XIV. **Appendices**  Supplementary Materials Essential to the Project Plan

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XIV. Appendix 1a. State-and-Transition Models

A state-and-transition model for the Sandy eco-site in MLRA 42, SD-2 land resource unit in southwestern New Mexico is shown as an example. Reversible community phases within the historical grassland state include black grama (*Bouteloua eriopoda*) grassland and a patchy, mixed grassland with large interconnected bare areas. Alternative states include a threeawn-dropseed grassland and a snakeweed-mesquite shrubland. Transitions: T1a. Continued grazing crosses a threshold because black grama is lost and erosion ensues. T1b. Restoration with seedings and two consecutive summers of above-average rainfall. T2a. Continuous grazing, erosion, and high winter rain leads to mesquite proliferation and black grama extinction. T2b. Restoration with shrub control, plantings, summer rain, and fire management. T3. Mesquite grow and spread with above average winter rain years. T4. Inappropriate stocking during drought with soil disturbance leads to high soil erosion rates in shrub interspaces. Transient perennial grass cover in high rainfall years associated with coppices.

Selected papers


XIV. Appendix 1b. Sampling Locations to Test State-and-Transition Models

Sample locations against a map of ecological sites for development of the multiscale rangeland variance (MURV) database to test Hypothesis 1a. Different colors represent different foci for plots, including plots centered on BLM photopoints and randomly stratified MURV plots.
XIV. Appendix 2. Monitoring Manual and Qualitative Assessment

In 2005, the Jornada published the "Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems" (Havstad and Herrick 2003; Herrick et al. 2005). This manual standardized traditional methods, such as point intercept, and introduced new methods, such as the gap intercept, soil stability kit and impact penetrometer (Herrick et al. 2001; Herrick and Jones 2002; Okin et al. 2006), that were developed by the Jornada. It also includes statistically-based guidelines for monitoring program design. It has been widely adopted throughout the western United States, and draft translations into Spanish, Chinese and Mongolian have been independently completed. By working closely with USGS and NRCS collaborators, we were able to ensure that the methods are identical to those used in the NRCS National Resource Inventory (Spaeth et al. 2003; Spaeth et al. 2006) and the USGS post-fire monitoring protocol recently adopted by the BLM (Wirth and Pyke 2006).

The Jornada also co-led the development and publication of the internationally adopted "Interpreting Indicators of Rangeland Health" protocol (Pellant et al. 1999). The Jornada subsequently initiated the development of the ecological site reference sheets (Pyke et al. 2003), which significantly increased the consistency of application of the method. These, products together with increased links to quantitative methods developed by the Jornada (Herrick et al. 2005), are described in the second published edition of the technical reference (Version 4 – Pellant et al. 2005). This document has also been independently translated into Spanish, Chinese and Mongolian.
Key Publications


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### JORNEX Datasets – GROUND DATA

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<tr>
<th>Sensor/System</th>
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<td>May 11-13, 2000</td>
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<td>Oct. 17-18, 2006</td>
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### JORNEX Datasets - MICRO-METEOROLOGICAL DATA

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<td>1996 Day 001-365</td>
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<td></td>
<td>1997 Day 224-290</td>
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<td>2000 Day 149-</td>
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<td>TOWER DATA (30 m)</td>
<td>1996 Day 127-365</td>
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<td>EDDY COVARIANCE DATA</td>
<td>1995 Day 265-270</td>
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<td>1996 Day 121-126</td>
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<td>1996 Day 250-254</td>
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<td></td>
<td>Sept. 16-18,1998</td>
<td>2 systems</td>
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<td></td>
<td>Sept. 24–28,1999</td>
<td>6 systems</td>
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<tr>
<td></td>
<td>June 8–10, 2000</td>
<td>3 systems</td>
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<tr>
<td></td>
<td>May 2002 – June 2007 (Continuous operation except for maintenance periods)</td>
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### Appendix 3b. Military Satellite Data Acquired for the Jornada Basin

<table>
<thead>
<tr>
<th>Date</th>
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<th>Archive Source</th>
<th>Film Type</th>
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<td>Corona</td>
<td>USGS</td>
<td>B/W</td>
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<td>June, Aug, Oct 1965</td>
<td>Corona</td>
<td>USGS</td>
<td>B/W</td>
<td>2 m</td>
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<td>June, Aug, Sept 1966</td>
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<td>USGS</td>
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<td>Jan, Apr, June, Nov 1967</td>
<td>Corona</td>
<td>USGS</td>
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<td>Feb 1968</td>
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<td>USGS</td>
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<td>July 1972</td>
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<td>Aug 1976</td>
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<td>Nov 1983</td>
<td>DOD</td>
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### Appendix 3c. Aerial Photos Acquired for the Jornada Basin

<table>
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<th>Date</th>
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<th>Archive Source</th>
<th>Spectral Type</th>
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<td>CIR</td>
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<td>CIR</td>
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<td>ARS(Weslaco)</td>
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<td>CIR</td>
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</table>
Acronyms for Appendix 3b and 3c:
APFO = Aerial Photography Field Office (USDA)
ARS = Agricultural Research Service
ASCS = Agriculture and Stabilization and Conservation Service
ASP = Airborne Sensor Program
BLM = Bureau of Land Management
DIA = Defense Intelligence Agency
DOD = Department of Defense
EDAC = Earth Data Analysis Center
EPA = Environmental Protection Agency
JER = Jornada Experimental Range
NAPP = National Aerial Photography Program
NARA = National Archives and Records Administration
NASA = National Aeronautics and Space Administration
NHAP = National High Altitude Photography
SCS = Soil Conservation Service
USGS = US Geological Survey
WCFAPC = Whittier College Fairchild Aerial Photography Collection
WSMR = White Sands Missile Range
CIR = color infrared       B&W = black and white
Vegetation at the Jornada was dominated by perennial grasslands (black grama) in 1858. By 1915, most of the area was dominated by shrublands (mesquite in red, tarbush in tan), and by 1998, only 8% of the Jornada was grasslands. Current shrublands are mostly mesquite (red) and creosotebush (brown). Note that the NE Jornada has been dominated by the native shrub, mesquite, for hundreds of years. (Modified from Gibbens R.P., McNeely, R.P., Havstad, K.M., Beck, R.F. and Nolen, B. 2005. Vegetation changes in the Jornada Basin from 1858 to 1998. Journal of Arid Environments. 61:651-668.)
### XIV. Appendix 5. Table of Historical Remediation Studies at the Jornada Experimental Range

<table>
<thead>
<tr>
<th>Treatment Description</th>
<th>Livestock Excluded</th>
<th>Year(s)</th>
<th>Plant Community</th>
<th>Soil Location (Pasture #)</th>
<th>Results</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trenching</strong> to 26&quot; around dune interspaces + Cutting mesquite roots + Seeding grass, shrub and subshrub species</td>
<td>Yes, in 1934</td>
<td></td>
<td>Mesquite dune</td>
<td>Onite (coarse-loamy, mixed Typic Haplargid)</td>
<td>Only <em>Sporobolus</em> spp. and <em>Paspalum stramineum</em> emerged. None survived 5 years.</td>
<td>JER 1958; Valentine, 1942</td>
</tr>
<tr>
<td><strong>Trenching</strong> to 26&quot; around dune interspaces + Transplanting grasses and <em>Atriplex canescens</em></td>
<td>1934-</td>
<td></td>
<td>Mesquite dune</td>
<td>Onite (coarse-loamy, mixed Typic Haplargid)</td>
<td>Unsuccessful</td>
<td>JER 1958; Valentine, 1942</td>
</tr>
<tr>
<td>Mesquite brush piles to capture <em>Atriplex canescens</em> seeds and improve microsite conditions for establishment in interspaces</td>
<td>Yes, in 1934</td>
<td>n/a</td>
<td>Mesquite dune</td>
<td>Onite (coarse-loamy, mixed Typic Haplargid)</td>
<td>Successful (1939). Unsuccessful (1942).</td>
<td>JER 1958; Valentine, 1942; JER 1939</td>
</tr>
<tr>
<td>Rodent exclusion + Mesquite brush piles + Denude dune tops (to facilitate wind erosion) + Trenches between dunes (to catch topsoil and seed) + Diesel oil applied to mesquite</td>
<td>Yes, in 1934</td>
<td>1934 (rodent exclude - 1936)</td>
<td>Mesquite dune</td>
<td>Onite (coarse-loamy, mixed Typic Haplargid)</td>
<td>Unsuccessful</td>
<td>JER 1958; Valentine, 1942</td>
</tr>
<tr>
<td>Rabbit and rodent control attempted throughout 640-acre exclosure and 1 mile buffer strip with poisoned grain in Jan., Feb. and Nov., 1934 for rodents and poisoned salt blocks for rabbits</td>
<td>Yes, in 1934</td>
<td>1934</td>
<td>Mesquite dune</td>
<td>Onite (coarse-loamy, mixed Typic Haplargid)</td>
<td>Unsuccessful. No data on kill % encountered.</td>
<td>Valentine, 1942</td>
</tr>
<tr>
<td>Hand grubbing areas averaging 30 mesquite plants/acre</td>
<td>Yes</td>
<td>1948</td>
<td>Black grama/ mesquite</td>
<td>Artificial revegetation exclosures</td>
<td>13.3% reinvasion after 7 years</td>
<td>JER 1958</td>
</tr>
<tr>
<td>Hand grubbing areas averaging 805 mesquite plants/acre</td>
<td>Yes</td>
<td>1948</td>
<td>Mesquite/ bunchgrass</td>
<td>Artificial revegetation exclosures</td>
<td>64.5% reinvasion after 7 years</td>
<td>JER 1958</td>
</tr>
</tbody>
</table>

