# Preview of Award 1235828 - Annual Project Report



## Cover

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| PD/PI Name: | Debra P Peters, Principal Investigator<br>Brandon Bestelmeyer, Co-Principal Investigator<br>Stephanie V Bestelmeyer, Co-Principal Investigator<br>Kris M Havstad, Co-Principal Investigator<br>Hugh C Monger, Co-Principal Investigator |
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## Accomplishments

*** What are the major goals of the project?**

Chihuahuan Desert landscapes exemplify the ecological conditions, vulnerability, and management challenges in arid and semi-arid regions around the world. The goal of the Jornada Basin Long Term Ecological Research program (JRN LTER) established in 1982 is to understand and quantify the key factors and processes controlling ecosystem dynamics and patterns in Chihuahuan Desert landscapes. In collaboration with the Jornada Experimental Range (USDA ARS), studies initiated in 1915 have been incorporated into the JRN LTER program. Previous research focused on desertification, a state change from

perennial grasslands to woody plant dominance that occurs globally. Based on findings from growing long-term databases, the breadth of studies in LTER-VI was expanded to include four additional state changes that occur in dryland systems worldwide: (1) a reversal to grassland states, (2) transitions among different states dominated by woody plants, (3) invasion by non-native grasses leading to novel states, and (4) transitions to human-dominated states. Processes of interest include water mediated plant-soil feedbacks, patch-scale contagion, landscape context, and time lags that are manifested as nonlinear dynamics and threshold behavior. The overall goal of Jornada LTER-VI (2012-2018) is to understand and quantify the mechanisms that generate alternative natural and human-dominated states in dryland ecosystems, and to predict future states and their consequences for the provisioning of ecosystem services. A modified conceptual framework and integrated research plan in LTER-VI is being used to: (1) test specific elements by coupling existing long-term studies of patterns with new experiments aimed at elucidating processes, (2) integrate data from long-term studies in novel ways to address new questions, both at the JRN and in the surrounding region, and (3) forecast alternative future landscapes and consequences for ecosystem services under a changing environment. The proposed research is organized around two major geomorphic units that characterize the Chihuahuan Desert, and that contain on-going long-term studies and a sensor network. Long-term studies are being combined with new mechanistic experiments designed to identify dominant processes and drivers with a focus on pattern-process relationships that transcend scales. The generality of this framework is being assessed with cross-site and regional studies. Simulation modeling is being used to synthesize and integrate data, both to understand current patterns and to predict future dynamics. New socio-economic studies and scenarios based on the Ecosystem Millennium Assessment are placing Jornada research into a broader socio-economic-ecologic context. Proposed research is resulting in five major products: (1) new understanding of state changes, in particular in drylands, that lead to theory development, testable hypotheses, and new experiments; (2) accessible data and visualization tools applicable at multiple scales; (3) explanatory and predictive relationships between drivers, patterns, and processes that can be used to (4) develop scenarios of alternative human- and natural-dominated states with assessments of their impacts on ecosystem services; and (5) usable information transfer to a broad audience including K-12 students and teachers, and NGO and government agency land resource managers.

The major goals of our project are:

1. To provide new understanding of state changes within geomorphic units at the Jornada

2. To compare state change transitions among different geomorphic units at the Jornada

3. To provide a more mechanistic understanding of regional dynamics within the Chihuahuan Desert

4. To provide education and outreach programs across a range of scales, from local to global

5. To enhance the accessibility of Jornada data to a broad range of users.

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**
Major Activities:

## GOAL 1. to provide new understanding of state changes within geomorphic units at the Jornada

***Grassland to shrubland transitions:*** this is the classic example of desertification dynamics found in arid and semiarid ecosystems globally. Little is known about how biotic interactions between grasses and shrubs influence state transition dynamics, or whether density dependent interactions set the upper limits of shrub cover at advanced stages of encroachment. We are addressing these knowledge gaps using selective removal experiments. **Grass effects on adult shrubs.** Growth of shrubs where grasses were removed from the area surrounding shrubs of different sizes are being analyzed to determine (i) the life history stage(s) in which shrubs respond to the loss of grasses, and (ii) if shrub growth responses to reductions in grass biomass linear or exponential. **Adult shrub effects on grass.** Grass growth response to shrub abundance is being analyzed to determine the critical size/density of shrubs required to influence grass productivity. **Shrub-shrub interactions.** To determine if density dependent interactions may set upper limits of woody cover, the growth of shrubs whose conspecific neighbors are removed are being compared with shrubs whose conspecific neighbors are left intact.

***Shrubland to grassland transitions:*** the recent increase in native perennial grasses in some desertified shrublands suggests that climate variability may initiate state change reversals, while long-term data show that the key recovery processes differ by grass species, and that grasses in mesquite shrublands are more responsive than in other shrub-dominated systems to extended wet periods. The infrequent nature of exogenous phenomena, such as El Niño, requires long-term manipulative experiments.

1. We are continuing a long-term experiment of rainfall manipulations (80% reduced PPT, ambient, 80% increased PPT) since 2007 to: (1) assess the effectiveness of the manipulations; (2) test hypotheses; (3) unravel the mechanisms behind hypotheses.
2. We are continuing an increased precipitation variability experiment since 2009 where we maintain mean precipitation constant. The goal of this experiment is to understand the long term effects of precipitation variability and to disentangle the effects of precipitation variance from those of precipitation amount on ANPP and functional diversity.
3. We are comparing long-term responses of perennial grasses in different shrubland ecosystems to determine the relative importance of climate versus local biotic and physical properties in wet and dry periods.

***Shrubland to shrubland transitions:*** transitions between shrubland types suggest that shrub-dominated states are dynamic in the post-enchroachment phase. It is unknown if drought-avoiding mesquite will give way to creosotebush, a true xerophyte, on the sandy basin under future climatic conditions.

1. We are determining the explanatory variables related to changes in shrub species composition beginning in the 1850s across the Jornada, with a focus on the eastern bajada. Although current paradigms state that each species dominates on its own soil texture-geomorphology zone, historic maps show changes in shrub dominance accompanied by or preceded by dynamic soil texture at similar locations. We will attempt to disentangle these relationships with simulation modeling.
2. We are addressing seasonal patterns of phenological states and soil water use for different shrub species through the installation of a network of sapflow sensors on the east bajada. This network is in close proximity to an eddy covariance tower where an empirical method for partitioning evapotranspiration (ET) into shrub transpiration and bare soil evaporation is being applied. Phenocam imagery is being used to determine vegetation greenness and relate it to remotely-sensed vegetation indices (MODIS) to obtain parameters for an ecohydrologic model.
3. The link between turbulent fluxes, soil moisture, and soil temperature is being explored throughout the footprints of two eddy covariance towers. The shrub composition within the time-variable footprint was found to be a determinant of the measured evapotranspiration and the fraction attributed to shrub transpiration. To date, phenological trends of key plant species (phenocam, hyperspectral, and phenophase measurements), and landscapes (hyperspectral and phenocam measurements) have been compiled. These show both marked seasonal and interannual differences between shrub species and how they respond to drought and other disturbances. Preliminary analyses linking species to landscape phenological trends with other ecosystem properties and processes show relatively strong linkages, highlighting that species specific cover and phenological trends play key roles in ecosystem function.

***Transitions to novel states:*** The exotic grass, Lehmann's lovegrass, has not been problematic across the Chihuahuan Desert. However, higher temperatures may promote expansion of this species. We are using a soil water model to simulate establishment of lovegrass across the Southwest including the Jornada for a range of soils. We are simulating multiple climate change scenarios to examine effects of climate on the probability of recruitment of lovegrass.

## GOAL 2: To compare state change transitions among different geomorphic units at the Jornada.

1. One NEON site on the basin floor and one NEON-like site on the piedmont slope continue to gather data, as do an additional flux tower and a station that is part of the Soil Climate Analysis Network (SCAN). Wind erosion is being measured at several sites across the basin floor and piedmont slopes.
2. Live-trapping grids for desert rodents and non-invasive camera traps for lagomorphs and mesocarnivores were established across shrubland-grassland ecotones to determine if animal community dynamics differ among ecological states.

## GOAL 3: To provide a more mechanistic understanding of regional dynamics within the Chihuahuan Desert.

1. We completed analyses of the relationships between biophysical variables and allotment dynamics.

## GOAL 4: To provide education and outreach programs from local to global scales

We continued to leverage partnerships and non-NSF funding to support our education and outreach objectives through various activities. Specifically, we:

1. Ran a flexible science education program for K-12 students and teachers, including field trips, classroom/schoolyard science lessons, teacher workshops, and family education events based on JRN research.
2. Hosted the fifth annual Data Jam competition using the EcoTrends web site for high school and middle school students in New Mexico, shared the Data Jam model with LTER Education and Outreach coordinators, and provided materials and advice to scientists and educators at BES and LUQ who subsequently hosted three Data Jams in Maryland, New York, and Puerto Rico.
3. Developed cooperative agreements with national and international organizations.
4. Led or co-led six 3-5 day rangeland monitoring and assessment workshops and training sessions for land management agency employees, contractors, land managers and the general public in the US.
5. Continued working with land management agencies to promote adoption of a common set of rangeland monitoring protocols based in part on JRN research.
6. Continued development of the JournalMap website .
7. Continued development of a Land-Potential Knowledge System (Herrick et al. 2016) with USAID support, and released two apps for soil and vegetation on Apple App Store.

## GOAL 5: To enhance the accessibility of Jornada data to a broad range of users

1. Reviewed and updated all metadata stored within the Jornada data catalog.
2. Facilitated analysis and visualization of Ecotrends data
3. Continued development of the Knowledge, Learning, Analysis System (KLAS)
4. Maintained and enhanced the computational resources and infrastructure of the Jornada to support its research collaborations

Specific Objectives:

## GOAL 1. to provide new understanding of state changes within geomorphic units at the Jornada

***Grassland to shrubland transitions:***

1. We are remeasuring soil and vegetation on the NEAT plot to determine how they have changed one decade after establishment.

2. The Dune Development Study will allow us to observe how plants and soils respond to increased aeolian transport. Our goal in this experiment is to kickstart the formation of a coppice dune system and to observe changes in soil, vegetation, and litter as this

transition occurs. This is the type of research that can only be conducted in a long term context.

3. Determine the strength and symmetry of plant-plant interactions at play in driving grassland to shrubland transitions. Specific objectives are to determine (i) the critical size/density of shrubs required to influence grass ANPP, (ii) at what life history stage shrub growth respond to the loss of grasses and if their response is linear or exponential, and (iii) if density dependent interactions may set upper limits of woody cover. These objectives are being addressed with field based selective removal experiments along a grassland to shrubland continuum. We continued to monitor these experiments in 2015-16.

