3.2x) stereo micrographs (B, E, H), and SEM micrographs (25x, 31x, and 35x for C, F, and I, respectively). In the SEM micrographs, black lines denote leaflet margins and white lines denote the edge of the soil film.

(4) Aeolian studies

Wind as a transport vector [Okin]

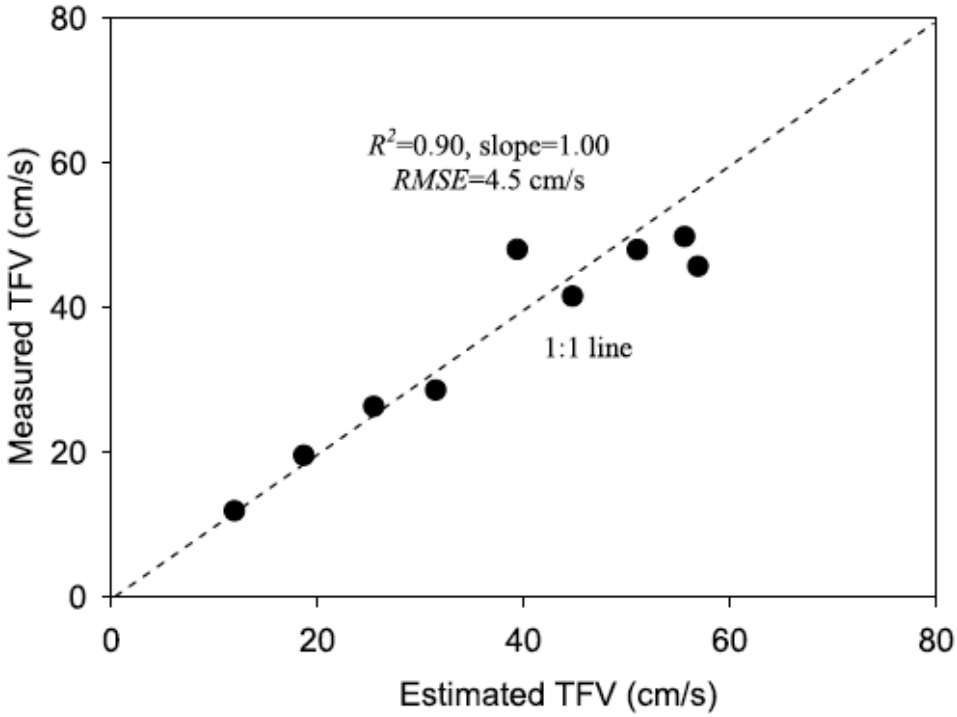
We concentrated on analysis of vegetation from our experimental wind erosion plots. In one study (Alvarez et al. 2011), we used high-precision surveying equipment to map vegetation distributions. We observed clumped grass distributions, indicating a lack of competition among grasses; random shrub distributions; and even grass distribution with respect to shrub locations, indicating competition between grasses and shrubs. We also observed a tendency for grass distributions to become more even over time, and grasses to become less even with respect to shrub locations over time. These changes occurred during a period of greater than average rainfall, indicating that greater water availability may lead to increased competition among grasses and decreased competition between grasses and shrubs. In a second study (Alvarez et al. Submitted), we observed that an increase in sediment flux resulted in a depletion of soil nutrients and seedbank, and an increase in *Prosopis glandulosa* (mesquite) cover compared to control areas. Grass cover on plots downwind of vegetation-removal areas decreased over time (2004-2007), while grass cover increased over time downwind of control areas; *P. glandulosa* cover increased on plots downwind of vegetation-removal areas, while decreasing on plots downwind of control areas.

We used a two-stage approach to compare the susceptibility of grasslands and three different shrublands to wind erosion and demonstrate how climate can indirectly moderate the magnitude of aeolian sediment flux through different responses of dominant plants in these communities. First, using results from 20 y of vegetation monitoring, we found perennial grass cover in grasslands declined with increasing mean annual temperature in the previous year, whereas shrub cover in shrublands either showed no change or declined as temperature increased, depending on the species. Second, we used these vegetation monitoring



Removal of vegetation in a wind-erodible landscape that, in the area downwind of the removal, grass cover decreased and shrub cover increased. The seedbank was depleted due to increased aeolian flux both in the area of erosion (upwind) and the area of deposition (downwind).

results and measurements of soil stability as inputs into a field-validated wind erosion model and found that declines in perennial vegetation cover coupled with disturbance to biological soil crust resulted in an exponential increase in modeled aeolian sediment flux. Thus the effects of increased temperature on perennial plant cover and the correlation of declining plant cover with increased aeolian flux strongly suggest that sustained drought conditions across the southwest will accelerate the likelihood of dust production in the future on disturbed soil surfaces (Munson et al. 2011).