Source: Jornada Staff (JER)
### XIV. Appendix 5. Table of Historical Remediation Studies at the Jornada Experimental Range (continued)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Livestock Excluded</th>
<th>Year(s)</th>
<th>Plant Community</th>
<th>Soil</th>
<th>Location (Pasture #)</th>
<th>Results</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Livestock exclusion</strong></td>
<td>Yes, in 1934</td>
<td>1934</td>
<td>Mesquite/grassland transition</td>
<td>Onite (coarse-loamy, mixed Typic Haplorgid)</td>
<td>Mesquite Sandhills Natural Revegetation Exclosure (4)</td>
<td>By 1955, area occupied by mesquite increased 89% and area occupied by black grama decreased 91%. By 1980, there was a net loss of 4.6 cm of soil and the entire 640 acres was covered by mesquite dunes.</td>
<td>JER 1958; Valentine, 1942; Gibbens et al., 1983.</td>
</tr>
<tr>
<td><strong>Lagomorph exclusion + Shrub removal + Seeding + Furrowing in a factorial design</strong></td>
<td>Yes</td>
<td>1938</td>
<td>Creosote</td>
<td>Canutillo gravelly sandy loam (Dona Ana) Upton gravelly loam (Ragged and Parker tanks)</td>
<td>Dona Ana Exclosure (6) Gravelly Ridges Exclosure (20) Parker Tank (20)</td>
<td>1956: No effects of furrowing and seeding. Grass density increased in shrub removal plots and increased most in shrub removal + lagomorph exclusion plots. 1995: Increased shrub and grass cover in lagomorph exclusion plots. Increased black grama cover in shrub removal plots, but minimal no significant increase in total grass cover due to higher Muhlenbergia porteri in shrub-intact plots.</td>
<td>JER 1958; Korzdorfer, 1968; Gravelly Ridges only: Gibbens et al., 1993; Havstad et al., 1999</td>
</tr>
<tr>
<td>Railing</td>
<td>n/a</td>
<td>1952</td>
<td>Tarbush</td>
<td>n/a</td>
<td>n/a</td>
<td>Fair control in May.</td>
<td>JER 1958</td>
</tr>
<tr>
<td>Grubbing</td>
<td>n/a</td>
<td>1937</td>
<td>Tarbush</td>
<td>n/a</td>
<td>n/a</td>
<td>Substantial increase in forage yield by 1945.</td>
<td>JER 1958</td>
</tr>
<tr>
<td>Mowing</td>
<td>n/a</td>
<td>1939</td>
<td>Snakeweed</td>
<td>n/a</td>
<td>n/a</td>
<td>&quot;Gave some promise&quot;.</td>
<td>JER 1958</td>
</tr>
<tr>
<td><strong>Burning with a flame gun</strong></td>
<td>n/a</td>
<td>1939</td>
<td>Snakeweed</td>
<td>n/a</td>
<td>n/a</td>
<td>Effective except when dormant.</td>
<td>JER 1958</td>
</tr>
<tr>
<td>Grubbing</td>
<td>n/a</td>
<td>1939</td>
<td>Snakeweed</td>
<td>n/a</td>
<td>n/a</td>
<td>Effective at all times of year.</td>
<td>JER 1958</td>
</tr>
<tr>
<td>Grubbing</td>
<td>n/a</td>
<td>1934-35</td>
<td>Locoweed</td>
<td>n/a</td>
<td>n/a</td>
<td>Successful when repeated over several years</td>
<td>JER 1958</td>
</tr>
</tbody>
</table>
## XIV. Appendix 5. Table of Historical Remediation Studies at the Jornada Experimental Range (continued)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Livestock Excluded</th>
<th>Year(s)</th>
<th>Plant Community</th>
<th>Soil</th>
<th>Location (Pasture #)</th>
<th>Results</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contour terraces</strong> constructed with a road grader. Twenty-one terraces 8 feet wide x 16-20&quot; high leaving 6-8 foot wide shallow pit on upslope side. Spacing 100-300' with closer spacing at top of slope. Added rock &quot;weeps&quot; to allow water to percolate through after several years to minimize breaks. Some terraces seeded to &quot;various native and cultivated plants&quot;.</td>
<td>Yes (for at least 11 years)</td>
<td>1935</td>
<td>Black grama (upper slope), creosote (mid-slope) and Mormon tea/short-lived perennial grasses (footslope)</td>
<td>&quot;Compact gravelly clay loam underlaid by a heavier compact clay loam and in places caliche at 24-36 inches&quot;. Higher permeability higher on slope.</td>
<td>210 acres on north-facing slope of Dona Ana Mountains</td>
<td>&quot;Little improvement that can be attributed to the terraces has taken place over the area in general.&quot; Temporary snakeweed increase on upslope side of terraces. Black grama increased in the one inter-terrace quadrat in which it occurred, but was less vigorous than in other areas.* Good grass establishment behind some terraces seeded to semidesert-adapted grasses. *Based on six m² quadrats in bottoms of basins above terraces and five on intervening undisturbed areas between terraces.</td>
<td>Jornada Staff (JER) Valentine, 1947</td>
</tr>
<tr>
<td><strong>Brush water spreaders. Brush held down at 2 foot intervals by wire ties anchored by driving knotted ends 10-12&quot; into soil. Spreaders across slope, but trending downslope (1/2%). Water supplied from small dams across gullies. Seed scattered in brush of some seeders.</strong></td>
<td>Yes (for at least 11 years) in one pasture. Light stocking in other pasture.</td>
<td>1937</td>
<td>Variable. Black grama. Black grama/teobosa. Creosote. Sparse fluffgrass with annual grasses and forbs.</td>
<td>Variable. Sandy loam (6-10&quot;) over coarse sandy loam with one small area of compact clay loam.</td>
<td>N and E facing slopes 2-4% slope at foot of Dona Ana Mountains</td>
<td>&quot;In general it is impossible to identify any area either above or below the spreaders that have been benefited from them&quot;. Spreaders effective until dams broke after several years. Within 9 years, most water not diverted. Effective in creating microsites for seedling establishment. Noted patches of perennial grass establishment 8 years after construction. *Based on observations and five pairs of square meter quadrats located above and below spreader.</td>
<td>Valentine 1947</td>
</tr>
</tbody>
</table>
### XIV. Appendix 5. Table of Historical Remediation Studies at the Jornada Experimental Range (continued)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Livestock Excluded</th>
<th>Year(s)</th>
<th>Plant Community</th>
<th>Soil</th>
<th>Location (Pasture #)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contour channels.</strong> Flat-bottomed trench along contour 24-30” wide x 6” deep with soil formed into ridges on each side by a road ripper with a piece of steel fastened to teeth. Intervals of 25-75’ on 2-3% slope. 50-60 acres.</td>
<td>Yes</td>
<td>1939</td>
<td>Creosote, mesquite, snakeweed with scattered patches of bunchgrasse.</td>
<td>Loose sandy loam over caliche at 0-30” depth.</td>
<td>In Dona Ana exclosure near lagomorph exclusion study</td>
<td>“As a whole, the treated area is little if any different from the surrounding untreated area and it may be fairly concluded that the treatment has been ineffective in bringing about any improvement of the site.</td>
</tr>
<tr>
<td><strong>Brush dams</strong> placed across slope between mesquite dunes. 12-16” high, tied down with wire (see &quot;Brush water spreaders&quot;).</td>
<td>Light grazing.</td>
<td>1937</td>
<td>Mesquite dunes with four-wing saltbush.</td>
<td>Loose sandy loam over ‘compacte’ sandy loam, sometimes exposed at surface. Caliche at &gt;30”.</td>
<td></td>
<td>“… structures have brought about only the slightest improvement and this is restricted entirely to the areas immediately beneath the brush dams.”</td>
</tr>
<tr>
<td><strong>Intensive contour</strong> structures and rabbit exclusion. 6” deep furrows located 4-6’ apart, 8” deep furrows located 25-35’ apart, 8” deep ridge contour furrows located 30-45’ apart, 6” deep x 24-30” wide ripper furrows located 10-12’ apart.</td>
<td>n/a</td>
<td>1939</td>
<td>Creosote, yucca, snakeweed, mesquite, fluffgrass and Croton corymbolus</td>
<td>Coarse sandy loam over coarse sand at 24”</td>
<td>NE facing slope extending from foot of Dona Ana Mountains</td>
<td>No effect of contour structures on either perennial vegetation or soil moisture (measured to 24”), and no effect of rabbit exclusion.</td>
</tr>
<tr>
<td><strong>Crescent-shaped dams,</strong> contour furrows (at 10-20’ intervals), check dams in gullies using grain sacks filled with soil and, in some cases, manure. Check dams were also constructed.</td>
<td>Yes</td>
<td>August, 1937</td>
<td>Creosote</td>
<td>North side of Dona Ana exclosure around 1915 black grama clipping</td>
<td>Heavy rains in September, 1937 and summer, 1938 “greatly damaged furrows and check dams”, but by the end of 1938, grasses had increased to 30% of total cover.</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Jornada Staff (JER) Valentine, 1947*
### XIV. Appendix 5. Table of Historical Remediation Studies at the Jornada Experimental Range (continued)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Livestock Excluded</th>
<th>Year(s)</th>
<th>Plant Community</th>
<th>Soil</th>
<th>Location (Pasture #)</th>
<th>Results</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seeding</strong></td>
<td></td>
<td>1947-1949</td>
<td>Snakeweed and Creosote (2 sites)</td>
<td>“Good soil” and “Poor soil”, respectively</td>
<td>Various on CDRRC (College Ranch)</td>
<td>Poor to no establishment 1947, 1948 and 1949. In 1948, concluded that “success with about 50% of plantings is the best that can be expected”.</td>
<td>NM Ag Expt Station, 1948, 1949, 1950.</td>
</tr>
<tr>
<td>Rodent, rabbit and livestock exclosures (various combinations).</td>
<td>See treatments</td>
<td>1940</td>
<td>Mesquite- snakeweed</td>
<td></td>
<td></td>
<td>1948 yield of “desirable grasses” dramatically higher in rabbit and rodent excluded plots in mesquite-snakeweed. Variable results in other 2 plant communities.</td>
<td>NM Ag Expt Station, 1949.</td>
</tr>
<tr>
<td>Rodent, rabbit and livestock exclosures (various combinations).</td>
<td>See treatments</td>
<td>1940</td>
<td><em>Erioneuron pulchellum – Aristida spp.</em></td>
<td></td>
<td></td>
<td></td>
<td>NM Ag Expt Station, 1949.</td>
</tr>
<tr>
<td>Rodent, rabbit and livestock exclosures (various combinations).</td>
<td>See treatments</td>
<td>1940</td>
<td><em>Bouteloua eriopoda</em></td>
<td></td>
<td></td>
<td></td>
<td>NM Ag Expt Station, 1949.</td>
</tr>
</tbody>
</table>


Twenty-five compounds have been tested individually to date (Estell et al. 1998b; 2000; 2002; 2005b; 2007 in press; unpublished data)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Negatively Related to Intake</th>
<th>Compound</th>
<th>Negatively Related to Intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>α-pinene</td>
<td>Yes</td>
<td>Caryophyllene oxide</td>
<td>Yes</td>
</tr>
<tr>
<td>limonene</td>
<td>No</td>
<td>β-pinene</td>
<td>No</td>
</tr>
<tr>
<td>camphor</td>
<td>Yes</td>
<td>γ-terpinene</td>
<td>No</td>
</tr>
<tr>
<td>borneol</td>
<td>No</td>
<td>α-copaene</td>
<td>No</td>
</tr>
<tr>
<td>cis-jasmone</td>
<td>No</td>
<td>α-terpinene</td>
<td>No</td>
</tr>
<tr>
<td>β-caryophyllene</td>
<td>No</td>
<td>Eugenol</td>
<td>No</td>
</tr>
<tr>
<td>p-cymene</td>
<td>No</td>
<td>α-terpineol</td>
<td>No</td>
</tr>
<tr>
<td>α-humulene</td>
<td>No</td>
<td>Terpin-4-ol</td>
<td>No</td>
</tr>
<tr>
<td>1,8-cineole</td>
<td>No</td>
<td>Methyl eugenol</td>
<td>No</td>
</tr>
<tr>
<td>3-carene</td>
<td>No</td>
<td>Cis-β-ocimene</td>
<td>No</td>
</tr>
<tr>
<td>sabinene</td>
<td>No</td>
<td>Cis-sabinene hydrate</td>
<td>No</td>
</tr>
<tr>
<td>camphene</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>myrcene</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Key Findings

a. Individual tarbush plants are differentially used by ruminants.  
   Reference: Estell et al. 1994b

b. Epicuticular wax on the leaf surface differs in high- vs. low-use plants (8.2 vs. 10.3%).  
   Reference: Estell et al. 1994b

c. Concentration of most volatile compounds on the leaf surface is highly variable among plants.  
   Reference: Estell et al. 1994c

d. Removal of surface compounds with organic solvents increases tarbush consumption by sheep (8, 45 and 88% for control, acetone-and ethanol-rinsed treatments, respectively).  
   Reference: Estell et al. 1994a

e. Mono- and sesquiterpenes on the leaf surface are related to amount of tarbush use in field studies with multivariate analyses (Figure 6.1). The subset of α-pinene, sabinene, 3-carene, p-cymene, limonene, camphor, borneol, cis-jasmone, α-copaene, β-caryophyllene, α-humulene, ledene, caryophyllene oxide, and flourensadiol is able to distinguish between high- and low-use plants.  
   Reference: Estell et al. 1998a

f. Three extracts (hexanes, diethyl ether, and ethanol extracts) of tarbush reduced intake by more than 50%.  
   Reference: Estell et al. 2001

g. Pre-exposure to odor of camphor and α-pinene (chemicals that affected intake individually) had no effect on subsequent intake of alfalfa pellets by lambs.  
   Reference: Estell et al. 2005a
Figure 6.1. Relationship of volatile compounds on the leaf surface of tarbush to degree of use by livestock. Defoliation (nearest 5% use class) was recorded daily on 160 tarbush plants exposed to high density stocking of cattle, sheep, and goats on 8 paddocks (0.6 ha) for 6-9 days during two years. High, moderate, and low use were defined as 50% defoliation at period midpoint, <50% defoliation at midpoint and 50% defoliation at period end, and <50% defoliation at period end, respectively.

Relationship of Concentration of Volatile Compounds in Tarbush and Degree of Use by Livestock
Selected publications


XIV. Appendix 7. Directional Virtual Fencing Example

Directional Virtual Fencing (DVFTM) is an innovative, patented methodology that allows real-time management of animal control and distribution with the flexibility equaled only by herding. DVFTM uses animal behavior and electro-mechanically produced cues to control an animal’s location and subsequently its movement across the landscape. DVFTM relies on a constellation of ca. 24 Global Positioning System (GPS) satellites that provide continuous information on an animal’s location on the landscape. Together with GPS, the solar powered animal-mounted device uses cues, activated by algorithms in the Central Processing Unit (CPU), to control animal behavior without conventional fencing. A Geographic Information System (GIS) allows pre-programmed longitude-latitude pairs to define a Virtual Center Line (VCLTM) located at the center of the Virtual Boundary (VBTM). A Virtual Paddock (VPTM) created from several VB’s™ can either hold animals stationary or move animal groups at variable rates across a landscape.