***Shrubland to grassland transitions:*** This experiment is testing three **hypotheses**. (1) Both water availability and the time that the ecosystem has been exposed to the new condition result in changes in ecosystem functioning through endogenous mechanisms. (2) The ecosystem sensitivity to reduced precipitation is different from sensitivity to increased precipitation resulting in asymmetries in the ecosystem response to chronic disturbances. (3) The interaction between cumulative endogenous with stochastic exogenous phenomena results in thresholds in population, community and ecosystem processes.

***Shrubland to shrubland transitions:***

1. To determine the transition patterns between shrub species at different locations across the landscape, and to determine the explanatory variables for the different transition patterns, we are overlaying spatial patterns in shrub species with different explanatory data layers, such as elevation, soil texture, geomorphology, long-term precipitation, and herbivore stocking rates.

2. To determine the extent to which individual shrub species are utilizing similar or different water sources in space and time within the geomorphic template of the Tromble weir watershed, we are using several techniques for measuring soil moisture– a network of soil profile sensors, a cosmic-ray soil moisture observing system (COSMOS) station, and water balance estimates.

3. To study the impact of shrub-to-shrub transitions on hydrologic conditions, we are parameterizing and using a distributed ecohydrologic model that incorporates high-resolution species-level data. Alternative vegetation scenarios will be assessed once model confidence is built based on comparisons to instrumentation networks at the Tromble weir watershed. The model will also be used to simulate the channel losses that are hypothesized to occur from field data as this is an important means for understanding the downstream consequences of vegetation state change.

***Transitions to novel states:*** To determine precipitation and temperature requirements for seedling establishment of the invasive Lehman's lovegrass on soils found throughout the Southwest.

## GOAL 2: To compare state change transitions among different geomorphic units at the Jornada

1. We are measuring the degree to which the climatic drivers interact with topography and soil to explain shrubland-grassland dynamics at the ecophysiological to landscape scale.

2. Specific objectives for the animal ecology study are to (a) quantify relationships among precipitation, ANPP, consumer abundances and biomass, and predator activity, (b) determine if these relationships differ among ecological states, and (c) evaluate potential for top-down versus bottom-up trophic cascades.

## GOAL 3: To provide a more mechanistic understanding of regional dynamics within the Chihuahuan Desert

For the BLM analysis, we are examining relationships between ownership variables (sale transfer rates and interfamily transfers) and biophysical variables. The broad goal is to understand how social and ecological processes interact to determine the distribution of ecological states at the regional scale. For the MBG project, our goal is to engage directly with a community of land managers (both federal and private) to ask and answer ecological questions of interest at the regional scale using geographic information systems analysis of large, spatial datasets and monitoring data gathered by the MBG. Based on meetings with MBG we determined that the use of fire and the effects of drought are the most important concerns, so we designed a project around that interaction.

## GOAL 4: To provide education and outreach programs from local to global scales

1. Increase the ability of local school districts to help students improve ecological understanding, including understanding the causes and potential impacts of climate change on local ecosystems (Schoolyard LTER program coordinated by Asombro Institute for Science Education).
2. Provide support to other LTER sites interested in adopting and adapting strategies developed in cooperation with JRN, including Data Jams (Asombro Institute).
3. Increase the ability of individuals and organizations to access, share and interpret knowledge and information necessary for climate change mitigation and adaptation (Climate Data Initiative and Climate Hub).
4. Increase the number, strength and diversity of partnerships through the development and strengthening of specific cooperative agreements with national and international organizations.
5. Continue to support US land management agencies in the development, application and interpretation of rangeland monitoring and assessment protocols based on JRN science (workshops).
6. Achieve adoption of a common set of rangeland monitoring protocols based in part on JRN research.
7. Increase the number of citations that can be searched for geographically through the JournalMap website, the quality of the interface, and the number of users.
8. Initiate development of a system to provide global access to site-specific predictions of potential productivity and sustainability of natural and human-dominated ecosystems based on an understanding of soil and climate variability, and landscape connectivity.

## GOAL 5: To enhance the accessibility of Jornada data to a broad range of users

1. Update all metadata stored within the LTER Data Catalog for completeness and accuracy
2. Continue to develop EcoTrends website
1. Complete phase 2 development which uses a combination of the existing EcoTrends database and the LTER Data Portal
2. Plan for phase 3 development which will use the LTER Data Portal as the data source and repository instead of the old EcoTrends database

- Continue development of KLAS
- Infrastructure upgrades
- Expand central storage capacity
- Increase the bandwidth to the field headquarters
- Upgrade Windows 2003 servers as it is no longer supported
- Upgrade and consolidate virtualization environment
- Deploy security appliance (firewall) following LTER site review
- Implement a consolidated backup solution to protect computational resources, research data, and associated metadata for central servers, storage, desktops, and

laptops
- Upgrade Drupal core and modules for all Drupal-based websites to mitigate security vulnerabilities and improve performance and stability

These improvements to Jornada infrastructure will improve stability, performance, and accessibility to Jornada research data by users as well as applications being developed at the Jornada and across the LTER Network.

Significant Results:

## GOAL 1. to provide new understanding of state changes within geomorphic units at the Jornada

***Grassland to shrubland transitions:***

1. There was a significant decrease in soil organic carbon (SOC) and total nitrogen (TN) in the NEAT treatments compared to the control, and concentrations in the upwind treatments were less than in the downwind treatment. Compared to the initial 2004 values, upwind treatment SOC and TN concentrations have been reduced by 1/3.

2. Our 6th year of monitoring the selective removal experiments initiated in 2010 was completed. Grass ANPP responded positively to shrub neighbor removal, particularly following consecutive years of above-average growing season precipitation (Fig. 1A). Allocation to vegetative reproduction (ramets) was also higher in the absence of shrub neighbors (Fig. 2A), which led to grass patch area expansion by year 5 of the experiment; grass patches with shrub neighbors intact initially declined in area relative to grass patches with shrub neighbors removed and their expansion in subsequent years was attenuated (Fig. 2B). The ANPP response of small shrubs to grass removal was positive in years with above-average growing season (2013) and cool season (2015) precipitation, a response not seen for shrubs > 50 cm canopy diameter regardless of precipitation patterns (Fig 1B). The removal of shrub neighbors did not influence ANPP of conspecific target shrubs in any year (Fig. 1C), nor was there a relationship between target shrub ANPP and abundance of shrub neighbors within 5 m. Grass or shrub removal did not appear to influence leaf water use efficiency (as indicated by d13C) and nor foliar N status (as indicated by d15N) of the target plants.

***Shrubland to grassland transitions:*** Results from our six-year field experiment of sequences of wet and dry years while maintaining precipitation amount constant showed that increased precipitation variability significantly reduced primary production. Dominant plant functional types showed opposite responses. Grass productivity presented a saturating response to precipitation where dry years had a larger negative effect than the positive effects of wet years. By contrast, shrubs showed an increasing response to precipitation that resulted in an increase in average productivity with increasing precipitation variability. In addition, the effects of precipitation variation increased through time and affected functional diversity that, in turn, ameliorated the impact of precipitation variability on ANPP. Results from the 8-year mean water availability manipulations show that ecosystem responses depend on water availability and on time of exposure to chronic resource alterations. Grass ANPP showed a fast and substantial response while shrub ANPP had little or no response to changes in water availability. The year 2013 was wetter than the previous 4 years however grasses that have been exposed to drought for 7 years were not able to respond to this increase in soil water.

***Shrubland to shrubland transitions:*** Spatial measurements of soil moisture and temperature around the eddy covariance tower at the Tromble Weir watershed yielded the first observational evidence for hysteresis in the relationship between the spatial variance and the mean soil moisture state (Fig. 3). Prior modeling studies suggested that this hysteresis is related to the differences between wetting and drying conditions. With continuous measurements over the two major seasons (Summer and Fall/Winter), the observational analysis identified this occurrence at the field scale (150 m by 120 m with 30 m spacing) and linked the behavior to underlying spatial differences in

topography, soil texture and vegetation type as sampled at high resolution around the eddy covariance tower.

## GOAL 2: To compare state change transitions among different geomorphic units at the Jornada

1. The banded vegetation zone at the SCAN site consists of three units: a tobosa grass zone, a linear dune, and a bare zone. The tobosa grass zone developed because the linear dune is perpendicular to runoff and forms a dam that collects water. Adjacent to the linear dune on the downslope side is a zone of bare soil. Measurements of soil moisture of these three side-by-side zones reveal the dune has lease soil moisture followed by the bare zone and the grass. Measurements of soil temperature show the dune has the highest temperatures followed by the grass and bare zone.

2. Total biomass of desert rodents does not differ across shrub cover gradients despite considerable changes in species composition. Functional groups respond differently to bottom-up pulses. Granivore biomass is related to NPP with a 1-year lag. Herbivore biomass responds directly to summer precipitation with a 1-year lag.

## GOAL 3: To provide a more mechanistic understanding of regional dynamics within the Chihuahuan Desert

We completed analysis of long-term BLM allotment monitoring data at a regional scale. We showed that a relatively small number of plots (10%) showed significant negative precipitation-adjusted trends in total perennial grass cover. Negative trends in black grama cover were related to soils with low water holding capacity. No geophysical variables could explain trends in other vegetation variables.

## GOAL 4: To provide education and outreach programs from local to global scales

1. A total of 18,269 K-12 students, 743 teachers, and 818 other adults participated in 35 field trips, 580 one-hour classroom/schoolyard lessons, 11teacher workshops, and 7 family events, where they learned about JRN research by participating in hands-on, inquiry-based activities. Three graduate students and REUs contributed more than 15 hours to help provide background information and assist with classroom lessons with students.
2. The 2016 Desert Data Jam competition was held in April 2016. In total, 172 students from southern New Mexico participated in the final competition in the high school or the middle school division. JRN staff also assisted other LTER site educators, who subsequently hosted spring 2016 Data Jam competitions in Maryland, New York, and Puerto Rico.
3. Over 250 individuals representing over 20 domestic and international organizations, received training in rangeland monitoring and assessment protocols.
4. NRCS and BLM adopted and are applying a common set of rangeland monitoring protocols based in part on JRN research.
5. As of September 5, 2014, JournalMap users can use geographic, including map-based, search tools and terms to access over 18,000 articles.
6. Two Land-Potential Knowledge System (Herrick et al. 2014) apps supported by cloud-based predictive models and simple analytics was successfully developed and tested on the Google Play Store.
7. Increased the number of graduate students conducting JRN related research through summer fellowship program and Desert Ecology Class in 2016 [Aaron Boydston, ASU (Sala); Eli Perez-Ruiz, ASU (Vivoni); Julie Schlichte, UTEP (Bestelmeyer); Junzhe Zhang, UCLA (Okin), Jennifer Hu Laura Boucheron via Bestelmeyer and Rick Estell), Junxin Huang, NMSU (Peters).
8. Four undergraduate REU students were supported in 2016 (Raymond Cooley [ASU, Sala], Frederick Hansen [NMSU, Pietrasiak], Nick Wright [NMSU, Peters], Carlos Tejeda [NMSU, Peters]).