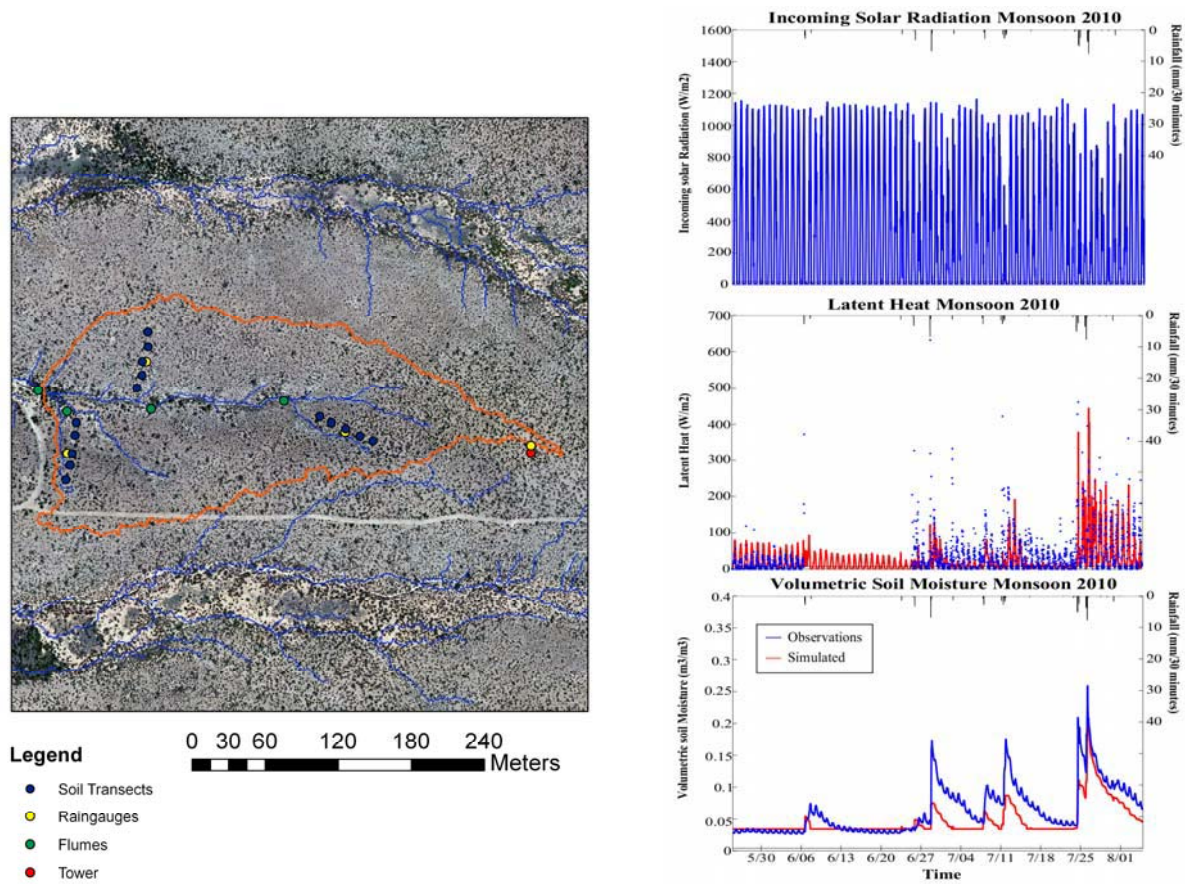


We used a combination of airgun and penetrometer methods to develop an equation that can be used to estimate threshold friction velocity for aeolian transport. A high correspondence between predicted and measured values was found.

(5) Ecohydrology:

Water as a transport vector [Vivoni]

A new JRN LTER watershed ecohydrology study has continued in a small Chihuahuan Desert Shrubland site on the Piedmont Slope. The site is a mixture of creosote, mesquite and tarbush, with some remnant black gramma, which has undergone significant historical vegetation changes. We have measured water, energy and carbon fluxes for the following sequence (beginning in 2010): summer-fall-winter-spring-summer period. A wet summer 2010 period resulted in several measured runoff events in the multiple flumes in the basin and substantial subsurface soil moisture, heat and carbon flux responses. A drier-than-average winter and spring has lead to a generally drying of the watershed, a reduction of soil moisture content at multiple depths and a lack of runoff events. Preliminary model runs using tRIBS at the eddy covariance tower reveal the model ability in simultaneously capturing the soil moisture and

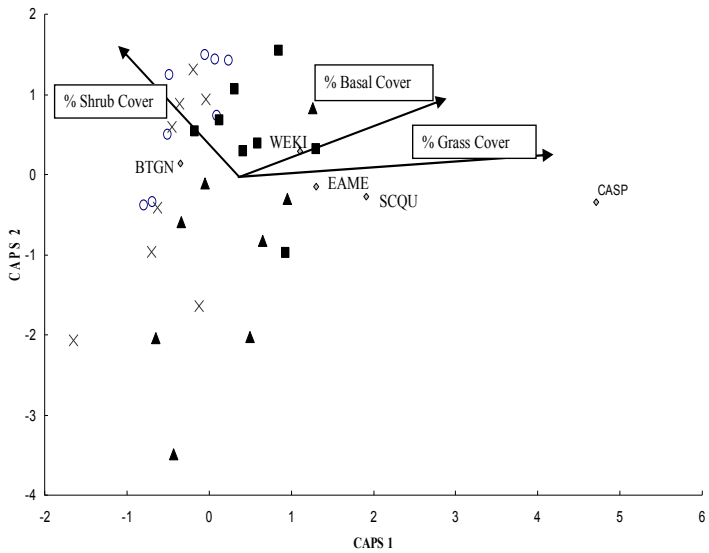


(left) Small watershed in the JRN LTER Piedmont slope within a Chihuahuan Desert Shrubland. Basin boundary derived from high-resolution (1-m) digital elevation model obtained from processing UAV imagery. High-resolution (6-cm) aerial imagery from UAV also shown. Location of the sensor network instrument sites, including eddy covariance tower. (right) Eddy covariance tower observations of precipitation and incoming solar radiation (top) for summer monsoon season in 2010. Comparison of tRIBS simulated and observed latent heat flux (evapotranspiration) (middle) and surface soil moisture in the top 5-cm (bottom) from preliminary runs at the point-scale.

evapotranspiration conditions during the wet summer 2010 period. Additional simulations during the entire period are underway at the point and catchment scales. Watershed characterization studies using UAV imagery and topography products, surveys with a differential GPS and soil and vegetation sampling have been completed and are ready for integration into the modeling exercises in the basin. A terrain analysis of the site revealed the adequate representation of the watershed characteristics with the environmental sensor network.

(6) Animal populations and biodiversity

Studies of animals at the Jornada Basin are focused on three themes: 1) the impacts of land-use on animal biodiversity, 2) feedbacks between native animals and transitions among states, and 3) the management of domestic grazing animals (especially cattle) in an ecosystem prone to state-transitions as a consequence of grazing. In addition, we maintain species lists (reptiles, amphibians, mammals, birds) for the entire Jornada Basin. Historical animal datasets have featured monitoring of small mammals, arthropods, and lizards in different vegetation types to understand the influence of interannual climate variations. We recently shifted our effort toward understanding how animal biodiversity changes over time on ecotones between grassland and shrubland states and how efforts to restore shrublands to grasslands affect animal populations. With regard to animal biodiversity monitoring, analyses conducted over the past year suggest that rodent populations collapsed in and have not recovered following the high rainfall years of 2006-2008.