When an animal penetrates a VB™, the angle of the animal’s head with respect to the nearest VCL™ determines to which side of the animal the cues will be delivered, and hence the cues encourage movement away from the boundary (Fig. 7.1). Our preliminary research suggests that VPTMs™ can assume any size and shape, can be moved across the landscape, and that groups of cattle can be controlled by the instrumentation of only a few animals.

Fig. 7.1. Animal movement is controlled by solar-powered devices mounted on the animal’s head that provide sensory cues to move the animal away from a boundary defined by a GPS satellite and GPS Coordinator.
Key Publications:


XIV. Appendix 8. Movement of Individual Animals of Different Breeds of Cattle

Preliminary results from the Jornada show that a Criollo breed of beef cattle from the arid Chinipas region of the Sierra Tarahumara, in Chihuahua, Mexico uses heterogeneous landscapes more evenly than temperate breeds (Angus x Hereford) commonly used in the Southwestern US. In the map below, all cattle were released from the southern part of the 1174 ha pasture; their position was recorded at 1 minute intervals. The fixed kernel estimates of home range for 95% (blue) and 50% (red) probabilities are shown below for twelve Angus x Hereford and nine Criollo cattle. While distance traveled did not differ for Day 14, Criollo cattle traveled further on nine days of the 17 day study.

Key publications

XIV. Appendix 9. ECOTONE Simulation Model

ECOTONE was developed to simulate vegetation and water dynamics of grass- and shrub-dominated ecosystems and their transitions in arid rangelands (Peters 2002). Driving variables include climate, soil texture, and disturbance. The model simulates 10-20 groups of species chosen to represent the life history traits of species found in arid and semiarid rangelands. The model simulates recruitment, growth, and mortality of each plant on a small plot (0.1-4 m²) at variable time steps. Recruitment and growth respond to climate and other drivers seasonally through the year, although biomass is incremented annually. Soil water dynamics are simulated daily to allow seasonal variation in water availability to affect plant recruitment and growth. Recruitment and mortality have stochastic components, whereas growth is deterministic and based upon competition for soil water. Recruitment includes a number of processes, including dispersal, production, and storage of viable seeds and the germination and establishment of seedlings. Each process is species-specific and has a probability of occurring on each plot in each year. Mortality for each plant on a plot depends on longevity and slow growth constraints, as well as disturbances.

Competition for soil water is determined by the overlap in functional root distribution for each plant and the amount of water available to each plant in each depth for each time step. Both root biomass and plant available water are simulated dynamically. Plant available water by depth in the soil profile is simulated by incorporating a daily time step, multilayer model of soil water (Parton 1978; Sala et al. 1992) into ECOTONE to allow seasonal dynamics in soil water availability to affect and be affected by the vegetation. Daily information on soil water processes, including losses to interception, evaporation, and transpiration, as well as soil water content by depth are simulated to determine plant available water which then affects seed production, establishment, and growth on a daily or monthly basis. Information on litter due to plant mortality or turnover of aboveground biomass and aboveground and belowground production by depth are simulated to affect plant available water. Amount of water available to each plant is converted to root biomass based on species-specific, water-use efficiency parameters. Functional root biomass is calculated as a proportion of total simulated root biomass modified by species-specific responses to temperature. A unique feature of ECOTONE is the effect of vegetation on soil physical properties with feedbacks to plant growth and establishment. Above and belowground production modify soil organic matter through litter inputs with resulting effects on infiltration capacity and water-holding capacity of the soil that affect soil water availability to plants. Recent modifications include the addition of horizontal redistribution of water to allow runon and runoff to be simulated. The model needs fine-scale elevation data to redistribute water horizontally.

ECOTONE has been used to simulate grasslands and shrublands in central New Mexico both under current climatic conditions and directional changes in climate (Peters 2002). The model has also been used to simulate arid and semiarid grasslands from the shortgrass steppe in northern Colorado to the Chihuahuan Desert in southern New Mexico (Peters and Herrick 2002, Symstad et al. 2003) to simulate seed dispersal as a spatially explicit process (Rastetter et al., 2003), and simulate invasive weeds (Goslee et al. 2001).
Key Publications:


Literature Cited


ECOTONE simulation model

Among spatial unit processes

Animal processes
Plant processes
Soil processes
Drivers

Within spatial unit processes

Water runon-runoff
Animals

SEED DISPERSAL

SEED PRODUCTION

ESTABLISHMENT

GROWTH

MORTALITY

SOIL STRUCTURE

PLANT AVAILABLE WATER

DECOMP

Animals

climate

disturbance

i=species
j=depth

Wavail (I,j)
BNPP(I,j)
ANPP (I)
litter

Navail (I,j)
BNPP(I,j)
ANPP (I)
litter

WHC INF-C

SWC (j)
XIV. Appendix 10. Long-term Studies

XIV. Appendix 10a. Map of Long-Term Study Sites at the Jornada Experimental Range

Selected Long Term Research Sites on the Jornada

- Artificial Revegetation Exclosure
- Mesquite-Grama Ecotone Livestock Exclosure
- Multiple Stressor Exclosure Sites
- Natural Revegetation Exclosure
- Permanent Chart Quadrat Locations
- Prescribed Burn Study 1
- Shrub Removal / Lagomorph Exclusion Plots
- USDA Rain Gauge Network
- Pasture Fences
XIV. Appendix 10b. Descriptions of Long-Term Studies

i. Vegetation Dynamics

Temporal changes in plant communities reconstruction of previous vegetative communities on the Jornada from historic records beginning with land survey data from 1858. Vegetative community type and species composition was mapped for 1915/16 and 1928/29. In 1998, aerial photography and field data were combined to create a current vegetation map of species composition and dominant species.

Initiation Date: 1858


Spatial Extent: The plains portion of the JER mapped on all dates except 1933 when only the mountain pasture was mapped.

Sampling procedures: 1858 map constructed using field notes taken along section lines during 1858 land survey. In 1915-16, 1928-29, and 1933 the objective was to determine number of forage acres present and field sheets included percentage composition of weeds (forbs), grasses, and shrubs by species for each polygon on hand-drawn maps. In 1963, shrub density estimated along section lines and map hand-drawn. Utilizing 1996 aerial photos, major dominants (up to four) estimated for each vegetation type in 1998. All maps have been digitized and are in ARC/INFO format. Spatial data attributes include species composition and dominant species.

Current Uses: Digitized vegetation maps form part of ongoing efforts to create a spatially explicit landscape-scale geo-database of biotic and abiotic components of the Jornada basin ecosystem.

Publications:


Temporal Changes in Plant Communities on the Jornada Experimental Range

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare</td>
<td>60</td>
<td>61</td>
<td>67</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Aristida spp.</td>
<td>3,344</td>
<td>1,601</td>
<td>76</td>
<td>5.7</td>
<td>2.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Black grama</td>
<td>11,126</td>
<td>11,235</td>
<td>699</td>
<td>19.0</td>
<td>19.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Burrograss</td>
<td>4,706</td>
<td>4,598</td>
<td>1,778</td>
<td>8.0</td>
<td>7.8</td>
<td>3.0</td>
</tr>
<tr>
<td>Sporobolus spp.</td>
<td>68</td>
<td>946</td>
<td>1,224</td>
<td>5.1</td>
<td>1.6</td>
<td>2.1</td>
</tr>
<tr>
<td>Tobosa</td>
<td>2,415</td>
<td>2,421</td>
<td>844</td>
<td>4.0</td>
<td>4.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Other grasses</td>
<td>0</td>
<td>167</td>
<td>39</td>
<td>0.0</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Broom snakeweed</td>
<td>3,568</td>
<td>2,209</td>
<td>34</td>
<td>6.1</td>
<td>3.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Creosotebush</td>
<td>2,665</td>
<td>8,221</td>
<td>14,485</td>
<td>4.5</td>
<td>14.1</td>
<td>24.9</td>
</tr>
<tr>
<td>Mesquite</td>
<td>12,275</td>
<td>19,558</td>
<td>34,387</td>
<td>26.1</td>
<td>33.5</td>
<td>59.1</td>
</tr>
<tr>
<td>Mesquite Dunes (1998)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarbush</td>
<td>14,812</td>
<td>6,519</td>
<td>3,426</td>
<td>25.3</td>
<td>11.2</td>
<td>6.6</td>
</tr>
<tr>
<td>Other shrubs</td>
<td>621</td>
<td>772</td>
<td>739</td>
<td>1.1</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Total hectares</td>
<td>58,602</td>
<td>58,288</td>
<td>58,192</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Vegetation Type:
- Bare
- Aristida spp.
- Black grama
- Burrograss
- Sporobolus spp.
- Tobosa
- Other grasses
- Broom snakeweed
- Creosotebush
- Mesquite
- Mesquite Dunes (1998)
- Mesquite Sandhills (1998)
- Tarbush
- Other shrubs

Original work by L. C. Hurt, S. Coville, C. L. Forsling, and E. W. Hummel.
Digital map by R. Gibbens, R. McNeely, and B. Nolen.
ii. Permanent Chart Quadrat Data

More than 100 meter-square permanent quadrats located by ARS in major grassland types across the Jornada. Charted annually from 1915 to 1979 then in 1995, 2001, and 2006. Basal area of perennial grasses, canopy cover of shrubs, and location of other species (annual grasses, forbs, and other shrubs) were charted in the field. Charts were digitized and numerical data extracted from the digitized charts.

Initiation date: 1915

Frequency of Sampling: Annually for all quadrats 1915 to 1947; annually for a portion of the quadrats 1947 to 1979; from 1995 to current, sampling was every 5 years. All permanent quadrats were charted in 2001 and 2006.

Spatial extent: Over 100 quadrats were located across the Jornada to represent typical vegetation types. All quadrat locations have been GPS'd and exist in an ARC/INFO format.

Sampling procedures: From 1915 to 1925 quadrats were charted with a decimeter grid. After 1925 quadrats were charted with a pantograph.

Current uses: Investigation of the relationship between spatial and temporal variation in landscape, climate, and anthropogenic factors. Examination of the demographics of dominant grass species over time and the replacement of perennial grasses by shrub communities.

Publications:


iii. **Soil Movement and Vegetation Change**

Soil deposition and erosion, centimeters of soil, were monitored along permanent transects starting in the 1930's. Vegetation was mapped in the 1930's and again in the 1980's.

**Initiation Date:** 1935


**Spatial Extent:** Natural Revegetation Exclosure and Pasture 8B

**Sampling procedures:** At the Natural Revegetation Exclosure, a transect with a steel stake every 50 ft starts 200 ft north of north fence of the exclosure and extends 200 ft south of south fence along grid line 30 East. A total of 113 stakes with reference mark for measuring soil level. In Pasture 8B, a 1500-foot-transect runs roughly east to west across what was a mesquite grass ecotone in 1935. Thirty steel stakes with reference marks for soil level remain.

**Publications:**


iv. Shrub Removal/Lagomorph Exclusion Plots

Factorial design of lagomorph exclusion, shrub removal, furrowing, and grass seeding in large exclosure plots replicated at three sites representing different landform-vegetation complexes. Extensive sampling of vegetation and soils approximately every 10 years since the 30's, currently resampled every 5 years.

Initiation date: Study was initiated in the fall of 1938 and set up was completed in the summer of 1939. At the Parker Tank and Gravelly Ridges sites, pretreatment sampling was done in 1938. At the Dona Ana site, pretreatment sampling was done in 1939.


Spatial extent: The sites are located in three different soil-landscape position-vegetation complexes. The three site locations have been GPS’d and are in ARC/INFO format.

Sampling Procedures: Each site is comprised of 16 plots placed in 4 rows of 4. The plots are 21.3 x 21.3m with a 7.6m buffer zone between them. Each plot is divided into halves and on each half, fourteen 10.68m transects are randomly selected and sampled for shrub canopy cover and grass basal area.

Current uses: Investigating the influence of small native herbivores and shrub removal on the species composition of shrub-dominated desert plant communities.

Publications:


Figure 1. Plots viewed on October 7, 1948 using black and white photos from the Fairchild Aerial Photography Collection, Whittier College.

Figure 2. Plots viewed on June 22, 1991 using color photos from a BLM aerial photo flight mission.