## GOAL 5: To enhance the accessibility of Jornada data to a broad range of users

1. Completed expansion of centralized storage by adding a new disk shelf (144 TB raw) and distributing file shares and server storage across the old and new volumes
2. Upgraded older Windows 2003 servers to either Windows 2008 R2 or 2012. This included upgrading the email server to GroupWise 2014
3. Upgraded virtual server environment to Citrix XenServer 6.5
4. Deployed the new firewall which had been purchased and setup prior to the LTER site review last year
5. Upgraded all Drupal-based websites to address security vulnerabilities and to improve performance and stability.

Key outcomes or Other achievements:

## GOAL 1. to provide new understanding of state changes within geomorphic units at the Jornada

***Grassland to shrubland transitions:***

1. A paper is in preparation that outlines results from the NEAT reanalysis. Two UCLA undergraduates (Dylan Oliva and Galen Coppage) participated in independent research at UCLA with Professor Okin for University credit.
2. The classic desertification paradigm emphasizes indirect abiotic feedbacks that reduce grass cover and reinforce state transition. Shrub suppression of grass ANPP was strongest at high levels of abundance, indicating that the direct biotic process of resource competition is another factor contributing to transition dynamics. Grass ANPP was also suppressed at relatively low levels of shrub abundance, suggesting that sites may be at risk for state transition earlier in the shrub encroachment process than expected.
3. In years with above average growing season precipitation, ANPP of small shrubs was reduced when grasses were present. These results from our selective removal experiments are consistent with results from precipitation manipulation experiments. Grasses may therefore slow the rate at which shrubs attain a physical stature that can modify the physical environment in self promoting ways. Conversely, reductions in grass cover via drought or grazing would ostensibly hasten grassland to shrubland transitions.
4. Results form the 6 year selective removal experiments will be the focus of Nate Pierce's PhD Dissertation. Chapters in the dissertation will be written as stand-alone manuscripts that can be readily submitted to refereed journals.
5. We are discussing whether or not to continue monitoring these experiments. If monitoring is continued, we will have to decide on priorities with respect to which variables to monitor and at what frequency.
6. Intraspecific interactions between shrubs were not evident in any year, even at high levels of shrub cover/density. This suggests that as shrub encroachment progresses, maximum woody cover may be more a function of constraints on plant size than on density dependent mechanisms.A paper is in preparation that outlines results from the NEAT reanalysis. Two UCLA undergraduates (Dylan Oliva and Galen Coppage) participated in independent research at UCLA with Professor Okin for University credit.

***Shrubland to grassland transitions:***

Results from the 10 year manipulations of precipitation amount showed a fast and substantial response while shrub ANPP had little or no response to changes in water availability. The last two years were wetter than the previous 5 years however grasses that have been exposed to drought for 8 years were not able to respond to this increase in soil water suggesting that grasses have crossed a threshold and lost their ability to respond to an increase in precipitation.

***Shrubland to shrubland transitions:***

1. Our view of the eastern bajada has changed from a static perception driven by today's patterns to a dynamically changing landscape based on a re-analysis of the vegetation maps at finer resolution than conducted previously. This re-analysis has led us to decide that a new, updated vegetation map is needed for the Jornada that we are planning in 2016-17.
2. Based on the multiple lines of observation of soil moisture, we conclude that first-order watersheds on the eastern bajada lose significant amounts of water within their channel systems to the deep subsurface. This contradicts conventional wisdom suggesting that most groundwater recharge is focused in downstream reaches or playas. To conclusively show this, additional soil moisture sensors have been installed and the ecohydrological model will be modified to simulate channel transmission losses.. A combination of observations and calibrated model scenarios of vegetation state changes will be used to determine the effect of dynamically changing landscapes on water yield and groundwater recharge from the first-order watersheds.

## GOAL 2: To compare state change transitions among different geomorphic units at the Jornada

1. Measurements of current climatic-soil relationships across the Jornada Basin LTER will improve predictions about which soils will have lower moisture and higher temperatures under different climate change scenarios. We hypothesize that changes in soil climate will have important feedbacks to vegetation and animal dynamics.

2. Temporal dynamics of desert rodents are consistent across ecological states, and desertification does not reduce overall abundances or biomass of these consumers. The processes linking precipitation pulses and biomass differ for granivores and herbivores. Periodic species colonizations and metacommunity dynamics play a key role.

## GOAL 3: To provide a more mechanistic understanding of regional dynamics within the Chihuahuan Desert

The results of the BLM study will advance our understanding of how social-ecological interactions impact the trajectories of Chihuahuan Desert landscapes. The MBG fire study was published this year and provides 1) an example in which LTER engages with a land management community based on their interests and 2) an unprecedented regional view fire distribution, effects, and interactions with climate.

## GOAL 4: To provide education and outreach programs from local to global scales

1. 18,269K-12 students with increased understanding of the Chihuahuan Desert and current research being conducted by LTER scientists.
2. More than 170 students who gained skills both interpreting and then communicating large, long-term, complex datasets to nonscientists through Data Jam competitions at their own schools.
3. Training on standard methods protocols increased the quality and consistency of rangeland monitoring and assessment data.
4. Significant cost savings were realized through the decision by NRCS and BLM to adopt a common rangeland monitoring manual developed by the Jornada instead of each agency developing its own. This also increases the future ability of the agencies to share and integrate their datasets.
5. The ability of scientists and other users to find studies based on geographic relevance was significantly increased.
6. Local awareness and understanding of how to generate and use an understanding of landscape-scale soil variability and connectivity was increased in pilot regions in Kenya and Namibia.

## GOAL 5: To enhance the accessibility of Jornada data to a broad range of users

1. Increased central storage capacity by 144 TB (unformatted)
2. Replaced old firewall
3. Upgraded older servers and services that ran on Windows 2003 Server
4. Upgraded virtualization environment to improve performance, stability, and security
5. Deployed comprehensive backup solution to protect Jornada servers, storage, desktops, and laptops
6. Upgraded Drupal core and modules on all Jornada Drupal-based websites

*** What opportunities for training and professional development has the project provided?**

1. 18,269 K-12 students have been trained with an increased understanding of the Chihuahuan Desert and current research being conducted by LTER scientists.
2. More than 170 students have gained skills in interpreting and then communicating large, long-term, complex datasets to nonscientists through Data Jam competitions at their own schools.
3. Four REU students were provided professional development through our summer program.
4. Six graduate students were trained as part of our summer and year-long graduate research assistantship program.
5. Ten students participated in our Desert Ecology class for undergraduates and graduate students in summer 2016.

*** How have the results been disseminated to communities of interest?**

## GOAL 1. to provide new understanding of state changes within geomorphic units at the Jornada

***Grassland to shrubland transitions:***

A paper titled “Enhanced precipitation variability decreases grass- and increases shrub-productivity” published in *PNAS* in October 2015 is in the top 5% of all research outputs scored by Altmetrics and is in the 96th impact percentile of outputs of the same age. It was picked up by six different news outlets and tweeted numerous times. Another paper titled “Enhanced interannual precipitation variability increases plant functional diversity that in turn ameliorates negative impact on productivity” and published in *Ecology Letters* was included as a Research Highlight in the Journal Nature Plants having a great impact and numerous tweets. Another successful collaboration yielded a paper in *Climatic Change*. Led by Osvaldo Sala, this paper published in March has already 4 citations and great deal of attention on social media.

***Shrubland to shrubland transitions:***

Results have been disseminated to press media through a public presentation and media activity at the AAAS Annual Meeting, resulting in worldwide coverage of the use of unmanned aerial vehicles for ecohydrology. In addition, conference presentations in the US and Mexico have been carried out to disseminate the study results.

## GOAL 2: To compare state change transitions among different geomorphic units at the Jornada

Results have been disseminated to scientific communities by conference presentations and to the general public by community lectures, magazine articles, and YouTube videos.

## GOAL 4: To provide education and outreach programs from local to global scales

1. 18,269 K-12 students have been trained with increased understanding of the Chihuahuan Desert and current research being conducted by LTER scientists.
2. More than 170 students have gained skills both interpreting and then communicating large, long-term, complex datasets to nonscientists through Data Jam competitions at their own schools.

## GOAL 5: To enhance the accessibility of Jornada data to a broad range of users

DEIMS Repository: http://github.com/lter-jrn/deims

Jornada source code enhancements to DEIMS are shared with the wider DEIMS and Drupal communities in the repository

DEIMS Project Page: http://www.drupal.org/project/deims

Jornada bug fixes and information related to DEIMS are shared with wider DEIMS and Drupal communities within the page

LTER Data Portal: https://portal.lternet.edu/nis/browseServlet?searchValue=JRN

EcoTrends Data Portal: http://www.ecotrends.info

Jornada Data Catalog: http://jornada.nmsu.edu/lter/data

Jornada Data Explorer: http://jornada.nmsu.edu/data-explorer-dashboard

Jornada research data and metadata are made available from multiple portals

DrupalCon Austin - June 2014

DEIMS Workshop: http://austin2014.drupal.org/session/deims-drupal-profile-ecological-data

Presentation and discussion of DEIMS to wider Drupal community

Science on Drupal Workshop: http://neworleans2016.drupal.org/bof/science-drupal

Science on Drupal Workshop: http://austin2014.drupal.org/bof/science-drupal

Birds of a feather sessions on Drupal's role in supporting the sciences and how agencies and research groups can share challenges and successes and get wider participation in science related Drupal development efforts

Federation of Earth Science Information Partners (ESIP) Conference - July 2014

Security Lab: http://commons.esipfed.org/node/2558

Maps and Visualization Lab: http://commons.esipfed.org/node/2559

Drupal Working Group (hosted DrupalCon BOF session), hosted training labs and facilitated discussions begun at DrupalCon on how we can leverage one another's work within Drupal without reinventing the same wheels

*** What do you plan to do during the next reporting period to accomplish the goals?**

## GOAL 1. to provide new understanding of state changes within geomorphic units at the Jornada

***Grassland to shrubland transitions:***

These analyses will be the core of Nate Pierce's dissertation and the manuscripts that will arise from his dissertation.

The Dune Development Study will be initiated.

We are gathering the final (20 year) measurement from the ThreshEx grazing-shrub removal study.

***Shrubland to grassland transitions:***

1. We are comparing responses during the 2004-2008 wet period with a previous wet period (1984-1988), and testing hypotheses about factors controlling similar responses. We are examining factors that led to the mortality of perennial grasses in 1989. We continue to reuse long-term data from multiple datasets and studies at the Jornada as we test additional hypotheses.