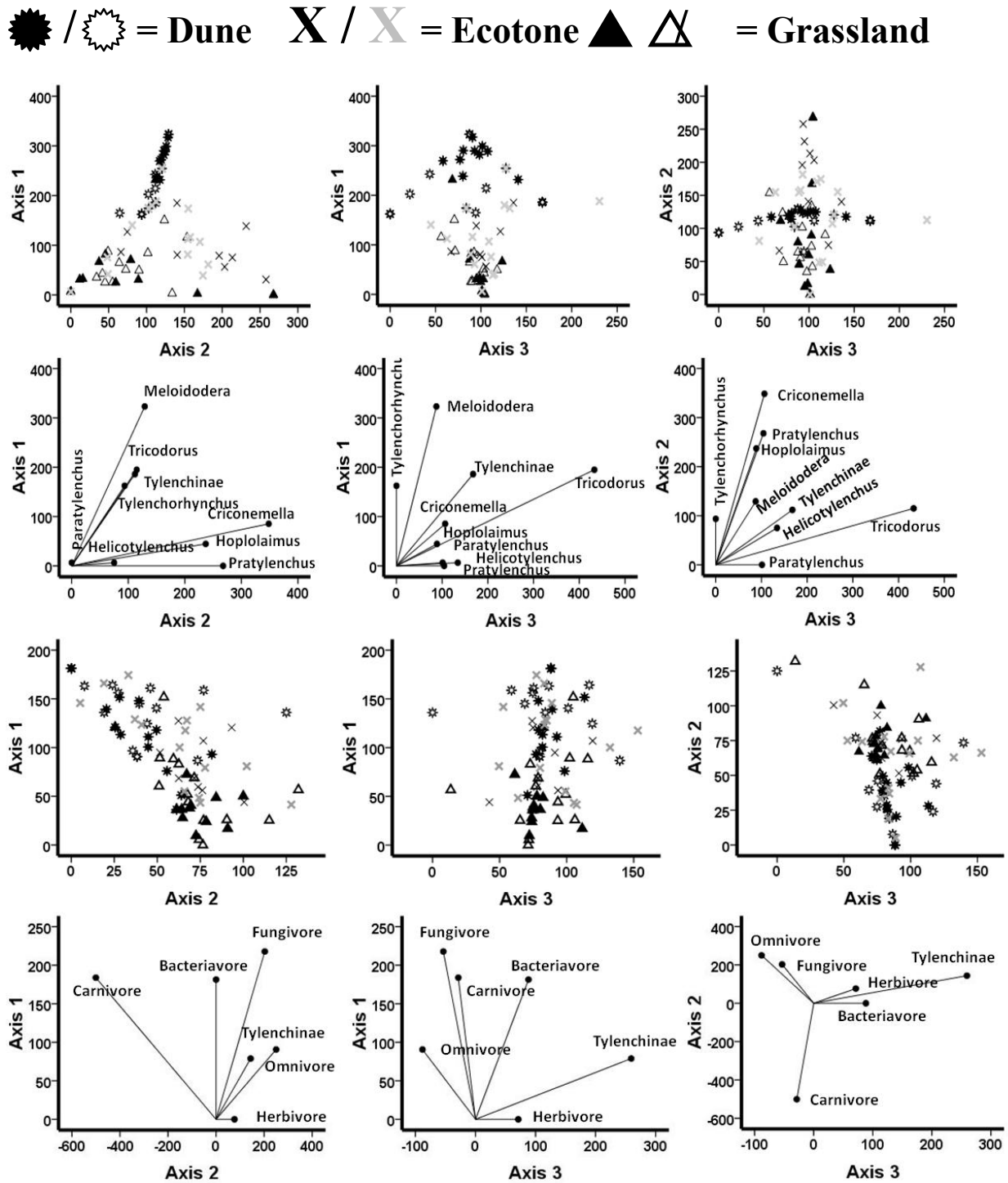


Distance-based redundancy analysis of shrub control effects on breeding bird community structure. The graph depicts the relationship between study sites and three environmental factors. The species scores show the direction of higher abundance of a particular species. Thus, Cassin's Sparrows are expected to have higher abundance at sites with higher percent grass cover, whereas Black-tailed Gnatcatchers have higher abundance with greater shrub cover and less grass cover. The solid triangles represent old treatments, the solid squares represent new treatments, the x's represents references sites paired with old treatments, and hollow circles represent references sites paired with a new treatment. CASP = Cassin's Sparrow, EAME = Eastern Meadowlark, SCQU = Scaled Quail, WEKI = Western Kingbird, and BTGN = Black-tailed Gnatcatcher.

(a) Bird populations [B. Bestelmeyer]- A master's thesis completed this year examined the effects of historical shrub control treatments on breeding bird populations. We found that several grassland obligate species were more abundant in areas where

shrubs were removed with herbicide, and these sites featured higher grass cover than untreated areas. Thus, our evaluation suggests that efforts to restore elements of historical grassland ecosystems via shrub control can be effective.

(b) Nematodes [Klass, Peters] Using nematode community structure as a proxy for examining differences in soil biotic communities and how those communities are spatially distributed across a desertification gradient showed that nematode distributions, and thus soil biotic communities, become altered with shrub dominance. As black grama grasslands become desertified, nematode communities become heterogeneously distributed and relegated to vegetated patches as well as becoming less diverse, where a shift in species guilds potentially perpetuates nutrient losses in shrublands. These results identify plant-soil interactions as a possible mechanism of desertification at fine scales. The greenhouse experiment is currently under way; however we have initially examined the nematode population within the differing soils from both black grama grasslands and mesquite dunelands. The two populations were found to be significantly different and we are awaiting the end of the growing period to extract nematode communities from "cultured" soils in order to compare trophic structure change to elucidate differences in soil biotic communities. Examination of the soil sterilization process has reinforced the "islands of fertility" theory and shown that upon sterilization, soil of the Jornada are higher in Mg and Mn with no interaction of vegetation × sterilization. I am in the process of analyzing the mineralology of sterilized vs. unsterilized soils using X-ray Defraction analysis to further explore the effects of the sterilization process and identifying possible co-founding factors that might influence the greenhouse experimental outcome. The fungal endophyte and plastid diversity analysis is under way and has yet to yield any results. Genomic analysis is currently being performed using CAMERA and NCBI genomic BLAST survey to be loaded into MEGAN for phylogenetic analyses.