Figure 3. Sample design at Gravelly Ridges plots.

C = shrubs removed at base
F = furrowed
R = rabbits excluded
S = seeded

v. **Perennial Grass Production and Cover - Pasture wide**
Basal area and aboveground biomass of perennial grasses sampled annually from plots located across multiple JER pastures.

vi. **Perennial Grass Production and Cover - Site specific**
Basal area and aboveground biomass of perennial grasses sampled annually until 1978; both forbs and grasses were sampled from 1978 to 1988.

Initiation Date: 1941 for pasture sampling and 1957 for site-specific sampling.

Frequency of Sampling: Sampled annually (fall) until 1974 for pasture sampling and annually (fall) until 1988 for site-specific sampling. The site-specific datasets are from two sites in Pasture 9, one site in Pasture 2S, one site in pasture11B east of main road, one site in Pasture 11A.

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west of main road. One each tobosa and burrograss type in NE exclosure (Pasture 12C) and one each tobosa and burrograss type in South Boundary exclosure (Pasture 6). In 1979, the tobosa and burrograss sites were moved outside of the exclosures to nearby areas dominated by tobosa and burrograss.

**Spatial Extent:** Pasture-wide transects (4 inch x 50 feet) were established at each location (not permanently marked) each year. Random locations placed on map to guide examiners. Originally confined to black grama type but eventually expanded to some tobosa and burrograss areas.

**Sampling Procedures:** Pasture-wide transects had vegetation basal intercept read under tape at one side of transect and perennial grass clipped from the 4 inch x 50 ft. area. The site-specific datasets are originally from Pasture 9, Pasture 2, and Pasture 11 where a 5.08 cm X 30.48 m transect was sampled every 0.16 km for 15 to 20 samples. From 1979 to 1988, five, 0.5 m² circular plots were clipped every 0.16 km for a total of 100 plots per site. Also, from 1979 to 1988, all species, not just perennial grasses, were clipped. From 1957 to 1978, tobosa and burrograss areas were sampled with 25, .305 X 1.463 m plots. From 1979 to 1988 these areas were sampled with 25, .305 x 1.524 m plots and all species were clipped.

**Publications:**


**vii. Vegetative Cover - Soil Type post-drought**

Annual basal area assessment of grasses and forbs and canopy cover of shrubs on over 1,000 transects located across the plains portion of the JER.

**viii. Exclosure Plots post-drought**

Annual vegetation cover and perennial grass aboveground biomass measured on four plots at two sites; factorial design of rodent, lagomorph and livestock exclusion.

**Initiation Date:** Both datasets were initiated in 1957 after a major drought in the Southwest.

**Frequency of Sampling:** Annual sampling until 1977.
Spatial Extent: Vegetative cover-soil type transects are located across the plains portion of the JER. Exclosure A is in Pasture 11B, 4km north of South Well and about 0.3km east of main road. Exclosure B is in pasture 8C, 1.6 km East of Co_op Well and 0.1km south of Co-op to HQ road.

Sampling Procedures: The vegetative cover-soil type dataset has line intercept of basal area of grasses and forbs and canopy cover of shrubs. For each tier of sections, a random starting location for a north-south line was selected near southern boundary of tier and a 100-ft-line sampled at 0.1 mile intervals until extensive mesquite dune type encountered. Soil type recorded (from map) at sampling points. The exclosure plots dataset has two exclosure sites. Each site had four 38.48 x 45.7m plots. One plot rodent, lagomorph and livestock exclusion; one plot lagomorph and livestock exclusion; one plot livestock exclusion; and one plot no exclusion. Each plot divided into 15 subplots 2.5m wide and 38.45m long. Vegetation cover estimated by sampling all vegetation basal cover and mesquite canopy cover on four, line-intercept transects in each subplot. Perennial grass production estimated by clipping three 5.08cm x 30.48m transects on every third subplot from 1959 to 1977.

Publications:


ix. Multiple Stressor Exclosure Sites

Datasets describing changes in plant and animal communities and soil properties in response to intensive seasonal cattle grazing. Factorial design with shrubs intact or removed and summer or winter livestock grazing. Small summer and winter rainout shelters in place in each plot for first 3 years of experiment. Small burned subplots within each main plot.

Initiation Date: 1995

Frequency of Sampling: Plots were fenced in 1993, shrub removal was completed in 1994, and grazing regimes began in 1995. Soil moisture was measured biweekly 1995 to 1996. Ant populations and canopy arthropods were measured annually (1993 to 1996). Vegetation sampling is ongoing (1993 to present). Soil C/N was measured once (1994 to1995). Small mammals were live-trapped and released from 1993 to 1995.

Spatial Resolution: Two sites with eighteen 0.5 hectare plots established in black grama-mesquite ecotone areas. Small (3m x 5m) rainout shelters were in place in each plot from 1994-1997.

Sampling Procedures: Ants were measured in pitfall traps. Soil moisture was taken with a dewpoint psychrometer in control plots in subplots (summer rainout shelters, winter rainout shelters, burned plots and controls). Canopy arthropods were sampled with sweep nets on three primary vegetation strata: mesquite, snakeweed and grasses. Vegetation basal area and canopy cover were measured with a line intercept method (five 70m lines per plot). Mesquite shrubs were mapped on X-Y coordinates. Soil depth to indurated calcium carbonate layer was measured by inserting steel rod into soil and mapped on X-Y coordinates. Annual plant frequencies were measured with quadrat frames. Soil surface roughness was measured with a large erosion bridge. Soil C/N was measured at 0-5cm in subplot treatments (summer & winter
rainout plots & burned plots, plus controls) using a combustion and infrared analysis method. Small mammals were live-trapped, marked and released to estimate population densities.

Current Uses: Research to identify key factors influencing vegetation dynamics of grassland/shrubland ecotones. Also used to extrapolate data from LTER long term NPP sites to other parts of the Jornada.

Publications:


x. Desert Soil Geomorphology Project (DSP)

Extensive and intensive soil taxonomy, morphology, and biogeochemical analyses of 92 pedons representative of arid and semiarid region soils. Originally funded by the Natural Resources Conservation Service. The DSP has been digitized and a series of ARC/INFO spatial databases were created, including argillic horizon, mollic epipedon, carbobate stage, and chronology 17,000 years ago.

Initiation date: 1959

Frequency of Sampling: Data originally collected from 1959 through 1971. Since 1999, the project is being augmented with additional soil geomorphology/classification work on the Jornada basin.

Spatial extent: Original project covered a 400-sq.-mi. area located south of and including the southern portion of the Jornada Experimental Range. The current project focuses on the Jornada basin.

Current uses: DSP measurements of soil organic and inorganic carbon (calcium carbonate) are being utilized in a project to map below ground carbon storage in rangelands of New Mexico. Another project examining changes in grass cover, grass patch structure, and shrub abundance following a severe drought (from 1959 to 2001) is comparing the original photographs taken at DSP pedons with recent photos and relating those changes to detailed soil and landscape measurements.

Publications:


xi. **Stocking Rate Records**
Monthly data of Animal Unit Months (AUMs) for cattle, horses, sheep, and goats summarized by pasture (specific pasture areas vary across time).

**Initiation Date:** 1915

**Frequency of Sampling:** Monthly records from 1915 to the present.

**Spatial Extent:** All pastures across the Jornada.

**Sampling procedures:** Animal unit months were kept for horses, cattle, sheep, and goats.

**Publications:**


xii. **Fire Studies**

**Fire, livestock grazing, and shrub removal** (burn study 1) A randomized, complete block, multifactorial experiment to examine cover and composition of nonwoody species in two sites after a growing season fire, livestock grazing, and shrub removal.

**Fire season and intensity effects on Prosopis glandulosa** (burn study 2) A completely randomized, multifactorial experiment to examine shrub stem density, stem length, and volume after dormant and growing season fires using natural, added, and no vegetation fuels.

**Fire and grazing effects on floral and faunal communities** (burn study 3) A randomized, complete block, multifactorial experiment to examine vegetation cover, composition, and native faunal demography after a growing season fire and grazing.

**Initiation date:** Burn study 1 was initiated in 1995. Burn studies 2 and 3 were initiated in 1999.

**Frequency of Sampling:** Burn study 1 has been sampled every 5 years; burn studies 2 and 3 were sampled in 1999 and 2000 and will now be sampled every 5 years.
**Spatial extent:** Five 8m-transects within each of eight 12 x 8m-plots located ≥10m apart in two sites (burn study 1); 240 shrubs in a 2ha-area (burn study 2); four 200 x 200m-plots located in each of 4 sites. In each plot, plant/animal responses were measured using (a) five 150m-transects, (b) five 0.81m² quadrats, (c) one 10 x 75m-belt-transect, and (d) ten 25m²-subplots (burn study 3).

**Sampling procedures:** Cover/composition of plant communities were determined along transects using a vertical point method every 10-cm (burn study 1). Shrubs were measured for height, diameter, stem length, and number (burn study 2). Cover, composition, and height of plant communities were measured in subplots and along transects using a vertical point transect method every 10cm. Faunal abundance was determined using transects also. In belt transects, *Prosopis glandulosa* shrubs were measured for height and diameter. In quadrats, aerial and basal cover and height of *Bouteloua eriopoda* were measured.

**Current uses:** Burn studies 1 and 3 will improve understanding of how fire affects biota and interacts with grazing and shrub encroachment. Burn study 2 will improve understanding how fire manipulations impact shrubs. All results will aid in desert grassland conservation.

**Publications:**


**xiii. JER Aerial Photo Database**

The Jornada Experimental Range is in the process of acquiring, digitizing, and archiving all past aerial photography taken over the Jornada basin starting in 1935. This aerial photography will be available in an interactive database accessible to Jornada investigators. The interactive system is currently being developed to allow a researcher to interrogate the air photo archive on the basis of geographic location or pasture, time, and resolution or scale and to view the photographic scene of interest. A digital product can be provided to an approved investigator for analysis upon request.

**Initiation Date:** 1935

**Frequency of Sampling:** Variable, at least once a decade, but not necessarily covering the entire Jornada basin.

**Spatial Resolution:** from 1m to 10m resolution.

**Current Uses:** Compilation of a record of past remediation activities in Jornada basin.
Publications:


xiv. **JORNEX: the JORNada EXperiment remote sensing campaign**

Remotely sensed data from aircraft and satellite platforms, including Landsat TM (satellite), Corona (satellite), AVIRIS (aircraft), and Laser Profiler (aircraft). Datasets on physical, vegetative, thermal and radiometric properties of three ecosystems–grass, grass-shrub transition, and shrub.

**Initiation Date:** September 1995

**Frequency of Sampling:** Twice a year, before and after rainy season, to coincide with Landsat and EOS overpasses and research aircraft flights.

**Spatial Resolution:** Depends on altitude of sensor so that resolution ranges from centimeters to hundreds of meters.

**Current Uses:** Evapotranspiration estimation, leaf area index measures, energy balance determination, roughness estimates, temperature and emissivity separation for arid regions.

**Publications:**


Experimental Range. 16th Biennial Workshop on Videography and Color Photography in Resource Assessment, pp. 485-495.

XIV. Appendix 11a. ITS Sequences from Micropropagated Chihuahuan Desert Plants and Associated Isolated and Uncultured Microorganisms.

Microbial endophytes detected microscopically in micropropagated plants from the Chihuahuan Desert are shown in Figure 11a. Attempts to isolate or identify these endophytes using molecular, PCR based methods have provided variable data which suggest the fungi represent several species (Lucero et al., 2006). A variety of universal and specific primers have amplified unique rDNA sequences from in-vitro propagated, asymptomatic *Bouteloua eriopoda* (black grama grass) and *Atriplex canescens* (fourwing saltbush) and from microorganisms isolated from these and other in-vitro cultures (Table 11a-1). In some cases, it has been remarkably unclear whether sequences obtained represent plant or endophyte DNA. For example, a BLASTn alignment (Altschul et al., 1997) of GenBank Accession DQ649075 (Table 11a-1), an ITS region amplified from micropropagated *B. eriopoda*, is more similar to *Moringa longituba*, a dicot plant, than to ITS regions from any grass species in GenBank (Benson et al., 1999). This sequence similarity suggests that either an rDNA polymorphism present in *B. eriopoda* is more similar to the rDNA gene of a very distantly related plant than it is to other *Bouteloua* rDNA alleles from this and other studies, or both plants (*M. longituba* and *B. eriopoda*) are colonized by genetically similar endophyte, and the *M. longituba* endophyte gene has been mistakenly
described as plant DNA. Similar errors have been made in characterization of spruce DNA (Camacho et al., 1997). Four other rDNA sequences obtained from the DNA of micropropagated B. eriopoda also align more closely with non-grass plant sequences than with any grass ITS sequence in GenBank (Table 11a-1). More data is needed to determine whether these sequences represent plant or endophyte genes.