2. We are continuing the long-term manipulation experiment.

***Shrubland to shrubland transitions:***

1. We will continue to monitor and analyze the sensor network observations from the Tromble weir watershed by quantitatively comparing: 1) different soil moisture measurement techniques at the watershed scale, 2) techniques for partitioning ET that account for individual shrub species and the spatial variability within the eddy covariance footprint, and 3) evaluating long-term simulations using the spatially-distributed approach that accounts for changes in shrubland types.

2. We will continue to obtain imagery from unmanned aerial vehicles to quantify vegetation phenology, link these to phenological data (phenocams and sampling) and identify possible state transitions related to shrub-shrub interactions. Additional phenocam observations will be deployed and similar technology used to quantitatively determine channel runoff.

3. We will process and analyze net ecosystem exchange observations from the long-term eddy covariance record and relate these to phenological measurements. Additional effort will be placed on measuring soil carbon storage and soil carbon fluxes to quantify the watershed carbon balance.

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4. We will conduct vegetation surveys throughout the eastern bajada to document the historic shifts in dominant shrub species through time, and conduct a literature review to obtain species-level parameters for seed germination and seedling establishment in the SOILWAT model, and for plant competition and mortality in the Ecotone model. After the models have been verified, we will conduct simulations of historic climate and soils conditions to determine the sequence of events needed to result in today's landscapes, and then examine scenarios under future climate.

5. We will use time series data from our eddy covariance tower, robotic tram system for measuring spectral reflectance, micro-meteorological network, phenocams, phenophase monitoring to explore the biophysical and species-specific controls of land-atmosphere fluxes.

***Transitions to novel states:***

We plan on running the Ecotone model to examine controls on the growth and expansion of these exotic grasses at the Jornada and throughout the Southwest.

## GOAL 2: To compare state change transitions among different geomorphic units at the Jornada

1. We are expanding our studies to include the Chihuahuan Desert Nature Park in the southern Jornada Basin. We will test hypotheses about how soils may respond to future change by investigating how they responded to past climate change using paleosols, erosion features, and carbon isotopes.

2. Each of the 15 CSIS sites measures wind speed at 4 heights, wind direction, and soil moisture at 10 cm. These will be instrumented as more complete met stations (air temperature, relative humidity, rainfall) this winter with 2015 supplement funds.

3. We will initiate the integration of data from the desert rodent study and the camera trap study to determine whether spatiotemporal variation in consumer abundances not explained by bottom-up effects (precipitation and ANPP) is explained by predator activity and top-down effects.

## GOAL 3: To provide a more mechanistic understanding of regional dynamics within the Chihuahuan Desert

Complete analyses of the relationships of desert grassland fire and biophysical variables at a regional scale.

## GOAL 4: To provide education and outreach programs from local to global scales

The JRN K-12 team will continue to plan and conduct field trips and classroom/schoolyard programs focused on JRN research. We will host at least one teacher workshop, two family education events, and the 2017 Desert Data Jam competition. We will continue to involve JRN graduate students in developing and implementing new K-12 programs.

## GOAL 5: To enhance the accessibility of Jornada data to a broad range of users

1. Continue KLAS development
2. Deploy EcoTrends website (Ruby-based) and begin developing the next version of EcoTrends that uses the web services from the LTER Data Portal without the limitations of the old databases. This will allow preliminary multi-variate analysis and the ability to update EcoTrends data being maintained in the LTER Data Portal.
3. Process and load short-term data to convert fixed format data files to comma-separated value format which will be subsequently loaded into relational database tables for use by scientists, applications, and the Data Explorer on the Jornada Basin LTER website.
4. Review and update dataset keywords to make Jornada data more discoverable from the Jornada website, LTER Data Portal, and DataOne. By implementing the LTER Controlled Vocabulary, our datasets can be found along with other LTER site datasets in these data portals.
5. Maintain and enhance computational resources and infrastructure to support the needs of our scientists, staff, and students.

**Supporting Files**

| Filename | Description | Uploaded By | Uploaded On |
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| Jornada Basin annual report 2015-16_figure1.pdf | Figure 1. ANPP of target black grama (Bouteloua eriopoda) or mesquite (Prosopis glandulosa) plants with shrub or grass neighbors removed (red) or intact (blue). (A) Black grama (B) Small mesquite plants, (C) Mesquite productivity. | Debra Peters | 09/26/2016 |
| Jornada Basin annual report 2015-16_figure2.pdf | Figure 2: (A) Mean (Â± SE) ramet production (2013 and 2015) and (B) number of 20 cm x 20 cm cells (out of 25) occupied by B. eriopoda in 1m x 1m subplots with shrub neighbors removed (red) or intact (blue). | Debra Peters | 09/26/2016 |
| Jornada Basin annual report 2015-16_figure3.pdf | Figure 3. Daily relations between the mean condition of soil moisture <Î¸> and the spatial variation of soil moisture (Ï?Î¸ obtained around an eddy covariance tower (a) Seasonal conditions and â??Overall Fitâ??. (b, c) Hysteretic cycles in summer and fall/winter. | Debra Peters | 09/26/2016 |

## Products

### Books

### Book Chapters

Archer, SR, Andersen EM, Predick KI, Schwinning S, Steidl RJ, and Woods SR (). Woody plant encroachment: causes and consequences. *Rangeland Systems: Processes, Management and Challenges* Briske DD. Springer. New York, USA. . Status = AWAITING_PUBLICATION; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes

Bestelmeyer, BT. (2016). A dryland ecologist's mid-career retrospective on LTER and the science-management interface. *Long-Term Ecological Research: Changing the Nature of Scientists* Willig, MR and Walker LR. Oxford University Press. 197. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes

Jaimes, A, Tweedie CE, Magoc T, Kreinovich V, and Ceberio M. (2014). Selecting the Best Location for a Meteorological Tower: A Case Study of Multi-objective Constraint Optimization. *Constraint Programming and Decision Making* Ceberio M and Kreinovich V. Springer International Publishing. Cham. 61--65. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/978-3-319-04280-0_7.

Peters, DPC. (2016). Tales from an LTER "lifer". *Long-Term Ecological Research: Changing the Nature of Scientists* Willig, MR and Walker LR. Oxford University Press. 204. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes

Sala, OE, Yahdjian L, Havstad KM, and Aguiar MR (). Rangeland ecosystem services: nature´s supply and humans´ demand. *Rangeland Systems: Processes, Management and Challenges* Briske DD. Springer. New York, USA. . Status = AWAITING_PUBLICATION; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes

Servin, C, Jaimes A, Ceberio MC, Tweedie, CE, Kreinovich VY (2013). How to Describe and Propagate Uncertainty When Processing Time Series: Metrological and Computational Challenges, with Potential Applications to Environmental Studies. *Time Series Analysis, Modeling and Applications: A Computational Intelligence Perspective* Pedrycz W and Chen S-M. Springer Berlin Heidelberg. Berlin, Heidelberg. 279--299. Status = PUBLISHED; Acknowledgement of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/978-3-642-33439-9_13.

### Inventions

### Journals or Juried Conference Papers

Anderson, CA, and Vivoni ER (2016). Impact of land surface states within the flux footprint on daytime land-atmosphere coupling in two semiarid ecosystems of the Southwestern U.S.. *Water Resources Research*. 52 (6), 4785--4800. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2015WR018016

Bestelmeyer, BT. (2015). Land ecology essay II: thresholds, novel ecosystems, and the sanctity of history. *Rangelands*. 37 244. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Brevik, EC, Richter D, Verrecchia EP, Ryan J, Poch RM, Crouvi O, Sauer D, Waroszewski J, Solleiro-Rebolledo E, Monger HC, Ottner F, and Targulian V (2016). The influence of Dan H. Yaalon: His impact on people . *\{CATENA\}* . 146 147 - 154. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: http://dx.doi.org/10.1016/j.catena.2015.10.012

Chu, C, Kleinhesslink AR, Havstad KM, McClaran MP, Peters DP, Vermeire VT, Wei H, and Adler PB (2016). Direct effects dominate responses to climate perturbations in grassland plant communities. *Nature communications*. 7 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1038/ncomms11766

Cosentino, BJ, Schooley RL, Bestelmeyer BT, McCarthy AJ, and Sierzega K. (2015). Rapid genetic restoration of a keystone species exhibiting delayed demographic response. *Molecular Ecology*. 24 6120. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

DaVanon, KA, Howard LK, Mabry KE, Schooley RL, and Bestelmeyer BT (2016). Effects of exurban development on trophic interactions in a desert landscape. *Landscape Ecology*. 1--12. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Estiarte, M, Vicca S, Peñuelas J, Bahn M, Beier C, Emmett BA, Fay PA, Hanson PJ, Hasibeder R, Kigel J, Kröel-Dulay G, Larsen KS, Lellei-Kovács E, Limousin JM, Ogaya R, Ourcival JM, Reinsch S, Sala OE, Schmidt IK, Sternberg M, Tielbörger K, Tietema A, and Janssens IA (2016). Few multi-year precipitation-reduction experiments find a shift in the productivity-precipitation relationship. *Global change biology*. 22 (7), 2570--2581. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/gcb.13269

Flombaum, P, Yahdjian L, and Sala OE (2016). Global-change drivers of ecosystem functioning modulated by natural variability and saturating responses. *Global Change Biology*. n/a--n/a. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/gcb.13441

Hargrove, WL, Borrok DM, Heyman JM, Tweedie CE, and Ferregut C. (2013). Water, climate, and social change in a fragile landscape. *Ecosphere*. 4 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1890/ES12-00269.1

Herrick, JE, Beh A, Barrios E, Bouvier I, Coetzee M, Dent D, Elias E, Hengl T, Karl JW, Liniger H, Matuszak J, Neff JC, Ndungu LW, Obersteiner M, Shepherd KD, Urama KC, van den Bosch R and Webb NP (2016). The Land-Potential Knowledge System (LandPKS): mobile apps and collaboration for optimizing climate change investments. *Ecosystem Health and Sustainability*. 2 (3), e01209--n/a. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/ehs2.1209

Hewins, DB, and Throop HL (2016). Leaf litter decomposition is rapidly enhanced by the co-occurrence of monsoon rainfall and soil-litter mixing across a gradient of coppice dune development in the Chihuahuan Desert . *Journal of Arid Environments* . 129 111 - 118. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: http://dx.doi.org/10.1016/j.jaridenv.2016.02.014

Itkin, D, Goldfus H, and Monger HC (2016). Human induced calcretisation in anthropogenic soils and sediments: Field observations and micromorphology in a Mediterranean climatic zone, Israel . *\{CATENA\}* . 146 48 - 61. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: http://dx.doi.org/10.1016/j.catena.2016.06.025