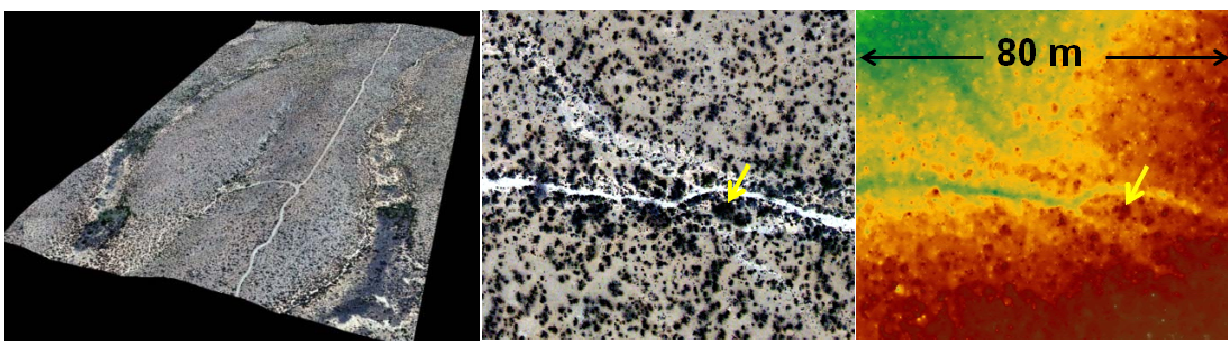


DCA of nematode trophic (a) and herbivore sampling (b) of the Jornada desertification gradient for both 2009 (closed symbols) and 2010 (open symbols) sampling years. Nematode species DCA scores are represented as vectors on the bottom panels for both trophic and herbivore groupings.

(7) Fine-scale pattern analyses: technology development

(a) Terrain model extraction from UAV imagery [Laliberte, Vivoni, Rango].

Very high resolution imagery acquired from UAV lends itself to extraction of fine detail elevation data, which can be fused with vegetation mapping products. In the fall of 2010, we acquired UAV imagery (6 cm resolution) over a small watershed at the Jornada (Tromble Weir) with the objective to obtain detailed information about the terrain and the vegetation spatial patterns for input to the tRIBS hydrologic model and for scaling up data acquired from a ground-based instrument network. A 1-m resolution digital elevation model (DEM) was extracted from the UAV imagery. The DEM allowed for a fine-scale characterization of the Tromble Weir watershed with respect to watershed boundary, elevation, slope, aspect, and curvature, representing a vast improvement over the existing products derived from 10-m resolution DEMs. A dense digital surface model (DSM) extraction approach using point clouds yielded an even finer resolution terrain model at the pixel level (6-cm resolution). The point cloud was encoded with the RGB values of the pixel, allowing for point cloud classifications. The high detail allowed for deriving vegetation heights from the fusion of a classified image and the DSM by obtaining a pseudo bare earth model from points located only in areas classified as bare ground. We created a canopy height model (CHM) by subtracting the bare earth model from the surface DSM and sub-setting the CHM to the vegetated class. Visual evaluations showed that vegetation heights were depicted realistically, and a comparison of field-measured shrub heights with the CHM-derived shrub heights indicated good correlation ($R^2 = 0.6$). However, we obtained some negative vegetation heights, and the CHM underestimated the shrub heights. We plan to expand on these preliminary results and apply the approach to larger areas.



UAV mosaic draped over DEM extracted from images (left), portion of UAV image (middle), and 6 cm resolution DSM from point cloud (right). The yellow arrow points to a shrub visible in both image and DSM.

(b) Development of a workflow for multispectral remote sensing from a UAV [Laliberte]

Over the last 6 years, we have developed a reliable and efficient workflow for acquisition, orthorectification, and classification of UAV imagery acquired with low-cost digital cameras (RGB). However, the low spectral and radiometric resolution is limiting the type of vegetation mapping and change detection that can be performed with this imagery. In 2010, we purchased a 6-band multispectral lightweight camera (MCA) for our UAV. The UAV manufacturer integrated the camera into the aircraft and made modifications to the flight computer software to allow for simultaneous acquisition of multispectral and RGB image acquisition. We identified multiple issues and difficulties with the camera hardware and software: proprietary file format incompatible with GIS/RS software, lack of robust band-to-band registration, inability of the software to handle 10-bit data, and strong vignetting. We developed algorithms, workflows and processing steps to 1) convert the raw file format into tif format, 2) co-register the bands using a 2nd order polynomial function, 3) restore data to a 6-band, 10-bit Erdas format, 4) apply radiometric corrections, and 5) correct vignetting in the mosaic process. The steps are implemented in batch processing mode, which allows for processing hundreds of images in an efficient manner, and repeated use of the same batch processing files. The orthorectification and mosaicking steps are identical to the workflows we developed for the RGB camera. We tested various calibration targets (size, material) for their suitability for radiometric calibration of the MCA imagery using an empirical line method. Image-based spectral measurements of targets, vegetation, and soil were compared with ground-based spectral measurements obtained with an ASD field spectrometer. The results were highly correlated ($R^2 = 0.94$), and we determined that it was preferable to first mosaic the individual images, followed by radiometric correction of the mosaic than to radiometrically correct individual images and subsequently mosaic the images. We will be repeating the radiometric test at other location(s) and various vegetation communities to confirm these results.

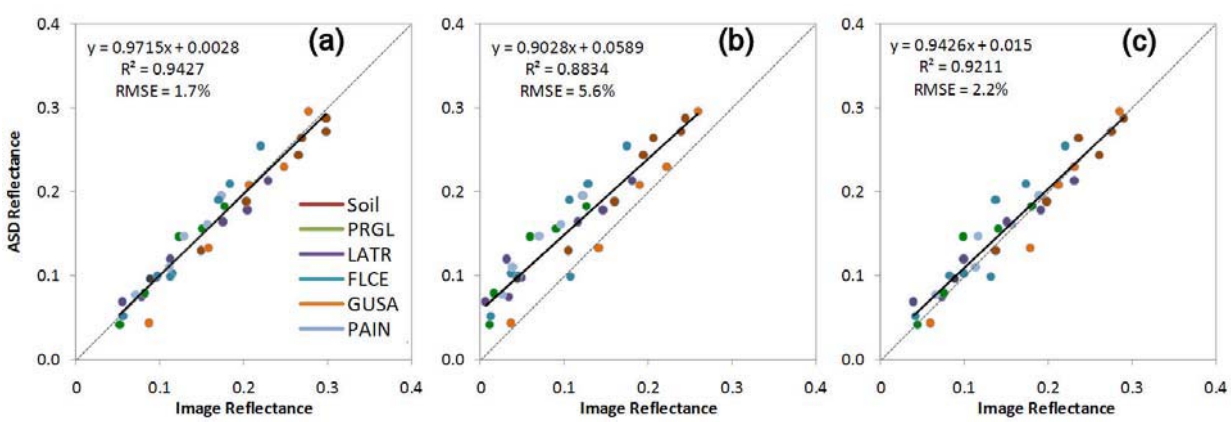


Image reflectance vs. ASD field spectrometer reflectance for 6 vegetation/soil samples in 6 bands of the MCA camera. Data are extracted (a) from single image, (b) from mosaic; images were individually radiometrically corrected , then mosaicked, and (c) from mosaic; images were mosaicked first, followed by radiometric correction of the mosaic.