In Atriplex, two bacterial isolates obtained from micropropagated fourwing saltbush and shadscale saltbush (Atriplex confertifolia), have been found (Table 11a-1). These bacteria contain ITS sequences\(^2\) that exhibit greater than 99.9% homology to Atriplex canescens sequences when analyzed with BLASTn (Altschul et al. 1997), and greater than 90% sequence homology to more than 100 GenBank sequences attributed to chenopod plants. It is possible that these isolates represent a bacterial taxa that is closely associated with chenopod plants, and that like the endophyte sequence mistaken for spruce DNA (Camacho et al. 1997), the sequences attributed to Atriplex species in GenBank actually represent endophyte DNA. The evidence that not one, but several endophyte species may colonize a single host plant, even in vitro, makes the majority of rDNA data reported for plants in GenBank suspect, and complicates efforts to identify individual, obligate endophytes based on rDNA sequence analysis (Camacho et al. 1997; Vandenkoornhuyse et al. 2002).

\(^2\) Isolate 1, 5’ to 3’ ITS gene sequence=
CGACTCAGCTATAGGGCGAATTGGGCCCTCTAGATGCATGCTCGAGCGGCCGGCCAGTGATGGATA
TCTGCGAGAATTGGCTTCCCTGCGTTATGATAGTCTTAACACTAGCGAGGCGCTGGACCTG
GGTCCGAGGCTTATTTGGCGCCCTAGGGCAGAACGATAGGCTCTGAGCGAGTGCTACCTG
CGATGGTGGGCTACTTACGTATTAGCTAGGTGACCTGCTTATTGATATGCTTAAACTCAGCGGGT
GGTTTGCAGAATTCGGTCTCCTCCGGTCTG

Isolate 2, 5’ to 3’ ITS gene sequence=
TCCTCGAGTATTAGTAGTGTATACACTCTAGCGAGGCGCTGGACCTG
GCCGCGGCTAGGGCGAAACAGTATAGGGCTCTAGGCTGAGCGAGTAGTACCTAGGGCGAGCTAC
GCTTTAGCCTAGGTAGGCTTTAGTATTTCCACAACTTACGCGGCGGCACTTGAACGGCAGGCCTC
ATTAAATAGGCATCAACGCAGGGTACCGTAGGGGAGGATGGCAGTCCTCGACCTCGACACG
GGGCCACTTACAGGAGGTAGGCTGAGGGGAGGATGGCAGTCCTGAGGCGCTTCTCGAGAGG
GACCAGAATTGAGGCTTCAGCCTCACGAGACCGAGGCGAGGTAGGCTGAGGGGAGGATGGCAGTC

\(\text{Version Date: 12/11/2007}\)
### Table 11a-1. DNA sequences obtained from micropropagated Chihuahuan Desert plant species or from microorganisms isolated from the micropropagated plants.

<table>
<thead>
<tr>
<th>Host Plant</th>
<th>DNA source</th>
<th>GenBank Accession Number</th>
<th>Sequence Description</th>
<th>Species with nearest BLASTn homology</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. canescens</td>
<td>Unidentified fungal isolate</td>
<td>awaiting sequencing</td>
<td>awaiting sequencing</td>
<td>Putative <em>Penicillium</em> (Ascomycete fungus)</td>
</tr>
<tr>
<td>A. canescens</td>
<td>Unidentified fungal isolate</td>
<td>awaiting sequencing</td>
<td>awaiting sequencing</td>
<td>Putative <em>Alternaria</em> (Ascomycete fungus)</td>
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<td>A. canescens</td>
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<td>ITS region</td>
<td><em>Penicilliumolsonii</em> AF484405 (in 2005)</td>
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</tr>
<tr>
<td>A. canescens</td>
<td>Unidentified bacterial isolate 1</td>
<td>Unsubmitted. Awaiting additional data</td>
<td>ITS region</td>
<td>AM420676.1 (Atriplex canescens—the host plant)</td>
</tr>
<tr>
<td>A. canescens</td>
<td>Unidentified bacterial isolate 2</td>
<td>Unsubmitted. Awaiting additional data</td>
<td>ITS region</td>
<td>AM420676.1 (Atriplex canescens—the host plant) <em>Oryza sativa</em> (rice) genome and <em>Puccinia coronata</em> (Basidiomycete fungus)</td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated <em>B. eriopoda</em></td>
<td>DQ058712 partial ITS region</td>
<td><em>Aspergillus ustus</em> (Ascomycete fungus)</td>
<td></td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated <em>B. eriopoda</em></td>
<td>DQ100460 ITS region</td>
<td><em>Aspergillus ustus</em> (Ascomycete fungus)</td>
<td></td>
</tr>
<tr>
<td>B. eriopoda</td>
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<td>DQ497244 ITS region</td>
<td>Bouteloua gracilis (expected hit)</td>
<td></td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>uncultured mycelia dissected from <em>B. eriopoda</em> root.</td>
<td>DQ497245 ITS region</td>
<td>Bouteloua gracilis (expected hit)</td>
<td></td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated <em>B. eriopoda</em></td>
<td>DQ520628 ITS region</td>
<td>Xenomeris raetica (Ascomycete fungus)</td>
<td></td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated <em>B. eriopoda</em></td>
<td>DQ645748 ITS region</td>
<td>Bouteloua gracilis (expected hit)</td>
<td></td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated <em>B. eriopoda</em></td>
<td>DQ645749 ITS region</td>
<td>Corydalis saxicola (dicot plant)</td>
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</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated <em>B. eriopoda</em></td>
<td>DQ645750 18S small subunit ribosomal RNA gene</td>
<td>Joinvillea ascendens (non-grass monocot)</td>
<td></td>
</tr>
<tr>
<td>Host Plant</td>
<td>DNA source</td>
<td>GenBank Accession Number</td>
<td>Sequence Description</td>
<td>Species with nearest BLASTn homology</td>
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<td>------------</td>
<td>------------</td>
<td>--------------------------</td>
<td>----------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated B. eriopoda</td>
<td>DQ645751</td>
<td>18S small subunit ribosomal RNA gene</td>
<td>Joinvillea ascendens (non-grass monocot)</td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>Engyodontium album isolated from B. eriopoda</td>
<td>DQ649066</td>
<td>ITS region</td>
<td>Engyodontium album (Ascomycete fungus)</td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>Aspergillus ustus isolated from micropropagated B. eriopoda</td>
<td>DQ649067</td>
<td>ITS region</td>
<td>Aspergillus ustus (Ascomycete fungus)</td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated B. eriopoda</td>
<td>DQ649068</td>
<td>ITS region</td>
<td>Eleusine jaegeri (grass)</td>
</tr>
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<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated B. eriopoda</td>
<td>DQ649069</td>
<td>ITS region</td>
<td>Calectasia cyanea (non-grass monocot)</td>
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<tr>
<td>B. eriopoda</td>
<td>Aspergillus ustus isolated from micropropagated B. eriopoda</td>
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<td>ITS region</td>
<td>Aspergillus ustus (Ascomycete fungus)</td>
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<td>DQ649071</td>
<td>ITS region</td>
<td>Aspergillus ustus (Ascomycete fungus)</td>
</tr>
<tr>
<td>B. eriopoda</td>
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<td>DQ649072</td>
<td>ITS region</td>
<td>Aspergillus ustus (Ascomycete fungus)</td>
</tr>
<tr>
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<td>Aspergillus ustus isolated from micropropagated B. eriopoda</td>
<td>DQ649073</td>
<td>ITS region</td>
<td>Aspergillus ustus (Ascomycete fungus)</td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated B. eriopoda</td>
<td>DQ649074</td>
<td>ITS region</td>
<td>Begonia alpina (dicot plant)</td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>regenerated shoots of micropropagated B. eriopoda</td>
<td>DQ649075</td>
<td>ITS region</td>
<td>Moringa longituba (dicot plant)</td>
</tr>
<tr>
<td>B. eriopoda</td>
<td>field collected, cleansed B. eriopoda</td>
<td>AY916752</td>
<td>25S ribosomal RNA gene</td>
<td>Marasmius oreades isolate AFTOL-ID 1525</td>
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<tr>
<td>B. eriopoda</td>
<td>Moniliophthora sp. isolated from micropropagated B. eriopoda</td>
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<td>18S small subunit ribosomal RNA gene</td>
<td>Moniliophthora roreri strain C21</td>
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<td>ITS region</td>
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<td>AY916756</td>
<td>elongation factor 1-alpha</td>
<td>Moniliophthora roreri strain C21</td>
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</tbody>
</table>
XIV. Appendix 11b. Transfer of Endophytes to Non-host Plants via Co-cultivation.

An effort to isolate obligate endophytes from their native hosts by co-cultivating the endophyte-laden host callus with germinating seedlings has provided a number of significant results that raise interesting questions. Co-cultivation experiments were initially carried out by exposing micropropagated *A. canescens* and *B. eriopoda* callus to aseptically germinated tomato seedlings. Three candidate sequences have been obtained from the tomato plants that appear to have originated in the host callus. Two of these are similar to rDNA ITS regions from fungi belonging to the genus *Mycosphaerella*\(^3\), a genus associated with salt marsh grasses and characterized as a saprophyte. The *Mycosphaerella*-like sequences have been amplified from tomato plants co-cultivated with *Bouteloua* and with *Atriplex*, but have not yet been amplified from the original callus. Failure to amplify the sequences from the host callus is thought to be due to the presence of competing sequences which are preferentially amplified by PCR (see Appendix 11c), and sequence specific primers are being designed and tested in the hopes of demonstrating that the sequence, absent from tomato plants that have not been co-cultivated, is present in both the host callus and the co-cultivated plants, thus providing proof that an uncultured endophyte transferred.

A second sequence, isolated from a DGGE band in profiles present in representatives *Atriplex* callus and co-cultivated tomato (Figure 11b-1) is identical to the sequence of the unidentified bacterial isolate 1 described in Table 11a-1 of Appendix 11a. These data support the hypothesis that co-cultivation has indeed resulted in endophyte transfer.

\(^3\) Partial SSU rDNA sequence obtained from tomato plants following co-cultivation with *Atriplex canescens* callus

```
GAATAGTAACGTTCGCTAGGTGACCTGCAGGAGGATCATTACAGGGCGGCTGCTGACGC
TCTGCTGTTGCCTCCCTCTCGGATTTGCGTCTCTGCGAAATGATAAGAGAAATGCTCCAGGGGC
CACCTCTCGCCACCAACACATAGTTTTATTACCTTTTCTTTGAGACTGCCTTTGCACAGATT
AACCCCTAACTAATTGCGATAACTAATGGGAATTGTAGAGACAAACTCAAACCGGACATCTTTAATT
CTCCGGTAAATCTATTTTCTTACGCTTATATCTATGGCGACCCCGAGGAGACATTTCATTATT
GCAATTCGTTGCTGTCTCTCTGCGATGCTAGCTTTCTTCTCTCTACATTTCCCGGCTCTCC
TTTACACGGGCTTGGGCTCCTATGACATTGTCCATCATATCATTACAAACGAAAGGACTCTGA
CAGATAGCAGCAACCCCATCTCTATTTCCCGGCGACATTAGCTCAGGAGA
```