Jaimes, A, Tweedie CE, Kreinovich VY, and Ceberio MC. (2012). Scale-invariant approach to multi-criterion optimization under uncertainty, with applications to optimal sensor placement, in particular, to sensor placement in environmental research.. *International Journal of Reliability and Safety*. 6 188. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Kosheleva, O, Tweedie CE, and Kreinovich V. (2015). Which bio-diversity indices are most adequate?. *2015 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE)*. 1. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1109/FUZZ-IEEE.2015.7337831

Laney, CM, Pennington D, and Tweedie CE. (2015). Filling the gaps: sensor network use and data sharing practices in ecological research. *Frontiers in Ecology and the Environment*. 13 363. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1890/140341

Levi, ML and Bestelmeyer BT (2016). Biophysical influences on the spatial distribution of fire in the desert grassland region of the southwestern USA. *Landscape Ecology*. 31 (9), 2079--2095. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1007/s10980-016-0383-9

Mascaro, G and Vivoni ER (2016). On the observed hysteresis in field-scale soil moisture variability and its physical controls. *Environmental Research Letters*. 11 (8), 084008. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1088/1748-9326/11/8/084008

Miller, JR and Bestelmeyer BT (2016). What's wrong with novel ecosystems, really?. *Restoration Ecology*. 24 (5), 577--582. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/rec.12378

Peters, DPC and Okin GS (2017). A toolkit for ecosystems ecologists in the time of big science. *Ecosystems*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Ramirez, C, Argaez M, Jaimes A, and Tweedie CE. (2012). Image inpainting in micrometeorological analysis. *19th IEEE International Conference on Image Processing (ICIP)*. 1725. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1109/ICIP.2012.6467212

Ramirez, C, Argaez M, Jaimes A, and Tweedie CE. (2014). Interpolating sparsely corrupted signals in micrometeorology. *Journal of Mathematics Research*. 6 10. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Schreiner-McGraw, AP, Vivoni ER, Mascaro G, and Franz TE (2016). Closing the water balance with cosmic-ray soil moisture measurements and assessing their relation to evapotranspiration in two semiarid watersheds. *Hydrology and Earth System Sciences*. 20 (1), 329--345. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.5194/hess-20-329-2016

Wang, J, Monger HC, Wang X, Serena M, and Leinauer B (2016). Carbon sequestration in response to grassland-shrubland-turfgrass conversions and a test for carbonate biomineralization in desert soils, New Mexico, USA. *Soil Science Society of America*. . Status = AWAITING_PUBLICATION; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Webb, NP, Galloza MS, Zobeck TM, and Herrick JE (2016). Threshold wind velocity dynamics as a driver of aeolian sediment mass flux . *Aeolian Research* . 20 45 - 58. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: http://dx.doi.org/10.1016/j.aeolia.2015.11.006

Webb, NP, Herrick JE, Van Zee JW, Courtright EM, Hugenholtz CH, Zobeck TM, Okin GS, Barchyn TE, Billings BJ, Bod R, Clingan SD, Cooper BF, Duniway MC, Derner JD, Fox FA, Havstad KM, Heilman P, LaPlante V, Ludwig NA, Metz LJ, Nearing MA, Norfleet ML, Pierson FB, Sanderson MA, Sharratt BS, Steiner JL, Tatarko J, Tedela NH, Toledo D, Sunnasch RS, Van Pelt RS and Wagner L (2016). The National Wind Erosion Research Network: Building a standardized long-term data resource for aeolian research, modeling and land management . *Aeolian Research* . 22 23 - 36. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: http://dx.doi.org/10.1016/j.aeolia.2016.05.005

Williamson, JC, Bestelmeyer BT, McClaran MP, Robinett D, Briske DD, Wu XB, and Fernandez-Gimenez M (2016). Can ecological land classification increase the utility of vegetation monitoring data?. *Ecological Indicators*. 69 657 - 666. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.ecolind.2016.05.030

Wilson, RS, Hardisty DJ, Epanchin-Niell RS, Runge MC, Cottingham KL, Urban DL, Maguire LA, Hastings A, Mumby PJ, and Peters DPC (2016). A typology of time-scale mismatches and behavioral interventions to diagnose and solve conservation problems. *Conservation Biology*. 30 (1), 42--49. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1111/cobi.12632

**Licenses**

**Other Conference Presentations / Papers**

Ramirez, G., Ramirez GA, Vargas SA, Luna NR, and Tweedie CE (2015). *A new digital imaging and analysis system for plant and ecosystem phenological studies*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status =

PUBLISHED;  Acknowledgement of Federal Support = Yes

Bestelmeyer, BT, Svejcar LM, and Peinetti HR (2016). *A simple, quantitative approach to state-and-transition models and ecological site classification*. Society for Range Management annual meeting. Corpus Christi, TX. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Galloza, M, Webb N, and Herrick J (2015). *AERO: A decision support tool for wind erosion assessment in rangelands and croplands*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Schooley, RL, and Bestelmeyer BT (2016). *Bottom-up pulses and desert rodent dynamics across shrubland-grassland ecotones*. American Society of Mammalogists annual meeting. Minneapolis, MN. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Browning, DM, Tweedie CE, Vivoni ER, Maynard JJ, and Karl J (2015). *Bridging multiple lines of evidence to quantify plant phenology and assess links to dryland ecosystem function*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Archer, SR (2015). *Brush management and ecosystem services*. ARS Southwest Watershed Research Center. Tucson, AZ. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Bestelmeyer, SB and Somerday R (2016). *Climate change and the water cycle: a free 6th-12th grade unit*. New Mexico Science Technology Engineering and Math (STEM) Symposium. Albuquerque, NM. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Peters DPC, Archer SR, Sala OE, Vivoni ER, Havstad KM, Monger C, Yao J, and Burruss N (2016). *Complex landscapes in the American Southwest: are desertified systems "novel"?*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Bestelmeyer, SB and Somerday R (2016). *Desert stories: integrating STEM and literacy in a 3rd grade program about the yucca and yucca moth*. New Mexico Science Technology Engineering and Math (STEM) Symposium. Albuquerque, NM. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Sala OE (2016). *Does an understanding of ecosystems responses to rainfall pulses improve predictions of responses of drylands to climate change?*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Vivoni ER, Pierini NA, Schreiner-McGraw AP, Anderson CA, Rivera G, Saripalli S, Mendez-Barroso LA, de la Llata E, Laliberte AS, and Rango A (2016). *Ecohydrology with unmanned aerial vehicles*. American Association for the Advancement of Science annual meeting. Washington, DC. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Gherardi LA, Sala OE, and Peters DPC (2016). *Effects of contrasting rooting distribution patterns on plant transpiration along a precipitation gradient*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Scott B, Sala OE, and Haussler JV (2016). *Enhanced minirhizotron image contrast from multispectral image analyses*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Peters, DPC, Yao J, Burruss N, Havstad KM, Sala OE, Derner JD, Hendrickson JR, Sanderson MA, Blair J, Collins SL, Gherardi L, Starks PJ, Steiner JL (2015). *Forecasting regional agroecosystem responses to drought and wet periods using long-term data from LTER and LTAR sites*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Herrick, JE (2016). *From wildlife biology to soil science, the USDA and the United Nations*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Archer, SR (2015). *Grassland-shrubland transitions: the rest of the story*. Soil Water & Environmental Sciences. University of Arizona, Tucson, AZ. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Pierce, N, Archer SR, and Bestelmeyer B (2016). *Grassland-to-shrubland state transitions in arid lands: competition matters*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Archer, SR (2016). *Grassland-woodland transitions: it's complicated*. Forestry Graduate Student Association. Northern Arizona University, Flagstaff, AZ. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Archer, SR (2015). *Imagining a new long-term ecological research site for arid lands*. 12th Annual Research Insights in Semiarid Ecosystems (RISE) Symposium. University of Arizona, Tucson, AZ. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Song, X, Xu X, and Tweedie CE (2015). *Impacts of precipitation diurnal timing on ecosystem carbon exchanges in grasslands: a synthesis of AmeriFlux data*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Tweedie, CE, Mazza Ramsay FD, and Samsel F (2015). *Intensifying the science, the senses, and the impact: a tale of collaboration between an academic research lab and two visual artists*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Yao, J, and Peters DPC (2016). *Interactions among climate and soil properties influence current and future geographic distribution of an invasive grass in the Chihuahuan desert*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Bestelmeyer, BT (2016). *Is desertification a dirty word?*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Havstad, K (2015). *LTAR linkages with other research networks: capitalizing on network interconnections*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Herrick, JE, Shawn WS, Bestelmeyer BT, Brown J, and Wills S (2016). *Landscape soil variability in relatively static and dynamic properties in arid and semi-arid ecosystems: Do they matter for restoration?*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Schreiner-McGraw, A, Vivoni ER, and Browning DM (2015). *Partitioning evapotranspiration to illustrate the effects of shrub competition and soil water on ecosystem state transitions*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Li, J, and Ravi S (2015). *Shifting from grassland to shrubland: new insights from recent experimental studies in the Chihuahuan Desert*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Pierce, N, Archer SR, and Bestelmeyer B (2015). *Shrub dynamics in pre- and post-encroachment phases of grassland-to-shrubland transition*. 12th Annual Research Insights in Semiarid Ecosystems (RISE) Symposium. University of Arizona, Tucson, AZ. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Archer, SR (2015). *Shrub encroachment and brush management: research priorities for competing land-use objectives*. Science in the Sonoita Plains symposium. Appleton-Whittell Research Ranch, Elgin, AZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Archer, SR (2015). *Shrub encroachment, brush management and competing land use objectives: tough choices*. Southwest Vegetation Management Association annual meeting. Sierra Vista, AZ. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Archer, SR (2016). *Shrubs in the anthropocene: a box of chocolates*. EJ Dyksterhuis Distinguished Lecture. Texas A&M University, College Station, TX. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Bestelmeyer, BT, Ash AJ, Brown J, Densambuu B, Fernandez-Gimenez ME, Johanson J, Levi MR, Lopez DR, Rumpff L, Peinetti HR, and Shaver PL (2016). *State and transition models for rangelands: where are we going from here?*. Society for

Range Management annual meeting. Corpus Christi, TX. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Archer, SR (2015). *Stewardship of wild drylands: land cover perspectives*. International symposium on “stewardship for future drylands”, Mexican Scientific Ecological Society and National Network on socioecosystems and sustainability. San Luis Potosi, Mexico. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Barnes, PW, Throop HL, and Archer SR (2016). *Sunlight and soil-litter mixing: drivers of dryland litter decomposition now and in the future*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Bestelmeyer, BT, Havstad KM, Sala OE, Sayre NF, and Webb N (2016). *Tipping points in rangeland social-ecological systems of the Southwest US: past and present*. Ecological Society of America annual meetings. Fort Lauderdale, FL. USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Vivoni ER (2016). *Using unmanned aerial vehicles for deriving landscape characteristics at high-resolution in numerical modeling applications*. Soil Science Society of America annual meeting. Phoenix, AZ. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Luna, NR, Browning DM, and Tweedie CE (2015). *Variability and controls of plant phenology in drylands: a novel case study from the northern Chihuahuan Desert*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Webb, N, Herrick JE, Clingan S, Cooper B, Courtright E, LaPlante V, and Van Zee J (2015). *Winderosionnetwork.org - portal to the national wind erosion research network*. American Geophysical Union fall meeting. San Francisco, CA, USA. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