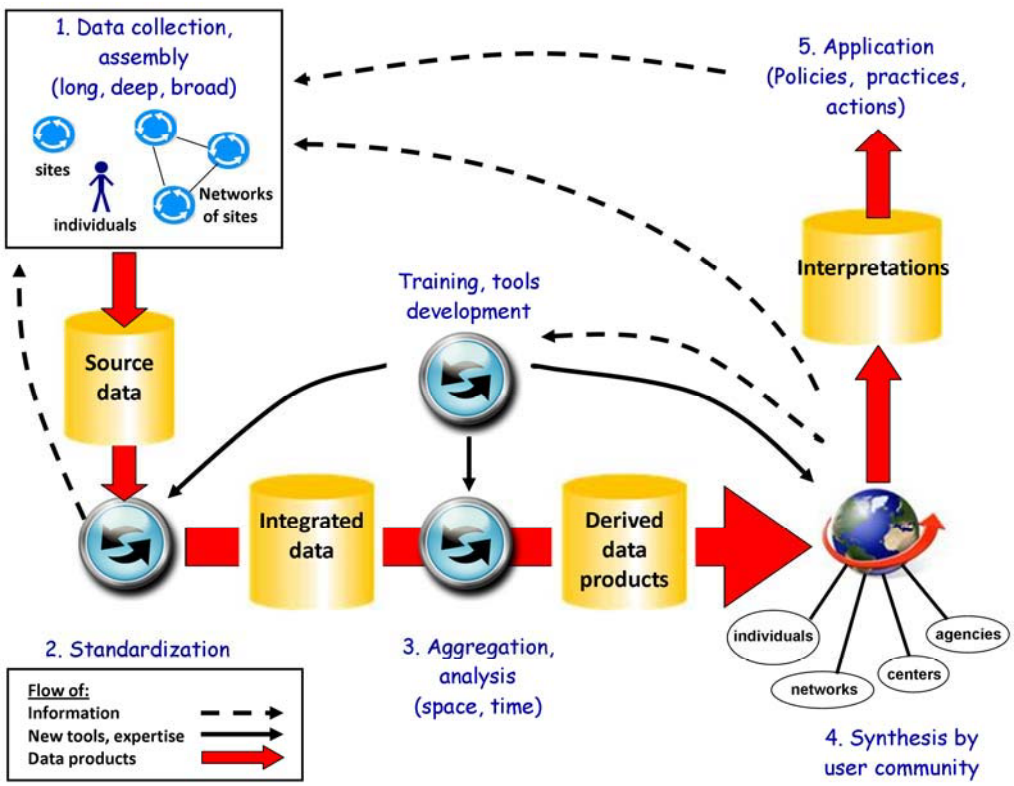
(8) Social science links to ecosystems [Skaggs]

Spatial analysis of grazing allotment life history data (obtained from BLM case history) files shows statistically significant clustering of ranch properties with high degrees of ownership turnover and for ranch properties with histories of interfamily transfers. A publication describing this research is in preparation (as of July 2011). Preliminary survey results of public land ranchers in the greater JER region indicate that there are numerous factors which influence long-term ranch management decisionmaking. Factors include: proximity to urbanizing areas, proximity to U.S.-Mexico border, public land management agency policy decisions, macroeconomic events, and cattle prices. Survey data collection will continue through 2011, and will be analyzed by Parry and the subject of his M.S. thesis (to be defended in Summer 2012).

(9) Synthesis and Integration

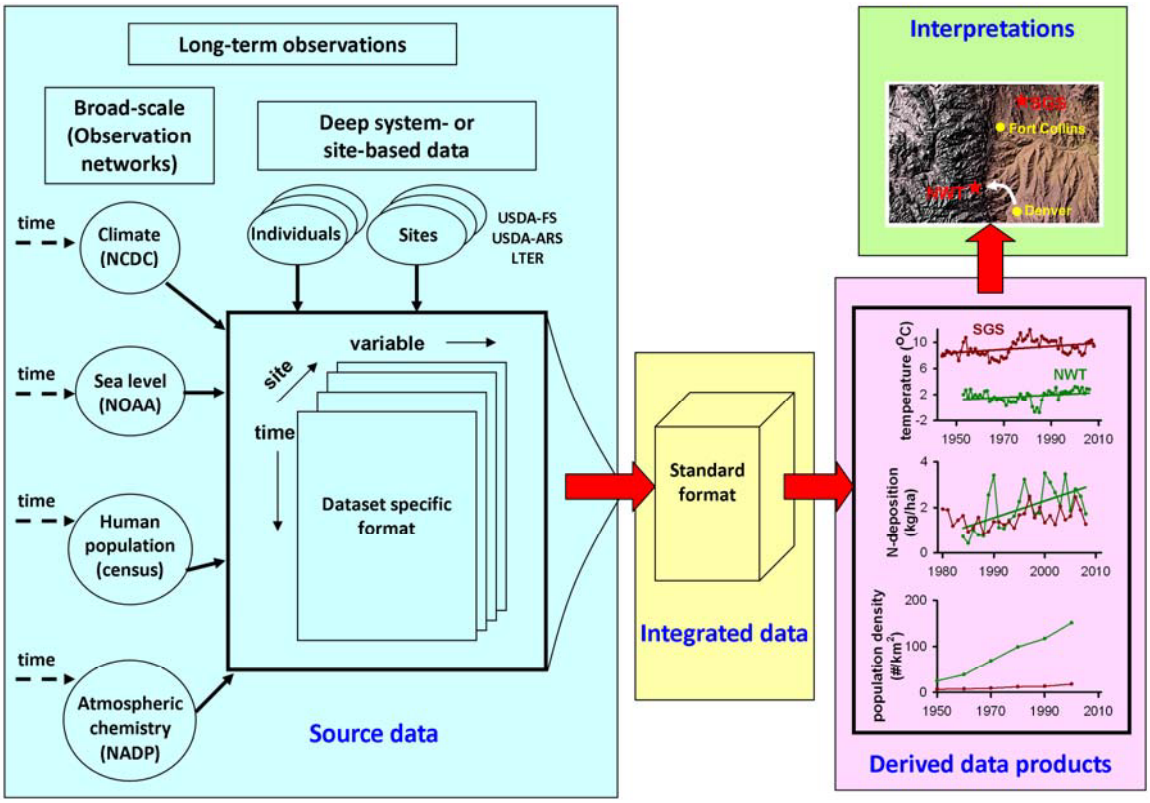
(a) Framework for Synthesis [Peters]