Partial SSU rDNA sequence obtained from tomato plants following co-cultivation with *Bouteloua eriopoda* callus

```
GAAACGTAAACGTTCGCTAGGTGACCTGCAGGAGGATCATTACAGGGCGGCTGCTGACGC
TCTGCTGTTGCCTCCCTCTCGGATTTGCGTCTCTGCGAAATGATAAGAGAAATGCTCCAGGGGC
CACCTCTCGCCACCAACACATAGTTTTATTACCTTTTCTTTGAGACTGCCTTTGCACAGATT
AACCCCTAACTAATTGCGATAACTAATGGGAATTGTAGAGACAAACTCAAACCGGACATCTTTAATT
CTCCGGTAAATCTATTTTCTTACGCTTATATCTATGGCGACCCCGAGGAGACATTTCATTATT
GCAATTCGTTGCTGTCTCTCTGCGATGCTAGCTTTCTTCTCTCTACATTTCCCGGCTCTCC
TTTACACGGGCTTGGGCTCCTATGACATTGTCCATCATATCATTACAAACGAAAGGACTCTGA
CAGATAGCAGCAACCCCATCTCTATTTCCCGGCGACATTAGCTCAGGAGA
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Version Date: 12/11/2007 215 Peters 6235-11210-005-00D PostPlan
Figure 11b-1. The denaturing gradient electrophoresis (DGGE) gel images above illustrate separation of Internal Transcribed Spacer (ITS) regions of ribosomal DNA. Lane 1 is a reference marker. Samples separated in remaining lanes represent DNA amplified from new leaves of untreated tomato (lane 2), tomato co-cultured with Atriplex canescens callus (Lane 3), tomato co-cultured with Bouteloua eriopoda callus (lane 4), A. canescens callus (Lane 5) and B. eriopoda callus (lane 6). The same gel is shown on the left and the right image. The right image has utilized gel analysis software to highlight bands that are not clearly visible to the unaided eye.

Each band represents a unique ITS sequence present in the DNA extracts. However, several bands differ in sequence by only one or two base pairs, and likely represent unique alleles within a single species. Bands that appear in tomato profiles only following co-cultivation, such as the band circled in lane 3 (right image), are thought to represent endophytes if a band with a similar migration distance is found in the donor callus (circled in lane 5). Sequences produced from the circled bands produced identical sequences to those obtained from the uncultured bacterial isolate 1, described in Appendix 11a, Table 11a-1, suggesting that bacterium migrated to the tomato during callus co-cultivation.
An unanticipated result of the co-cultivation and putative endophyte transfer was a rapid increase in vigor of the putative recipient plant (Lucero et al., 2006; Lucero et al., in press). This phenomenon has now been reproduced with a number of callus and putative recipient plant species, and may provide a powerful new mechanism for increasing the success of revegetation efforts. The technique is expected to have applications in production agriculture as well (Barrow and Lucero, 2005). Figure 11b-2 illustrates species-specific differences in the late-season biomass of tomato plants which were aseptically co-cultivated with endophyte-laden callus for 5 days following germination.

The effects of co-cultivation and putative endophyte transfer appear to vary not only by callus (donor), but also by recipient genotype. Table 11b-1 summarizes responses of 14 recipient plant genotypes representing 8 botanical families to co-cultivation with one of four endophyte donor callus species. Although studies underway continue to seek evidence confirming endophyte transfer, the possibility that some of the observed differences are due to biochemical interactions between donor and recipient plant species have not been ruled out.

The potential to transfer unculturable endophytes, combined with the demonstrated ability of transferred endophytes to increase establishment potential of native grasses (Lucero et al., in press) offers a promising mechanism for studying plant-microbe interactions and for using endophytes to increase the success rate of revegetation efforts in arid lands.

![Figure 11b-2](image)

**Figure 11b-2.** A general linearized means distribution of tomato biomass following co-cultivation with endophytes from six Chihuahuan Desert plant species. Different letters indicate statistically different means ($f=23.83$, $p<=0.0001$). Endophytes present in the callus are believed to have transferred to the tomato seedlings, causing the differences in plant biomass.
Table 11b-1. Host diversity of putatively transferred endophytes. The plants above were either co-cultivated with endophyte-laden callus from the indicated host species or directly injected with endophytes isolated from the indicated plant species. *Brassica rapa* and *Nicotiana tabacum* were maintained in light-controlled growth chambers and chlorophyll content was measured. All other species, with the exception of watermelon\(^4\), were transferred to potting soil following one week of co-cultivation in vitro, then hardened and transferred to a greenhouse. After 6-8 weeks in the greenhouse, root and shoot length, fresh weight, dry weight, and crown diameter were measured. For each species, the most statistically significant variable measured is shown.

<table>
<thead>
<tr>
<th>Plant Common Name</th>
<th>Family</th>
<th>Genus</th>
<th>Species</th>
<th>Measured Variable</th>
<th>Endophyte Source*</th>
<th>Treated Value</th>
<th>Control</th>
<th>Trt/Cont</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato</td>
<td>Solanaceae</td>
<td><em>Lycopersicon</em></td>
<td><em>esculentum</em></td>
<td>Root Dry Wt.</td>
<td><em>Atriplex canescens</em></td>
<td>3.35</td>
<td>0.80</td>
<td>4.18</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Mexican Primrose</td>
<td>Onagraceae</td>
<td><em>Oenothera</em></td>
<td><em>berlandieri</em></td>
<td>Root Dry Wt.</td>
<td><em>Atriplex canescens</em></td>
<td>0.48</td>
<td>0.14</td>
<td>3.35</td>
<td>0.0162</td>
</tr>
<tr>
<td>Watermelon(^4)</td>
<td>Cucurbitaceae</td>
<td><em>Citrullus</em></td>
<td><em>lanatus</em></td>
<td>Root Dry Wt. Chlorophyll ug/ml extract</td>
<td><em>Atriplex canescens</em></td>
<td>0.12</td>
<td>0.08</td>
<td>1.42</td>
<td>0.0064</td>
</tr>
<tr>
<td>Brassica</td>
<td>Brassicaceae</td>
<td><em>Brassica</em></td>
<td><em>rapa</em></td>
<td>Root Dry Wt.</td>
<td><em>Atriplex canescens</em></td>
<td>930.21</td>
<td>688.91</td>
<td>1.35</td>
<td>0.0010</td>
</tr>
<tr>
<td>Cotton</td>
<td>Malvaceae</td>
<td><em>Gossypium</em></td>
<td><em>hirsutum</em></td>
<td>Root Dry Wt.</td>
<td><em>Atriplex canescens</em></td>
<td>4.00</td>
<td>4.11</td>
<td>0.97</td>
<td>0.5249</td>
</tr>
<tr>
<td>Strawberry</td>
<td>Rosaceae</td>
<td><em>Fragaria</em></td>
<td></td>
<td>Root Dry Wt.</td>
<td><em>Atriplex canescens</em></td>
<td>0.53</td>
<td>0.59</td>
<td>0.89</td>
<td>0.4044</td>
</tr>
<tr>
<td>Carrot</td>
<td>Apiaceae</td>
<td><em>Daucus</em></td>
<td><em>carota</em></td>
<td>Root Dry Wt.</td>
<td><em>Atriplex griffithsi</em></td>
<td>7.54</td>
<td>3.63</td>
<td>2.08</td>
<td>0.0460</td>
</tr>
<tr>
<td>Tobacco</td>
<td>Solanaceae</td>
<td><em>Nicotiana</em></td>
<td><em>Tabacum</em></td>
<td>Fresh weight</td>
<td><em>Atriplex griffithsi</em></td>
<td>2.68</td>
<td>1.55</td>
<td>1.73</td>
<td>0.0350</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Poaceae</td>
<td><em>Sorghum</em></td>
<td><em>bicolor</em></td>
<td>Root Length</td>
<td><em>Bouteloua eriopoda</em></td>
<td>6.00</td>
<td>2.70</td>
<td>2.22</td>
<td>0.0050</td>
</tr>
<tr>
<td>Eastern Gamagrass</td>
<td>Poaceae</td>
<td><em>Trypsacum</em></td>
<td><em>dactiloides</em></td>
<td>Root Length</td>
<td><em>Bouteloua eriopoda</em></td>
<td>7.46</td>
<td>3.50</td>
<td>2.13</td>
<td>0.0050</td>
</tr>
<tr>
<td>Tobacco</td>
<td>Solanaceae</td>
<td><em>Nicotiana</em></td>
<td><em>tabacum</em></td>
<td>Crown Diameter</td>
<td><em>Bouteloua eriopoda</em></td>
<td>10.47</td>
<td>5.82</td>
<td>1.80</td>
<td>0.0010</td>
</tr>
<tr>
<td>Sand dropseed</td>
<td>Poaceae</td>
<td><em>Sporobolus</em></td>
<td><em>cryptandrus</em></td>
<td>Crown Diameter</td>
<td><em>Sporobolus cryptandrus</em></td>
<td>2.01</td>
<td>1.57</td>
<td>1.28</td>
<td>0.0900</td>
</tr>
<tr>
<td>Sand dropseed</td>
<td>Poaceae</td>
<td><em>Sporobolus</em></td>
<td><em>cryptandrus</em></td>
<td>Crown Diameter</td>
<td><em>Sporobolus cryptandrus</em></td>
<td>1.58</td>
<td>1.57</td>
<td>1.01</td>
<td>0.0900</td>
</tr>
</tbody>
</table>

\(^4\) Watermelon seeds did not tolerate surface disinfestation. After several attempts to germinate seeds in-vitro in order to co-culture with callus from *Atriplex canescens*, seeds were germinated in potting soil in greenhouse flats. To avoid competition with soil and leaf surface microbes, endophytes were transferred by injecting a mixed fungal and bacterial culture isolated from *A. canescens* callus directly into the plant stems following emergence of true leaves. An *Aspergillus ustus* fungus and the unidentified bacterium 1 described in Table 11a-1 of Appendix 11a have since been purified from the mixed culture (unpublished data, M. Lucero).
Appendix 11c. Pros and Cons of Utilizing ribosomal RNA Genes (rDNA) as Targets for Detection and Characterization of Unidentified Obligate Endophytes.

DNA sequences representing ribosomal genes are commonly targeted for species identification. These genes are present, with slight variation, in all living cells. Therefore, they serve as nearly universal targets for molecular markers and species identifiers. A typical fungal ribosomal gene is shown in Figure 11c-1. Plant ribosomal genes are similar.

**PROS**

All species make ribosomes. Within a cell, ribosomes provide a key component of the central dogma by which genes are transcribed and translated into proteins. This function is so critical to cellular function, that all cellular organisms require functional ribosomes to exist. Therefore, the ribosomal RNA gene provides a universal target for molecular fingerprinting.

Availability of data for sequence comparisons. Hundreds to thousands of copies of this gene may exist in a single genome. The absolute abundance of rDNA within a cell provided an easy target for early efforts at molecular characterization, either through sequencing or fingerprint methods. Hence, even before amplification techniques like polymerase chain reaction (PCR) were widely practiced, fingerprinting and even sequencing of rDNA was feasible. This long history of utilizing rDNA for molecular fingerprinting and sequence-based phylogenetic techniques has provided a deep base of literature and electronic data against which novel sequences can be compared.

The number of polymorphisms (variations in DNA sequence) is considered proportional to evolutionary distance. While many polymorphisms can exist between alleles within a species, it is generally accepted that rDNA gene sequences from individuals within a taxa are more similar than rDNA sequences across taxa. Therefore, differences in fingerprints or sequences derived from rDNA are useful for preliminary species identification.

Both conserved and variable regions are easily amplified by Polymerase Chain Reaction (PCR). Regions within the rDNA gene vary in tendency to exhibit polymorphisms, or regions of variation. Highly variable internal transcribes spacer (ITS) regions are bordered by highly conserved large and small subunit ribosomal RNA genes (Figure 11c-2). Since the ITS region spans a distance that is easily amplified by PCR, it is common to amplify and sequence the ITS region for initial species classification. This is particularly true for eukaryotic cells, where variation in the more conserved 18S and 28S subunit regions may be insufficient to distinguish closely related individuals. Granted, any one gene sequence is rarely enough for thorough taxonomic classification. Phylogeneticists typically rely on combinations of coding and non-coding nuclear and organelle DNA sequences for complete characterization of novel taxa. Yet despite the growing use of alternate targets for phylogenetic analysis, rDNA sequence analysis continues to be valued for initial characterization and for estimates of population diversity. It is unlikely that any other as evidenced by the fact that nearly 900,000 unique rDNA sequences were deposited in GenBank as of June, 2007 (Benson et al. 1999).

**CONS**

Sample contamination. A set of “universal primers” described by White et al., nearly two decades ago permits PCR amplification of the ITS regions from previously uncharacterized species (White and Taylor, 1990). More taxa-specific primers have since been developed (Gardes and Burns 1993) (Haugland et al. 2004). Such primers are useful for targeting ITS regions from taxa whose rDNA sequences have not been previously characterized. However,
the vast majority of available primers were developed for targeting DNA isolated from organisms presumed to be pure. However, asymptomatic plants collected from field settings, often presumed “pure” by researchers, may contain remarkably complex endophyte communities (Vandenkoonhuyse et al. 2002; Lucero et al. 2006; Barrow et al. 2007). This presumption can result in false characterization of source organisms for gene sequences, since DNA isolated from plant tissues, particularly plants collected from field samples, typically represents both plant and endophyte DNA.