**Other Products**

**Other Publications**

Webb, NP, Herrick JE, Van Zee JW, Hugenholtz CH, Zobeck TM, and Okin GS (2015). *Standard methods for wind erosion research and model development: protocol for the national wind erosion research network*.  USDA-ARS Jornada Experimental Range. Las Cruces, NM, USA. ISBN 978-0-9755552-4-8. 74 pp.. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

Herrick JE, Arnalds O, Bestelmeyer B, Bringezu S, Han G, Johnson MV, Kimiti D, Lu Y, Montanarella L, Pengue W, Toth G, Tukahirwa J, Velayutham M, and Zhang L (2016). *Unlocking the sustainable potential of land resources: evaluation systems, strategies and tools. A report of the working group on land and soils of the international resource panel.*.  UNEP. 89 pp. Status = PUBLISHED;  Acknowledgement of Federal Support = Yes

**Patents**

**Technologies or Techniques**

**Thesis/Dissertations**

Smith, JG.. *An exploration of the influence of animals on soil organic carbon dynamics in dryland ecosystems*. (2014).  New Mexico State University. Acknowledgement of Federal Support = Yes

McKenna, OP. *Desert playa wetlands: Ecological controls of their functioning and responses to climate change*. (2016). Arizona State University. Acknowledgement of Federal Support = Yes

Jaimes, AH. *Furthering our understanding and scaling patterns and controls of land-atmosphere carbon, water and energy exchange in a Chihuahuan Desert shrubland with novel cyberinfrastructure*. (2014).  University of Texas at El Paso. Acknowledgement of Federal Support = Yes

Gherardi, LA. *The effects of interannual precipitation variability on the functioning of grasslands*. (2014).  Arizona State University. Acknowledgement of Federal Support = Yes

Davanon, KA.. *The effects of urbanization on mammalian predator-prey dynamics in Las Cruces, New Mexico*. (2015).  New Mexico State University. Acknowledgement of Federal Support = Yes

Laney, CM. *Toward a new data and information management solutions for data-intensive ecological research*. (2013). University of Texas at El Paso. Acknowledgement of Federal Support = Yes

| Name | Most Senior Project Role | Nearest Person Month Worked |
|---|---|---|

**Websites**

## Participants/Organizations

**Research Experience for Undergraduates (REU) funding**

Form of REU funding support: REU supplement

How many REU applications were received during this reporting period? 6

How many REU applicants were selected and agreed to participate during this reporting period? 4

REU Comments:

**What individuals have worked on the project?**

| Name | Most Senior Project Role | Nearest Person Month Worked |
|---|---|---|
| Peters, Debra | PD/PI | 1 |
| Bestelmeyer, Stephanie | Co PD/PI | 6 |
| Bestelmeyer, Brandon | Co PD/PI | 1 |
| Havstad, Kris | Co PD/PI | 1 |
| Monger, Hugh | Co PD/PI | 1 |
| Archer, Steve | Co-Investigator | 1 |
| Duniway, Michael | Co-Investigator | 1 |
| Herrick, Jeffrey | Co-Investigator | 1 |
| Okin, Gregory | Co-Investigator | 1 |
| Rango, Albert | Co-Investigator | 1 |
| Sala, Osvaldo | Co-Investigator | 1 |
| Sayre, Nathan | Co-Investigator | 1 |
| Schooley, Robert | Co-Investigator | 1 |
| Tweedie, Craig | Co-Investigator | 1 |
| Vivoni, Enrique | Co-Investigator | 1 |
| del Toro, Israel | Postdoctoral (scholar, fellow or other postdoctoral position) | 1 |
| Gherardi, Laureano | Postdoctoral (scholar, fellow or other postdoctoral position) | 3 |

| Name | Most Senior Project Role | Nearest Person Month Worked |
|---|---|---|
| Levi, Matthew | Postdoctoral (scholar, fellow or other postdoctoral position) | 6 |
| Ramirez, Geovany | Postdoctoral (scholar, fellow or other postdoctoral position) | 12 |
| Brown, Joel | Other Professional | 1 |
| Browning, Dawn | Other Professional | 1 |
| Buenemann, Michaela | Other Professional | 1 |
| Burruss, Nathan | Other Professional | 8 |
| Grace, Libby | Other Professional | 6 |
| Haan-Amato, Stephanie | Other Professional | 6 |
| Huang, Haitao | Other Professional | 6 |
| Pemberton, Ryan | Other Professional | 6 |
| Somerday, Marianne | Other Professional | 6 |
| Anderson, John | Technician | 12 |
| Chepsongol, Roxanne | Technician | 12 |
| Gamboa, Bernice | Technician | 1 |
| Gename, Kyle | Technician | 12 |
| Hall, Seth | Technician | 12 |
| Harrison, Charlene | Technician | 6 |
| Lenz, James | Technician | 3 |
| Ramirez, Gesuri | Technician | 3 |
| Ramsey, Kenneth | Technician | 12 |
| Schrader, Theodore | Technician | 3 |
| Yao, Jin | Staff Scientist (doctoral level) | 2 |
| Boydston, Aaron | Graduate Student (research assistant) | 3 |
| Haussler, Josh | Graduate Student (research assistant) | 3 |

| Name | Most Senior Project Role | Nearest Person Month Worked |
|---|---|---|
| Huang, Junxin | Graduate Student (research assistant) | 3 |
| McKenna, Owen | Graduate Student (research assistant) | 3 |
| Perez Ruiz, Eli | Graduate Student (research assistant) | 3 |
| Schreiner-McGraw, Adam | Graduate Student (research assistant) | 3 |
| Solgi, Mitra | Graduate Student (research assistant) | 12 |
| Zhang, Junzhe | Graduate Student (research assistant) | 3 |
| Cooley, Raymond | Research Experience for Undergraduates (REU) Participant | 3 |
| Hansen, Frederick | Research Experience for Undergraduates (REU) Participant | 3 |
| Schlichte, Julie | Research Experience for Undergraduates (REU) Participant | 3 |
| Stoner, Jake | Research Experience for Undergraduates (REU) Participant | 3 |
| Tajeda, Carlos | Research Experience for Undergraduates (REU) Participant | 3 |
| Wright, Nicholas | Research Experience for Undergraduates (REU) Participant | 3 |

**Full details of individuals who have worked on the project:**

**Debra P Peters**
**Email:** debra.peters@osec.usda.gov
**Most Senior Project Role:** PD/PI
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Lead PI responsible for vision and project direction, reporting to NSF.

**Funding Support:** This project.

**International Collaboration:** No
**International Travel:** No

**Stephanie V Bestelmeyer**
**Email:** stephanie@asombro.org
**Most Senior Project Role:** Co PD/PI
**Nearest Person Month Worked:** 6

**Contribution to the Project:** Director of the Asombro Institute for Science Education, the Jornada LTER schoolyard LTER program

**Funding Support:** This project

**International Collaboration:** No
**International Travel:** No

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**Brandon T. Bestelmeyer**
**Email:** brandon.bestelmeyer@ars.usda.gov
**Most Senior Project Role:** Co PD/PI
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Co-PI responsible for state-and-transition model development.

**Funding Support:** This project

**International Collaboration:** Yes, Mongolia
**International Travel:** No

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**Kris M Havstad**
**Email:** kris.havstad@ars.usda.gov
**Most Senior Project Role:** Co PD/PI
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Co-PI leading large animal studies on the Jornada LTER.

**Funding Support:** This project.

**International Collaboration:** No
**International Travel:** No

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**Hugh C Monger**
**Email:** curtis.monger@lin.usda.gov
**Most Senior Project Role:** Co PD/PI
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Co-PI leading geomorphology studies on the Jornada.

**Funding Support:** This project

**International Collaboration:** No
**International Travel:** No

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**Steve Archer**
**Email:** sarcher@ag.arizona.edu
**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Provides scientific expertise on grass-shrub interactions at individual plant scale with a focus on demography and physiology

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

**Michael C. Duniway**
**Email:** mduniway@usgs.gov
**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Provides scientific expertise on plant-soil water relationships at individual plant scale with links to hydrology at patch to landscape scales

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Jeffrey E. Herrick**
**Email:** jeff.herrick@ars.usda.gov
**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Provides scientific expertise on developing and using qualitative assessment and quantitative monitoring tools

**Funding Support:** this award

**International Collaboration:** Yes, Kenya
**International Travel:** No

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**Gregory S. Okin**
**Email:** okin@ucla.edu
**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** provides scientific expertise in dust and aeolian dynamics, both field studies and simulation modeling

**Funding Support:** this award

**International Collaboration:** Yes, Botswana
**International Travel:** No

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**Albert Rango**
**Email:** alrango@nmsu.edu
**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** provides scientific expertise on snowmelt modeling, and collecting long-term climatic data relative to the water cycle

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Osvaldo E. Sala**
**Email:** osvaldo.sala@asu.edu

**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** provides scientific expertise in biodiversity, sustainability, and biogeochemistry of grasslands and shrublands

**Funding Support:** this award

**International Collaboration:** Yes, Argentina
**International Travel:** No

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**Nathan F. Sayre**
**Email:** nsayre@berkeley.edu
**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** provides scientific expertise on traditional ecological knowledge in rangelands

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Robert L. Schooley**
**Email:** schooley@illinois.edu
**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Provides scientific expertise on small animal population dynamics and metapopulations

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Craig E. Tweedie**
**Email:** ctweedie@utep.edu
**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** provides scientific expertise on cyberinfrastructure (hardware, software) technologies for new uses in ecology

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Enrique R. Vivoni**
**Email:** vivoni@asu.edu
**Most Senior Project Role:** Co-Investigator
**Nearest Person Month Worked:** 1

**Contribution to the Project:** provides scientific expertise in ecohydrology and dynamics of watersheds

**Funding Support:** this award

**International Collaboration:** Yes, Mexico
**International Travel:** No

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**Israel del Toro**
**Email:** israedt@gmail.com
**Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position)
**Nearest Person Month Worked:** 1

**Contribution to the Project:** working with B. Bestelmeyer on nat dynamics

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Laureano Gherardi**
**Email:** lgherar1@asu.edu
**Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position)
**Nearest Person Month Worked:** 3

**Contribution to the Project:** working with Sala on experimental rainfall plots

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Matthew Levi**
**Email:** mrlevi21@nmsu.edu
**Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position)
**Nearest Person Month Worked:** 6

**Contribution to the Project:** postdoc working with B. Bestelmeyer to examine relationships between ownership variables and biophysical variables across the Chihuahuan Desert region.