Large volumes of data have been collected to document the many ways that ecological systems are responding to changing environmental drivers. A general buy-in on solutions to these problems can be reached only if these and future data are made easily accessible to and understood by a broad audience that includes the public, decision-makers, and other scientists. We developed a framework for synthesis that integrates three main strategies of ecological research (long-term studies, short-term, process-based studies, broad-scale observations) with derived data products and additional sources of knowledge (Peters TREE 2010). This framework



A framework for synthesis and integration.

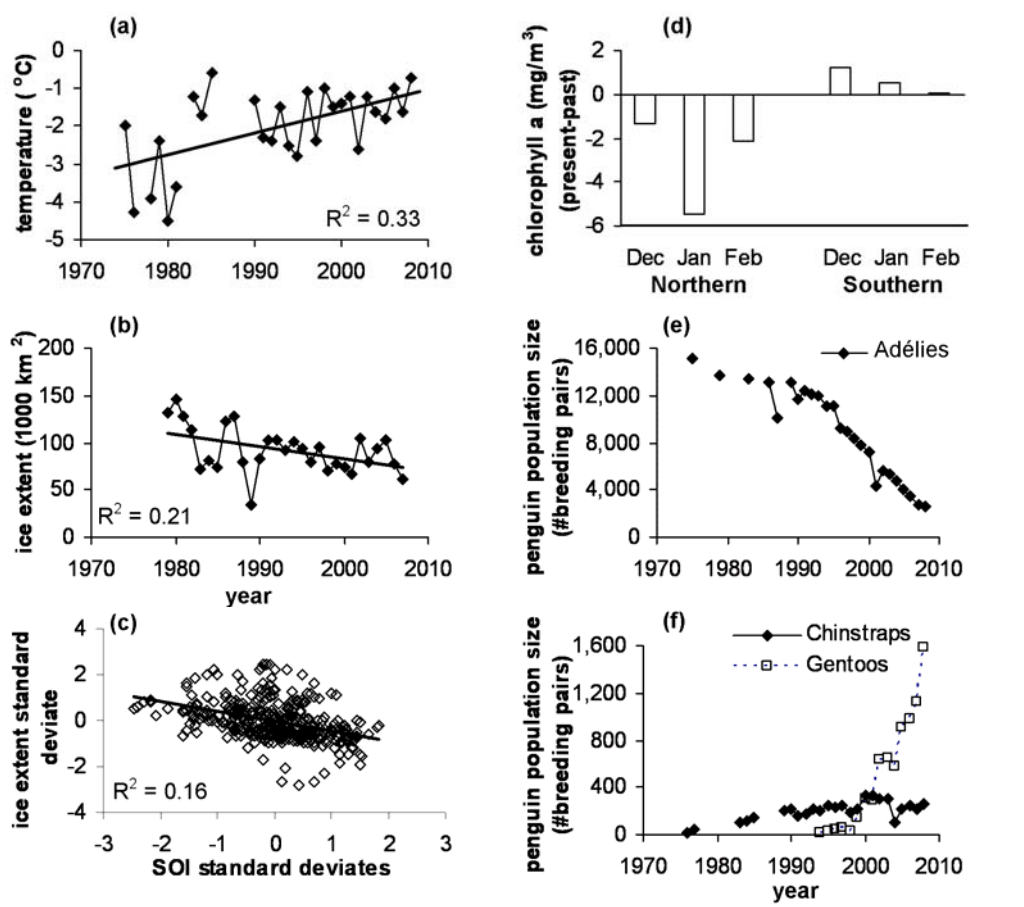
focuses on making data from multiple sources and disciplines easily understood by many, a prerequisite for finding synthetic solutions and predicting future dynamics in a changing world. The framework has five main steps (data collection, data and metadata standardization, aggregation and analysis, synthesis and integration, and application to policy, practices, and actions).



Example application of the synthesis framework.

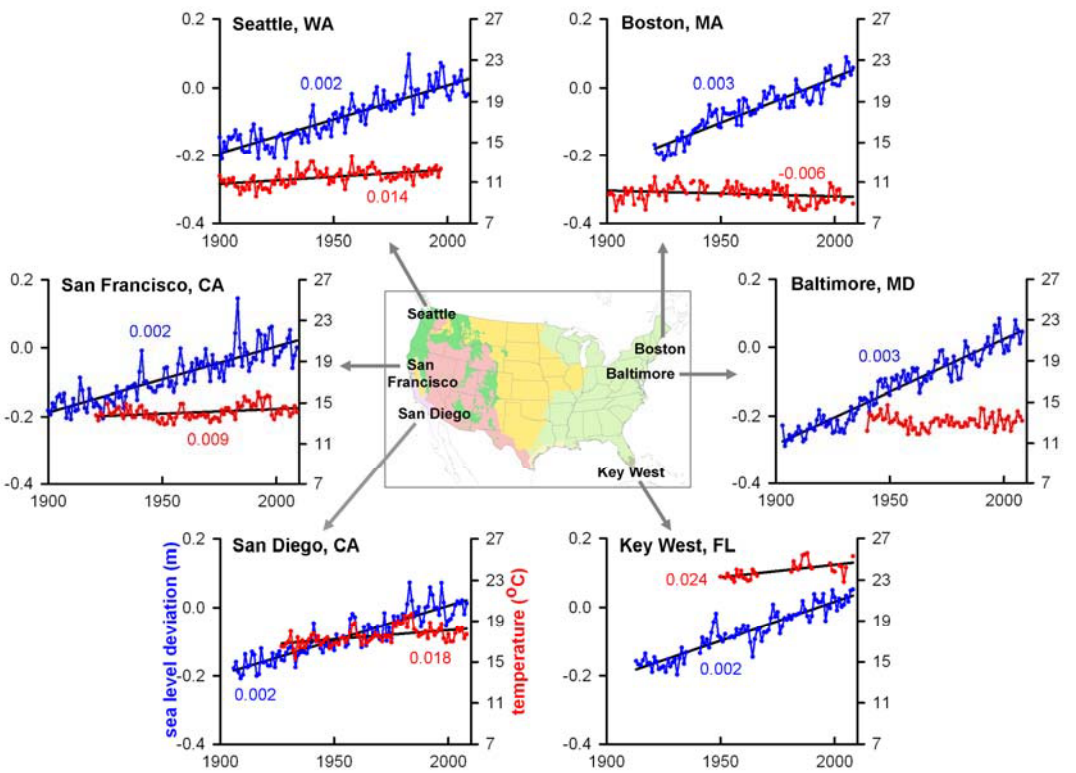
(b) Synthesis of long-term data within and across sites [Peters]