**PCR Bias.** When universal primers are used to target unknown species in mixed population, it is unlikely that all rDNA genes will be amplified at the same rate. Preferential binding of primers to sequences from one or more species within the mixture can quickly bias the amplification process, selecting these targets at the expense of others, and masking the true diversity of the population. Since PCR increases the copy number of amplified genes exponentially, unequal binding in early cycles of the reaction can significantly reduce the relative number of initial sequences represented in the final product (Figure 11c-2).

Like the green species, the gene of the brown species also complements the primers perfectly. However, this gene has an unusually long ITS2 region, which cannot be copied with the chosen PCR method. Only partial-length, single-stranded DNA products result. As a result, sequences from the brown species also remain undetected.

**Figure 11c-1.** A typical series of fungal ribosomal genes, consisting of multiple copies of the three subunits (18S, 5.8S, and 28S), separated by internal transcribed spacer (ITS) regions. Subunit genes are highly conserved, meaning few differences in either size or DNA sequence are found across taxa. This conserved nature enables universal primers described by White and Taylor, 1990 to bind to predicted sites even when the target species is unknown. However, the ITS regions vary considerably between individuals, and differences are typically proportional to evolutionary distance. This combination of conserved regions that permit binding of universal primers and variable regions to permit genotyping have made ribosomal genes valuable for genotyping.
Poorly-matched primers impede PCR, delay generation of new copies.

Well-matched primers result in rapid copy of the ITS.

Primer Binding Site

A very long ITS region will take longer to transcribe, and may fail to amplify when competing for primers with shorter sequences.

Figure 11c-2. Structural variation among ITS regions or primer binding sites results in preferential amplification of DNA (PCR bias). Here, a sample illustrated by full length ribosomal genes, begins with DNA from three species (blue, green, and brown) equally represented. The primer binding site of the blue species complements the universal primers perfectly and the distance between primers is short. The sequence is amplified copiously during PCR, and many copies exist in the final product. The green species has two mutated base pairs that do not complement the primer. The primer binds inefficiently, reducing the number of final products. The resulting green products are easily masked by more abundant copies of the blue species.
Selected JER Publications


Literature Cited


XIV. Appendix 12. SOILWAT Simulation Model

SOILWAT simulates the interception, evaporation, transpiration, and infiltration of water through the plant canopy and soil layers through time. SOILWAT is a “tipping bucket” model where movement of water between layers is simulated based upon inputs and outputs of water in adjacent layers. Input parameters include daily temperature and precipitation, and monthly wind speed, relative humidity, and cloud cover. Monthly estimates of aboveground biomass (live and standing dead) and litter are needed for interception, evaporation, and transpiration estimates. Site parameters of soil texture (% sand, silt, and clay), % rocks by volume, and root distributions are defined by depth, and used to determine evaporation, transpiration, and infiltration rates. Losses of water to deep drainage are possible, but occur infrequently in upland arid environments. SOILWAT has been modified from its original formulation (Parton 1978) to simulate arid land soils by adding the influence of rocks on soil volume (Peters 2002).

We have used SOILWAT to simulate the probability of seed germination and seedling establishment of *Bouteloua gracilis* (blue grama) and *B. eriopoda* (black grama) in central New Mexico and for a gradient of sites from northern Colorado to southern NM (Peters 2002). More recently, we used SOILWAT to simulate the effects of historic and current climate, soils, and vegetation on establishment of black grama at the Jornada (Peters et al. 2006). The effects of plant-soil feedbacks have also been simulated (Peters et al. 2007).

**Key Publications**


XIII. Appendix 13. Knowledge of toolbox

Decision tree for OHV impact assessment and monitoring

Processes simulated
Water movement
Soil layer
Input parameter

Italics: changed through time

By layer
soil texture
root biomass (%)
evaporation (%)

PET
Temperature
Litter

Precipitation

Aboveground biomass
Litter

Transpiration
Evaporation

Interception

Infiltration

Soil layer 1

Soil layer 2

Soil layer 3

Soil layer n
XIV. Appendix 13. IMMA Knowledge Toolbox

Draft prototype decision trees have been developed for OHV impact assessment and monitoring (a) and management (b). These decision trees, when used in conjunction with ecological site descriptions and state and transition models (Bestelmeyer et al. 2003; Bestelmeyer et al. 2004; Herrick et al. 2006), represent a concrete example of a component of a proposed ‘ecological knowledge system’ (Herrick and Sarukhan 2007). They are designed to help managers decide how to use assessment tools to decide when management actions are required and to identify where and what needs to be monitored.

Decision tree for OHV impact assessment and monitoring.

Figure C. Assessment component example.

- Management prevention response may be required.
Decision tree for OHV impact management and restoration.

Management component assumes that degradation has occurred (see Assessment component)

Key publications


XIV. Appendix 14. Letters of Collaboration

Dr. Catherine Aime, USDA-ARS, Systematic Botany and Mycology Laboratory
Dr. Steve Archer, University of Arizona
Dr. Dallas Bash, Dept. of Defense, US Army
Dr. Jayne Belnap, USGS, Utah
Director Max Bleiweiss, New Mexico State University
Dr. David Briske, Texas A&M University
President Li Changyou, Inner Mongolia Agricultural University
Dr. Vimal Chaitanya, New Mexico State University, Vice President for Research
Dr. Andres F. Cibils, New Mexico State University
Dr. Scott L. Collins, Sevilleta LTER Program, University of New Mexico
Dr. Justin Derner, USDA-ARS, High Plains Grassland Research Station
Dr. James Foster, NASA, Goddard Space Flight Center
Dr. Brad Geary, Brigham Young University
Dr. Philip Heilman, USDA-ARS, Southwest Watershed Research Center
Mr. Barry R. Lavine, Independent Consultant, Portland, Oregon
Director, Julie Maitland, New Mexico Department of Agriculture
Dr. Robert E. Marsh, AgriTech Electronics LC
Dr. Mitchel McClaran, University of Arizona, Santa Rita Experimental Range
Asst. District Manager Jim C. McCormick, USDI, Bureau of Land Management
Dr. H. Curtis Monger, New Mexico State University
Dr. Mary Nichols, USDA-ARS, Southwest Watershed Research Center
Dr. Gregory S. Okin, University of California, Los Angeles
Dr. Robert Paramenter, Valles Caldera National Preserve
Dr. Anthony Parsons, The University of Sheffield, UK
Dr. George L. Peacock, Jr., NRCS, Grazing Lands Team
Dr. Fred Pierson, USDA ARS, Boise, UT
Dr. William E. Puckett, NRCS, Deputy Chief
Dr. David A. Pyke, USDI, US Geological Survey
Dr. Hildy Reiser, NPS
Dr. Jeffrey Repp, NRCS West National Technology Support Center
Dr. Jerry C. Ritchie, USDA-ARS, Hydrology and Remote Sensing Laboratory
Dr. Jozo Rogosic, University of Zadar, Croatia
Dr. Daniela Rus, MIT
Dr. Nathan F. Sayre, University of California, Berkeley
Dr. Tom Schmugge, New Mexico State University
Dr. Pat L. Shaver, USDA-NRSC, West National Technology Support Center
Dr. Rhonda Skaggs, New Mexico State University
Dr. Michael L. Smith, The Scottish Agricultural College, Scotland, UK
Dr. Tony Svejcar, USDA ARS Burns, OR
Dr. Dave Swain, CSIRO, J.M. Rendel Laboratory Livestock Industries
Dr. Jim Swanson, Grazing Animal Project Southern England Coordinator
Dr. S. Tserendash, The J. Sambuu Research Institute of Animal Husbandry (RIAH)
Dr. William Wergin, Wergin Associates, Inc., Vice President
Dr. Steve Whisenant, Texas A&M University
Dr. John ‘Jack’ Wright, New Mexico State University
29 May 2007

USDA ARS, Jornada Experimental Range
PO Box 30003, MSC 3 JER, NMSU
Las Cruces, NM 88003

Re: Management Technologies for Arid Rangelands

To whom it may concern,

Thank you for the invitation to continue our collaboration with scientists in your unit. In the past I have assisted in identification and molecular characterization of endophytic fungi found associated with grasses at Jornada, especially *Bouteloua eriopoda* and *Atriplex canescens*. I look forward to continuing this collaboration.

Should any additional information be required, please do not hesitate to contact me.

Sincerely,

M. Catherine Aime, Ph.D.
Research Mycologist
tel. 301.504.5758
dist. 301.504.5810
cathie.aime@ars.usda.gov

Systematic Botany and Mycology Laboratory
Bldg. 011A, Rm. 304, BARC-West
10300 Baltimore Avenue
Beltsville, MD 20705-2350
An Equal Opportunity Employer
16 May 2007

Drs. Kris Havstad and Deb Peters
Jornada Experimental Range
Box 30003 MSC 3JER
Las Cruces, NM USA 88003-8003

Dear Drs. Havstad and Peters:

By way of this letter, I wish to express my interest in collaborating with UADA ARS scientists at the Jornada Experimental Range on the Management Technologies for Arid Rangelands Project. I am specifically interested in working on objectives related to (a) developing management and monitoring strategies/decision tools that conserve natural resources while maintaining economic objectives, (b) identifying factors that can be used to predict or minimize the risk of rangeland degradation; (c) understanding mechanisms of weed invasion; and (d) restoring degraded rangelands. I am also amenable to supporting activities of the unit as a whole, in areas where my expertise might be of use.

My interactions with the scientists at the Jornada Experimental Range and have been enriching and productive; and I look forward to continuing our collaboration.

Sincerely,

Steve Archer
Professor
Dear Dr. Peters,

I am writing to communicate support for continued collaboration between the Department of Defense and the USDA-ARS Jornada Experimental Range on the “Management Technologies for Arid Rangelands” project.

The research generated by our collaborative efforts during the past 10 years has dramatically improved our understanding of arid ecosystem responses to disturbance, and monitoring protocols developed by the Jornada are now being implemented on both Fort Bliss and Holloman Air Force Base. During the next 5 years, we are particularly interested in expanding collaborative research related to Objectives 1 and 2 of your research plan in order to enhance our development and implementation of monitoring and remediation programs.

Relative to Objective 1, we are interested in increasing our ability to integrate ground-based data with satellite and airborne imagery. The Jornada’s internationally-recognized expertise in assessment and monitoring technologies is essential to moving this work forward.

Relative to Objective 2, increased military training in the region requires ecologically-based remediation technologies, and more targeted application of these technologies based on an understanding of plant-soil-vegetation interactions. We began testing several technologies developed by the Jornada and are applying state and transition models to future planning. The work associated with Objective 3 is also relevant as much of our land is grazed by livestock and/or native and exotic ungulates.

Sincerely,

[Signature]

Dallas Bash
Resource Biologist/GIS/Remote Sensing Specialist
IMSW-BLIS-Z-DOE-C
Bldg 624
Fort Bliss, TX 79916
Phone: 915.568.3018
August 27, 2007

Kris M. Havstad, Ph.D.
Supervisory Rangeland Scientist
USDA – Agricultural Research Service
Jornada Experimental Range
PO Box 30003, MSC 3JER, NMSU
Las Cruces, NM 88001

Dear Dr. Havstad:

I am writing to confirm our continued commitment to collaboration on research of shared interest with the USDA-ARS, Jornada Experimental Range, in association with the “Technologies for Management of Arid Rangelands” project and enthusiastically support the five-year plan being submitted. We have been collaborating with the Jornada staff for many years, and our work has been significantly enhanced through cooperation on projects designed to identify key plant and soil processes, and environmental factors, including landscape position, land use history, and climate that influence the potential for remediation success. These efforts have been highly rewarding, both from a scientific viewpoint and in helping us assist land managers in their decisions.

The Jornada has been, and continues to be, a leader in understanding the ecosystem functioning of desert systems by providing an invaluable site for continued scientific investigations and by providing logical support for these efforts. We have long-term study plots located at the Jornada that we plan on monitoring with Jornada staff far into the future, and we are grateful for the assistance we have received in the establishment and maintenance of these plots.

In addition, the Jornada has been outstanding in translating scientific information into training for land managers, the public, and outdoor education groups. This is an essential step for any scientific endeavor, and we have all benefited greatly by these efforts.

We look forward to continuing our cooperative work in the deserts of the southwestern United States.

Sincerely,