**Funding Support:** this award and BLM

**International Collaboration:** No
**International Travel:** No

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**Geovany Ramirez**
**Email:** geoabi@gmail.com
**Most Senior Project Role:** Postdoctoral (scholar, fellow or other postdoctoral position)
**Nearest Person Month Worked:** 12

**Contribution to the Project:** working with Peters on KLAS project to use machine learning with long-term data

**Funding Support:** this award and EAGER funding

**International Collaboration:** No
**International Travel:** No

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**Joel R. Brown**
**Email:** joelbrow@nmsu.edu

**Most Senior Project Role:** Other Professional
**Nearest Person Month Worked:** 1

**Contribution to the Project:** provides expertise on soils and national soils databases; key collaborator with the NRCS

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Dawn Browning**
**Email:** dbrownin@nmsu.edu
**Most Senior Project Role:** Other Professional
**Nearest Person Month Worked:** 1

**Contribution to the Project:** provides expertise in remote sensing and plant phenology

**Funding Support:** this award and USDA

**International Collaboration:** No
**International Travel:** No

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**Michaela Buenemann**
**Email:** elabuen@nmsu.edu
**Most Senior Project Role:** Other Professional
**Nearest Person Month Worked:** 1

**Contribution to the Project:** Provides expertise in GIS and spatial analyses

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Nathan Dylan Burruss**
**Email:** dylanb@nmsu.edu
**Most Senior Project Role:** Other Professional
**Nearest Person Month Worked:** 8

**Contribution to the Project:** working with Peters on shrubland-shrubland transitions

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Libby Grace**
**Email:** libby@asombro.org
**Most Senior Project Role:** Other Professional
**Nearest Person Month Worked:** 6

**Contribution to the Project:** Science education specialist at Asombro

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Stephanie Haan-Amato**
**Email:** s.haan-amato@asombro.org
**Most Senior Project Role:** Other Professional
**Nearest Person Month Worked:** 6

**Contribution to the Project:** Science education specialist with Asombro Institute for Science Education

**Funding Support:** this award and Asombro

**International Collaboration:** No
**International Travel:** No

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**Haitao Huang**
**Email:** haitaohuang@hotmail.com
**Most Senior Project Role:** Other Professional
**Nearest Person Month Worked:** 6

**Contribution to the Project:** programming support on ecosystems models and data handling and manipulation

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Ryan Pemberton**
**Email:** ryan@asombro.org
**Most Senior Project Role:** Other Professional
**Nearest Person Month Worked:** 6

**Contribution to the Project:** Science education specialist at Asombro

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Marianne Somerday**
**Email:** rink@asombro.org
**Most Senior Project Role:** Other Professional
**Nearest Person Month Worked:** 6

**Contribution to the Project:** Asombro program coordinator

**Funding Support:** this award and Asombro

**International Collaboration:** No
**International Travel:** No

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**John Anderson**
**Email:** janderso@nmsu.edu
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 12

**Contribution to the Project:** LTER site manager responsible for data collection, QA/QC, interactions with scientists and visitors on data issues

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Roxanne Chepsongol**
**Email:** rofranke@nmsu.edu
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 12

**Contribution to the Project:** member of LTER field crew

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Bernice Gamboa**
**Email:** bgamboa@nmsu.edu
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 1

**Contribution to the Project:** provides office support

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Kyle Gename**
**Email:** kgename@nmsu.edu
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 12

**Contribution to the Project:** LTER field technician

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Seth Hall**
**Email:** sethahall08@gmail.com
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 12

**Contribution to the Project:** LTER field technician

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Charlene Harrison**
**Email:** charhrsn@nmsu.edu
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 6

**Contribution to the Project:** provides office support, budget and travel support

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**James Lenz**
**Email:** jlenz@nmsu.edu
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 3

**Contribution to the Project:** IT specialist with the Jornada

**Funding Support:** this award and USDA

**International Collaboration:** No
**International Travel:** No

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**Gesuri Ramirez**
**Email:** gesuri@gmail.com
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 3

**Contribution to the Project:** worked with Tweedie on eddy flux tower calibration and testing

**Funding Support:** this award and UTEP

**International Collaboration:** No
**International Travel:** No

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**Kenneth Ramsey**
**Email:** kramsey@nmsu.edu
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 12

**Contribution to the Project:** Information manager for the Jornada Basin LTER

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Theodore Scott Schrader**
**Email:** schrader@nmsu.edu
**Most Senior Project Role:** Technician
**Nearest Person Month Worked:** 3

**Contribution to the Project:** provides GIS and spatial analysis support

**Funding Support:** this award and USDA

**International Collaboration:** No
**International Travel:** No

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**Jin Yao**
**Email:** jyao@nmsu.edu
**Most Senior Project Role:** Staff Scientist (doctoral level)
**Nearest Person Month Worked:** 2

**Contribution to the Project:** provides statistical analyses and QA/QC, updating on long term datasets

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Aaron Boydston**
**Email:** aboydsto@asu.edu
**Most Senior Project Role:** Graduate Student (research assistant)
**Nearest Person Month Worked:** 3

**Contribution to the Project:** MS graduate student working with Sala on rainfall manipulation experiment

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Josh Haussler**
**Email:** jhaussle@asu.edu
**Most Senior Project Role:** Graduate Student (research assistant)
**Nearest Person Month Worked:** 3

**Contribution to the Project:** graduate student working with Osvaldo Sala on rainfall manipulation experiments

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Junxin Huang**
**Email:** hjunxin@nmsu.edu
**Most Senior Project Role:** Graduate Student (research assistant)
**Nearest Person Month Worked:** 3

**Contribution to the Project:** graduate student working with Peters on long term NP data analyses

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Owen McKenna**
**Email:** omckenna@luc.edu
**Most Senior Project Role:** Graduate Student (research assistant)
**Nearest Person Month Worked:** 3

**Contribution to the Project:** working with Sala on carbon and nitrogen cycling in playas

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Eli Perez Ruiz**
**Email:** eperezru@asu.edu
**Most Senior Project Role:** Graduate Student (research assistant)
**Nearest Person Month Worked:** 3

**Contribution to the Project:** graduate student working with Vivoni on ecohydrology studies

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Adam Schreiner-McGraw**
**Email:** apschrei@asu.edu
**Most Senior Project Role:** Graduate Student (research assistant)
**Nearest Person Month Worked:** 3

**Contribution to the Project:** working with Vivoni on hydrology studies

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Mitra Solgi**
**Email:** msolgi@nmsu.edu
**Most Senior Project Role:** Graduate Student (research assistant)
**Nearest Person Month Worked:** 12

**Contribution to the Project:** updating the Jornada LTER web site

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Junzhe Zhang**
**Email:** zhangjunzhe@ucla.edu
**Most Senior Project Role:** Graduate Student (research assistant)
**Nearest Person Month Worked:** 3

**Contribution to the Project:** graduate student working with Okin on wind erosion studies

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No

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**Raymond Cooley**
**Email:** rcooley@asu.edu
**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant
**Nearest Person Month Worked:** 3

**Contribution to the Project:** REU working with Osvaldo Sala on rainfall manipulation experiment

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No
**Year of schooling completed:** Sophomore
**Home Institution:** ASU
**Government fiscal year(s) was this REU participant supported:** 2016

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**Frederick Hansen**
**Email:** fredh@nmsu.edu
**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant
**Nearest Person Month Worked:** 3

**Contribution to the Project:** REU working with Nicole Petrasziak (NMSU) on soil crusts

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No
**Year of schooling completed:** Freshman
**Home Institution:** NMSU
**Government fiscal year(s) was this REU participant supported:** 2016

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**Julie Schlichte**
**Email:** julie.marie.schlichte@gmail.com
**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant
**Nearest Person Month Worked:** 3

**Contribution to the Project:** REU working on arthropod biodiversity with B. Bestelmeyer and I. del Toro

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No
**Year of schooling completed:** Junior
**Home Institution:** UTEP
**Government fiscal year(s) was this REU participant supported:** 2015

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**Jake Stoner**
**Email:** jakestoner21@gmail.com
**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant
**Nearest Person Month Worked:** 3

**Contribution to the Project:** REU student working with Sala on rainfall manipulation experiments

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No
**Year of schooling completed:** Junior

**Home Institution:** Arizona State University
**Government fiscal year(s) was this REU participant supported:** 2015

**Carlos Tajeda**
**Email:** chtejada@nmsu.edu
**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant
**Nearest Person Month Worked:** 3

**Contribution to the Project:** REU working with Peters to animate long term Jornada landscape dynamics

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No
**Year of schooling completed:** Junior
**Home Institution:** NMSU
**Government fiscal year(s) was this REU participant supported:** 2016

**Nicholas Wright**
**Email:** nickswright98@gmail.com
**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant
**Nearest Person Month Worked:** 3

**Contribution to the Project:** REU working with Peters and Anderson on long term data analyses

**Funding Support:** this award

**International Collaboration:** No
**International Travel:** No
**Year of schooling completed:** Freshman
**Home Institution:** Vassar
**Government fiscal year(s) was this REU participant supported:** 2016

**What other organizations have been involved as partners?**

| Name | Type of Partner Organization | Location |
|---|---|---|
| Arizona State University | Academic Institution | Tempe, AZ |
| Asombro Institute for Science Education | Other Nonprofits | Las Cruces, NM |
| University of California-Los Angeles | Academic Institution | Los Angeles |
| University of Illinois | Academic Institution | Urbana-Champaign |
| University of Texas-El Paso | Academic Institution | El Paso, TX |
| Bureau of Land Management | Other Organizations (foreign or domestic) | Las Cruces, NM |
| Center for Applied Remote Sensing in Agriculture, Meteorolog | Academic Institution | Las Cruces, NM |

| Name | Type of Partner Organization | Location |
|---|---|---|
| Institute for Natural Resource Analysis and Management | Academic Institution | Las Cruces, NM |
| US Geological Survey | Other Organizations (foreign or domestic) | Moab, UT |
| USDA ARS, Jornada Experimental Range | Other Organizations (foreign or domestic) | Las Cruces, NM |
| USDA NRCS | Other Organizations (foreign or domestic) | Las Cruces, NM |
| University of Arizona | Academic Institution | Tucson, AZ |
| University of California-Berkeley | Academic Institution | Berkeley, CA |

**Full details of organizations that have been involved as partners:**

**Arizona State University**

**Organization Type:** Academic Institution
**Organization Location:** Tempe, AZ

**Partner's Contribution to the Project:**
Financial support
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** ASU provides office and lab facilities for Sala and Vivoni and their students