We synthesized long-term data for multiple drivers and ecological responses as part of the EcoTrends Project. For example, at the Palmer LTER site off the coast of the Western Antarctic Peninsula, multiple long-term datasets show patterns in drivers and biotic responses that can be used to infer causal relationships: (a) surface air temperatures have increased at some of the fastest recorded rates (temperature[oC] = -119 + 0.06*Time[years]; R2 = 0.33; p=0.001) globally [36] (data from http://www.ecotrends.info), (b) sea ice spatial extent has decreased significantly (ice extent[1000 km2] = 2707 – 1.3*Time[years]; R2 = 0.21; p=0.01) with a later advance and an earlier retreat of ice [37], (c) sea ice is related to the Southern Oscillation Index (SOI), and tends to advance during cooler La Nina periods, and retreat during warmer El Niño periods [38] (data from http://pal.lternet.edu shown as deviations from the mean: ice extent = -0.04 – 0.4*SOI; R2=0.16; p<0.0001), (d) phytoplankton biomass has shifted southward through time with decreases in the north (past: 1978-1986; present: 1998-2006) [39]. This shift in phytoplankton biomass is expected to reduce biomass of krill in the north, an important food source for Adélie penguins, (e) whose populations have been decreasing through time compared with (f) increases in populations of the ice-avoiding Gentoo and Chinstrap [40] (data from http://www.ecotrends.info). Identifying the key processes driving the state change between penguin species requires detailed studies of predator-prey relationships under multiple environmental conditions can be difficult to conduct in these systems.



Long term data from the Palmer LTER site showing a state change between penguin species and potential causal drivers (Peters TREE 2010).

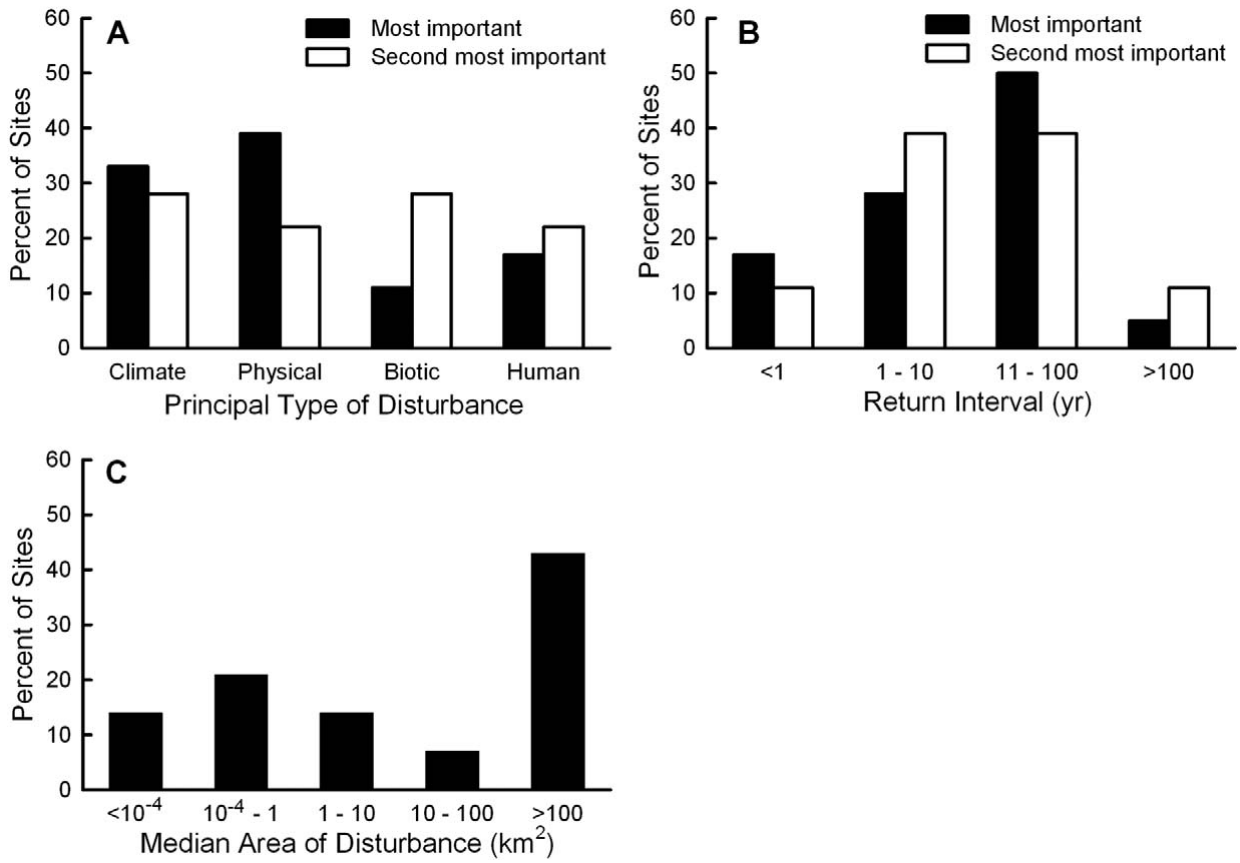
Cross-site comparisons are also facilitated using integrated datasets. Broad-scale patterns can be compared using networks of sites either coordinated to collect similar data with standard protocols or integrated via the post-collection standardization of similar data. For example, sea level measured by the US Geological Survey (http://tidesandcurrents.noaa.gov/) using standard methods and instruments were used to calculate trends through time for cities along the east and west coasts of the country [19]. Long-term climate data obtained from a different source (https://www.ncdc.noaa.gov/) were used to calculate trends in average air temperature for the same cities or nearby research sites. Significant regression lines and slopes ($p \leq 0.5$) are shown in blue (sea level) and red (air temperature). All panels share the same y-axes labels of sea level and temperature. Comparing trends in the two drivers shows that most coastal sites are experiencing an increase in sea level between 2 to 3 mm/y over the past 100 years. All west coast sites and Key West, FL are also experiencing increasing air temperatures at rates from 0.01 to 0.02^{o}C /y. (Condensed data from http://www.ecotrends.info). Understanding the processes driving these patterns through time and predicting ecological responses requires detailed studies of mechanisms, both at individual sites and across environmental gradients, to capture variation in drivers and the biota.