**Asombro Institute for Science Education**

**Organization Type:** Other Nonprofits
**Organization Location:** Las Cruces, NM

**Partner's Contribution to the Project:**
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** Asombro operates the Jornada Basin schoolyard LTER program

**Bureau of Land Management**

**Organization Type:** Other Organizations (foreign or domestic)
**Organization Location:** Las Cruces, NM

**Partner's Contribution to the Project:**
In-Kind Support
Facilities
Collaborative Research

**More Detail on Partner and Contribution:** BLM provides legacy data and photos of range sites near the Jornada

**Center for Applied Remote Sensing in Agriculture, Meteorolog**

**Organization Type:** Academic Institution
**Organization Location:** Las Cruces, NM

**Partner's Contribution to the Project:**
In-Kind Support
Facilities
Collaborative Research

**More Detail on Partner and Contribution:** CARSAME provides imagery and analyses for remotely sensing applications

**Institute for Natural Resource Analysis and Management**

**Organization Type:** Academic Institution
**Organization Location:** Las Cruces, NM

**Partner's Contribution to the Project:**
Facilities

**More Detail on Partner and Contribution:** INRAM provides equipment and supplies for soil analyses

**US Geological Survey**

**Organization Type:** Other Organizations (foreign or domestic)
**Organization Location:** Moab, UT

**Partner's Contribution to the Project:**
Financial support
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** USGS provides salary, office, and lab support for Duniway

**USDA ARS, Jornada Experimental Range**

**Organization Type:** Other Organizations (foreign or domestic)
**Organization Location:** Las Cruces, NM

**Partner's Contribution to the Project:**
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** Jornada Basin LTER office and numerous PIs' offices are housed in the USDA bldg. The Jornada land base is primary site for LTER research.

**USDA NRCS**

**Organization Type:** Other Organizations (foreign or domestic)
**Organization Location:** Las Cruces, NM

**Partner's Contribution to the Project:**
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** Supports collaborative research through Joel Brown, an NRCS employee

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**University of Arizona**

**Organization Type:** Academic Institution
**Organization Location:** Tucson, AZ

**Partner's Contribution to the Project:**
Financial support
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** UA provides office and lab support and salary for Archer and his students

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**University of California-Berkeley**

**Organization Type:** Academic Institution
**Organization Location:** Berkeley, CA

**Partner's Contribution to the Project:**
Financial support
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** UC-Berkeley provides office and lab support and salary for Sayre and his students

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**University of California-Los Angeles**

**Organization Type:** Academic Institution
**Organization Location:** Los Angeles

**Partner's Contribution to the Project:**
Financial support
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** UCLA provides office and lab support and salary for Okin and his students

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**University of Illinois**

**Organization Type:** Academic Institution
**Organization Location:** Urbana-Champaign

**Partner's Contribution to the Project:**
Financial support

In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** University of Illinois provides office and lab support and salary for Schooley and his students

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**University of Texas-El Paso**

**Organization Type:** Academic Institution
**Organization Location:** El Paso, TX

**Partner's Contribution to the Project:**
Financial support
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

**More Detail on Partner and Contribution:** UTEP provides office, lab, and salary support for Tweedie and his students

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### What other collaborators or contacts have been involved?

Nicole Pietrasiak (NMSU), Erik Lehnhoff (NMSU), Laura Boucheron (NMSU): collaborators

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## Impacts

### What is the impact on the development of the principal discipline(s) of the project?

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 can exacerbate patchiness in soil resources and provide a positive feedback to continued shrub dominance has stimulated research at the Jornada and other sites globally. More recently, our landscape linkages framework expands on the plantinterspace model to explicitly include a range of interacting spatial scales with a focus on transport processes that connect patches. This framework has been used to explain historic patterns that were unaccounted for by the single scale plantinterspace model of Schlesinger et al. (1990). The framework has also been applied to grass recovery in desertified shrublands following a 5year wet period, and to explain longterm grass dynamics and threshold behavior following drought. The application of this crossscale approach to broader scales has implications for continentalscale ecology and the development of environmental observatories and networks to address broadscale questions. The Jornada Program has also pioneered a new paradigm for ecosystem services. Previously, ecosystem services were studied from the ability of ecosystems to supply them. The new paradigm focuses on reconciling supply and demand of ecosystem services.

### What is the impact on other disciplines?

Jornada LTER research on state changes has promoted an understanding by soil scientists about the properties of soils, including soil moisture, temperature, and microbial dynamics, in aridlands that influence their resilience and resistance to future disturbance. LTER research has been particularly important in allowing geomorphologists, ecohydrologists, and soil scientists to explore the feedbacks between soil properties, terrain conditions, and vegetation cover across a range of temporal and spatial scales. Range managers are using LTER research findings to develop stateandtransition models for millions of acres of land in the western US and globally. The identification of early indicators of state changes for diverse terrestrial, aquatic, and marine ecosystems is being aided by Jornada longterm data and analyses. Jornada research is contributing to the development of Earth System Science and the understanding of phenomena that link ecosystems to global environmental change. Specific examples include interactions between desertification and the generation and export of dust to the atmosphere that feeds back to terrestrial ecosystem processes. Recent research on inorganic carbon at the Jornada is

increasing knowledge of terrestrial biomineralization and the carbon cycle at the global scale. Jornada research is actively supporting the development of remote sensing technology and analysis. Remote sensing in aridlands has traditionally been constrained by technical difficulties (i.e., predominance of the bare soil surface signal), but the vast expanses of relatively inaccessible arid lands with significant largescale variation is demanding better remote sensing technologies. Ground truth data and extensive processlevel studies available at the Jornada allow crossreferencing with imagery from aerial, including drones and UAVs, and satellite platforms. There are few such wellstudied locations in arid and semiarid regions of the world, and Jornada will continue to make important contributions to this field. The special issue in Frontiers in Ecology and Environment to be published in 2015 and led by the Jornada Program is an example of interdisciplinarity. For example, in this issue the Jornada Program describes a new framework for legacies that encompasses ideas from the geological sciences and plant physiology to the social sciences.

**What is the impact on the development of human resources?**

The Jornada program supports graduate and undergraduate students from numerous institutions and departments within those institutions, and attracts postdocs and visiting scientists from around the world. NMSU, UTEP, ASU, and UA are all minority, Hispanicserving institutions, and we routinely include minority and female students in our program. In addition, Jeff Herrick has been an active mentor of the ESA SEEDS program for many years. This program recruits and supports students from underrepresented minority groups in ecology.

**What is the impact on physical resources that form infrastructure?**

The Jornada Program has built a wellreplicated rainfall manipulation facility, which is unique in the world and has attracted numerous scientists who took advantage of the facility and launched additional experiments. For example, Diana Wall and Zack Sylvain from Colorado State University studied the effects of our rainfall manipulations on nematode populations. This research was recently published in Global Change Biology. The Jornada Program has been successful in receiving resources to build additional facilities that gather and make data available online at the research site. Consequently, the use of the site has increased, both locally and by visiting scientists and classes. Activities at the Jornada have been leveraged extensively in other research projects that have helped to build new infrastructure, including instrumentation networks and coordinated observation sites.

**What is the impact on institutional resources that form infrastructure?**

The Jornada as a large research program on the campus of NMSU is able to have input on future faculty hires and expansion in the areas of ecology and environmental science by the university.

**What is the impact on information resources that form infrastructure?**

The Jornada was the cofounder of the EcoTrends Project where the goal is to make longterm data and derived data products from many sites easily accessible and usable by others. The Jornada maintains and upgrades the EcoTrends web site, and has focused on making the longterm data easily used by high school students.

**What is the impact on technology transfer?**

The Jornada Program has developed the Automatic Rainfall Manipulation System (ARMS), which is a system that includes rainout shelters that intercept 50 or 80% of incoming PPT, store water temporarily in tanks connected to irrigation systems and transfer the water to the +50 or +80% of ambient PPT wateraddition treatments. The ARMS system has been patented by ASU. The Jornada established formal, individual state agreements with Cooperative Extension Services in New Mexico, Nevada, Utah, Arizona and Hawaii to specifically collaborate to deliver science based information to private land managers through Extensionled workshops across these 5 states. An agreement through the ARS based in Davis, California, and linked to the University of California system accomplishes a similar goal for people managing agricultural lands in California. The Jornada established a specific cooperative agreement with the Bureau of Land Management to transfer sciencebased assessment, monitoring and inventory methods for monitoring hundreds of millions of acres of arid and semiarid public rangelands across the western US, including Alaska.

**What is the impact on society beyond science and technology?**

LTER research findings have been used in the development of assessment and monitoring methods to evaluate the status of arid and semiarid land, and the ability of this land to provide food and fiber to humans. Much of the American West is composed of these lands, thus there is substantial debate about the appropriateness of particular land uses and their impacts

on ecosystem and economic sustainability. Our applications provide tools that are used by regulatory and land management agencies as well as by private land owners.

Human populations and land use patterns are changing rapidly. Jornada research provides a basic understanding of the limits to management of livestock in these systems. Moreover, Jornada research on changing land use patterns, biodiversity, air and water quality, climate change, and other aspects of humanenvironment interactions are being used in regional to global efforts to understand and manage for human activities in arid systems beyond livestock production.

Our highly successful schoolyard LTER program works to increase local K12 science literacy while also providing models of K12 science education that can be applied more broadly. We operate in a region of the US with a largely poor, minority population  Las Cruces public schools are 5080% Hispanic with 6090% of the students qualifying for free or reduced lunches. Thus, our program addresses scientific literacy at early stages for a diverse, underserved population. Our middle and high school Data Jam competition is now being replicated at several other sites, thus increasing K12 science literacy well beyond our region. These programs include both classroom and field investigations of basic ecological principles and the effects of past and present climate change.

Research approaches to characterize alternative states based on Jornada research have been applied throughout Mongolia and adopted by government ministries as a basis for interpreting land condition and recommending management strategies. In addition, these approaches are being applied in certain areas within Argentina.

Restoration actions carried out by the Bureau of Land Management in southwestern New Mexico now include experimental designs and monitoring procedures developed by the Jornada to test restoration effects and as a basis for adaptive management.

These types of tools are already widely applied by land managers and policymakers in the US. We have also obtained funding from USAID to develop a LandPotential Knowledge System (LandPKS), which will eventually allow these types of sitespecific assessments and predictions to be made globally. Finally, we are leading development of a United Nations report to increase awareness and understanding of including resilience in land potential assessments.

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## Changes/Problems

**Changes in approach and reason for change**
Nothing to report.

**Actual or Anticipated problems or delays and actions or plans to resolve them**
Nothing to report.

**Changes that have a significant impact on expenditures**
Nothing to report.

**Significant changes in use or care of human subjects**
Nothing to report.

**Significant changes in use or care of vertebrate animals**
Nothing to report.

**Significant changes in use or care of biohazards**
Nothing to report.