Sea level data from USGS gauges are combined with air temperature data from the National Climate Data Center in the EcoTrends database to allow multiple drivers to be easily compared across many sites (Peters TREE 2010).

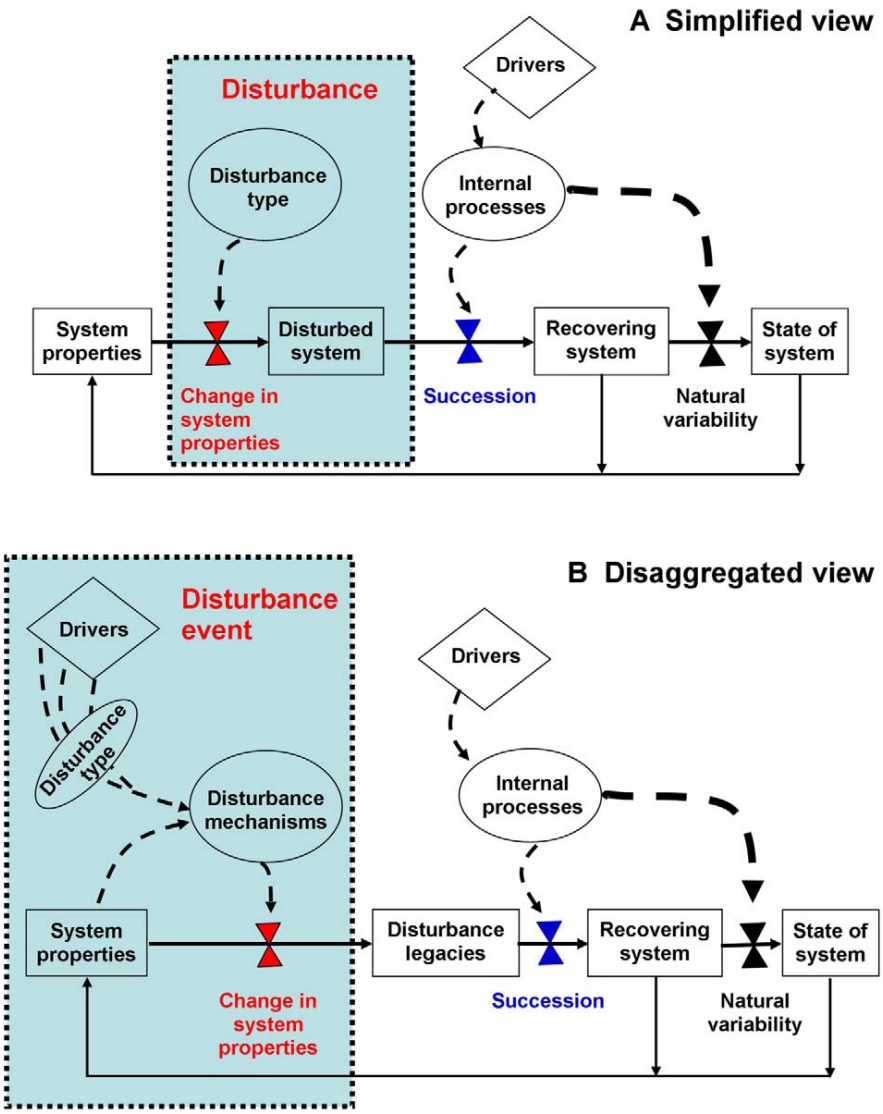
(c) Cross-site comparisons of disturbance studies [Peters]

Given that ecological effects of disturbance have been extensively studied in many ecosystems, it is surprising that few quantitative syntheses across diverse ecosystems have been conducted. Multi-system studies tend to be qualitative because they focus on disturbance types that are difficult to measure in an ecologically relevant way. In addition, synthesis of existing studies across systems or disturbance types is challenging because sufficient information needed for analysis is not easily available.



Data from ecosystems represented by 26 sites in the US Long-Term Ecological Research (LTER) network were used to qualitatively compare disturbance regimes (hhttp://www.ecotrends.info) (Peters et al. 2011. Ecosphere). Quantitative comparisons are limited by the lack of standardization in defining and measuring disturbance characteristics and ecosystem responses.

As part of the EcoTrends Disturbance Working group led by Peters, we synthesized information about many disturbance types into an integrated framework to allow quantitative comparisons of disturbance across ecosystem types. This framework recognizes individual disturbance events that consist of three quantifiable components: (1) environmental drivers, (2) initial system properties, and (3) physical and biological mechanisms of effect, such as deposition, compaction, and combustion. These components result in biotic and abiotic legacies that can interact with subsequent drivers and successional processes to influence system response. Through time, a coarse-scale quasi-equilibrial state can be reached where variation in drivers interacting with biotic processes and feedbacks internal to the system results in variability in dynamics. At any time, a driver of sufficient magnitude can push the system beyond its realm of natural variability to initiate a new kind of event.



Simplified view of disturbance often used to characterize disturbance effects that are then difficult to compare, and integrated view that disaggregates a disturbance event into individual components (Peters et al. 2011 Ecosphere).

As part of this effort, we used long-term data from diverse terrestrial ecosystems to illustrate how our approach can facilitate cross-system comparisons, and provide new insights to the role of disturbance in ecological systems. We also provided key disturbance characteristics and measurements needed to promote future quantitative comparisons across ecosystems.