Jayne Belnap, Ph. D.
Research Ecologist
May 17, 2007

Jornada Experimental Range
P.O. Box 30003
MSC 3JER, NMSU
Las Cruces, NM  88003-8003
Attn: Deb Peters, or Kris Havstad

To Whom It May Concern:

As Director of New Mexico State University’s Center for Applied Remote Sensing in Agriculture, Meteorology, and Environment (CARSAME), I would like to acknowledge past collaborations with the USDA ARS, Jornada Experimental Range under the project “Management Technologies for Arid Rangelands” and our desire to continue such support. Our ongoing collaborative efforts have included the remote sensing of snow covered areas for the purpose of forecasting runoff in the Rio Grande Basin, and co-development of aerial remote sensing capabilities to further the monitoring, assessment and understanding of rangeland conditions. We are also in the process of implementing a semi-distributed hydrology model that will allow better understanding of the distribution of the water in the Rio Grande Basin and serve as a decision support tool for regional stakeholders.

Future collaborations include development of a technique for remote sensing of soil moisture from elevated platforms that should greatly enhance our understanding of the distribution of water in the near surface of the earth and demonstrate an inexpensive tool for use by a wider audience.

We work together, through CARSAME, to further the use of earth observation data for the sustainable development of arid lands.

Sincerely,

[Signature]

Max P. Bleiweiss, Director
CARSAME

New Mexico State University is an equal opportunity/affirmative action employer and educator. NMSU and the U.S. Department of Agriculture cooperating.
Texas A&M University
College of Agriculture and Life Sciences
Department of Ecosystem Science and Management

4 June 2007

Dr. Kris Havstad
Supervisory Scientist
USDA-ARS
Jornada Experimental Range
Box 30003 MSC 3JER
Las Cruces NM 88003

Dear Dr. Havstad:

I am writing to express my interest in continuing collaborative activities with the USDA-ARS, Jornada Experimental Range on Management Technologies for Arid Rangelands Project over the period 2007-2012. Strong mutual interests among our respective programs in numerous areas of rangeland ecology and management will support viable and productive research linkages. I anticipate that our collaboration has the potential to address multiple objectives described in the ARS National Program in Rangelands, Pastures and Forages.

I have enjoyed and benefited from recent professional interactions and I look forward to future collaborations. Please contact me if additional information is required.

Sincerely,

David D. Briske
Professor

College Station, Texas 77843-2138  Tel 979-845-5033  Fax 979-845-6049
May 18, 2007

Drs. Kris Havstad and Deb Peters
United States Department of Agriculture
Agricultural Research Service
Jornada Experimental Range
Box 30003 MSC 3JER
Las Cruces, NM USA 88003-8003

Dear Drs. Havstad and Peters:

The purpose of this letter is to express my interest in continuing my collaboration with the United States Department of Agriculture (USDA), Agricultural Research Service (ARS) scientists at the Jornada Experimental Range on the Management Technologies for Arid Rangelands Project. I am specifically interested in working on objectives related to (a) developing management and monitoring strategies/decision tools that conserve natural resources while maintaining economic objectives, (b) identifying factors that can be used to predict or minimize the risk of rangeland degradation; and (c) restoring degraded rangelands. I am also amenable to supporting activities of the unit as a whole, in areas where of the faculty at the Inner Mongolia Agricultural University expertise might be of use.

Since 2005 my University has worked under a formal collaboration through a Specific Cooperative Agreement with the USDA, ARS research unit at the Jornada Experimental Range. This agreement has allowed us to establish scientific collaborations through in country site visits in China and the USA in 2005 and in 2007. We have ongoing collaborative programs and research activities planned for upcoming years, including a workshop in Inner Mongolia as part of the 2008 International Rangeland Congress in 2008. My interactions, and those of my faculty at this University, with the scientists at the Jornada Experimental Range have been enriching and productive; and I look forward to continuing our collaboration.

Sincerely,

Li Changyou

President. Professor
2007 年 5 月 18 日

Kris Havstad 和 Deb Peters 博士
美国农业部农业局 Jornada 草地研究所
Box 30003 MSC 3JER
Las Cruces, NM USA 88003-8003

亲爱的 Havstad 和 Peters 博士：
写这封信的目的是表达我对继续与美国农业部农业局 Jornada 草地研究所的科学家在干旱区草地管理技术项目进行合作的兴趣。我特别对以下几个方面的合作感兴趣：（1）在保持经济目标的同时发展保护自然资源的管理和监测对策或决策工具；（2）鉴定可用于预测或减少草地退化风险的因素；（3）恢复退化草地。我也愿意以整个单位支持这些活动，涉及这些活动的内蒙古农业大学所有教职员工都可以参与。

从 2005 年开始，我们大学通过签署正式合作协议，与美国农业部农业研究的研究单位 Jornada 草地研究所开展了研究工作。这个协议使得我们通过 2005 年和 2007 年在中国和美国野外实地考察建立了科学合作关系。我们有计划好的近年的合作研究项目和科研活动安排，包括作为 2008 年内蒙古举办的国际草原大会一部分的研讨会。我和内蒙古农业大学教授与 Jornada 草地研究所科学家的交流在不断加深和产出增加。我愿意继续合作。

李畅

校长、教授

[手写签名]
June 12, 2007

Dr. Debra Peters, Lead Scientist  
USDA-ARS  
Jornada Experimental Range  
Box 30003 MSC 3JER  
Las Cruces, NM 88003

Dear Dr. Peters:

I am pleased to write this letter of support for collaboration with the Jornada Experimental Range (JER) Project Area on Management Technologies for Arid Rangelands research. Over the past years, New Mexico State University’s research opportunities have been enhanced due to collaborative efforts with JER research ranging from long-term ecological research to development of techniques to monitor and assess arid and semiarid rangelands. In addition, these projects have enhanced our mentoring opportunities for undergraduate and graduate students. This close cooperation has existed since the establishment of JER in 1912. We envision strong collaboration continuing in the future. Current details concerning our collaborations are described in our existing Specific Cooperative Agreement.

New Mexico State University (NMSU) benefits from having the USDA JER located on our campus, which enhances cooperation between NMSU and JER researchers and students. Additionally, the vast JER facility north of Las Cruces has historically been a key location for cooperative research projects that bring together university and U.S. Government scientists. We look forward to our participation in the project on Management Technologies for Arid Rangelands and the exciting research opportunities created by it.

The Jornada Experimental Range has mounted a very productive research program, and NMSU is proud to be a part of this collaboration.

Sincerely,

Vimal Chaitanya, Ph.D.  
Vice President of Research,  
Graduate Studies and International Studies
May 15, 2007

Dr. Debra Peters  
Lead Scientist  
USDA ARS Jornada Experimental Range  
PO Box 30003, MSC 3JER  
Las Cruces, NM 88003-8003

Dear Deb,

I am pleased to write this letter in support of the outstanding work conducted by the USDA ARS Jornada Experimental Range in the project area of Management Technologies for Arid Rangelands.

Over the past four years I have been greatly enriched by the opportunity to collaborate with USDA ARS Jornada Experimental Range scientists on animal-plant interaction projects. I very much look forward to continue and expand these collaborative efforts over the next five years.

I also look forward to continuing collaboration with your research unit in the important teaching mission of the Range Science program at New Mexico State University. Collaboration received from Jornada Experimental Range scientists in undergraduate and graduate level classes has added and continues to add tremendous value to our teaching program.

Sincerely,

[Signature]

Andrés F. Cibils  
Assistant Professor of Rangeland Science  
Ph. 646-4342
12 May 2007

Dr. Kris Havstad
Dr. Deb Peters
Jornada Experimental Range
PO Box 30003  MSC 3JER
New Mexico State University
Las Cruces, NM 88003-8003

Dear Kris and Deb:

I am sending this letter on behalf of the Sevilleta LTER program at the University of New Mexico to express our enthusiastic desire to continue our productive collaboration with USDA scientists at the USDA ARS Jornada Experimental Range. This important collaboration extends back for more than a decade. Not only is there important on-going research between Sevilleta LTER scientists and the Management Technologies for Arid Rangelands group at the Jornada (Small Mammal Exclosure Study, JORNEX, long-term studies on patch structure and dynamics), but I anticipate even more collaboration and greater cross-site interactions will develop soon. Thus, we look forward to working with you in the future. If I can provide additional information, please do not hesitate to contact me.

Sincerely,

[Signature]

Scott L. Collins
Professor, Department of Biology
PI, Sevilleta LTER Program
May 24, 2007

Dr. Deb Peters
USDA-ARS
Lead Scientist
Jornada Experimental Range
Las Cruces, NM 88003

Dear Dr. Peters:

The Rangeland Resources Research Unit’s National Program 215 CRIS entitled “Semi-arid Rangeland Ecosystems: The Conservation-Production Interface” has scientific expertise in grazing management, rangeland ecology, landscape ecology, weed ecology and monitoring of rangeland health through aerial and ground photography. In addition, our research unit has extensive long-term data sets regarding vegetation, animal and soil responses to different grazing intensities in both shortgrass steppe and northern mixed-grass prairie rangeland ecosystems. We look forward to collaborating with your CRIS project to compare and contrast ecosystem responses to management strategies in semi-arid grasslands and desert ecosystems, as well as the development of monitoring tools for land managers.

We agree to commit the necessary time and resources needed to complete these collaborative projects. Any costs incurred during these collaborative efforts will be the responsibility of each participating Unit’s projects. As Lead Scientist on our CRIS project, I will manage the portion of these interesting and innovative collaborative projects that are associated with our CRIS project.

Sincerely,

Justin D. Dermer

Dr. Justin Dermer
USDA-ARS, NPA
High Plains Grasslands Research Station
8408 Hildreth Road
Cheyenne, WY 82009 USA
Phone: 307-772-2433 x.113
FAX: 307-637-6124
Justin.Dermer@ars.usda.gov
National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771
Reply to Attn of: Code 614.3

Jornada Experimental Range

P.O. Box 30003, MSC 3JER, NMSU

Las Cruces, NM 88003-8003

June 7, 2007

To whom it may concern,

I am writing this recommendation letter to strongly endorse Dr. Al Rango and his colleagues at the USDA, ARS, Jornada Experimental Range in Las Cruces, NM. The ARS research unit based at Jornada is staffed with scientists having world class expertise, thus possessing a deep understanding of the important issues in agricultural research associated with Management Technologies for Area Rangelands.

For example, personnel at Jornada have played a strong role in developing algorithms and models needed for interpreting and analyzing water resource data. My colleagues and I have worked with Dr. Rango to improve our understanding of the effects of snow crystals on the response of microwave radiation as detected from space-borne sensors. This has utility in improving our knowledge of energy/water fluxes at the land/atmosphere interface. Additionally, meaningful scientific discussions have continued to the present time, leading to our current interactions regarding common science issues, especially those related to remote sensing of snow and snow hydrology. Remote sensing observations of snow cover extent and snow water equivalent along with associated modeling, are crucial to better forecasting streamflow and thus better managing are precious and dwindling water resources. For the past six years, Dr. Rango has been instrumental in strengthening this remote sensing/modeling approach at Jornada.

My experience with the scientific staff at Jornada is that they are willing to share their critical insights while at the same time are receptive to inputs and new ideas on water resources related research problems. We look forward to continuing meaningful collaboration in the future.

Sincerely,

[Signature]

James Foster
Hydrological Sciences Branch / Code 614.3
Hydrospheric and Biospheric Sciences Laboratory
June 13, 2007

Bernice Gamboa  
Jornada Experimental Range  
Box 30003 MSC 3JER  
Las Cruces, New Mexico 88003

Dear Bernice Gamboa:

I am pleased to write this letter in support of the USDA ARS, Jornada Experimental Range in Las Cruces, New Mexico. The project that I am collaborating with is the, “Management Technologies for Arid Rangelands.” I and my research group at Brigham Young University in Provo, Utah have enjoyed excellent communication and collaboration on research projects and intend to keep these collaborative efforts intact for many years. If there are any questions or concerns I would be happy to visit with you personally, my contact information is listed below.

Sincerely,

Brad Geary, Ph.D.  
Assistant Professor of Plant & Animal Sciences  
Brigham Young University  
brad_geary@byu.edu  
801-422-2369
June 19, 2007

Drs. Jeff Herrick and Al Rango
USDA-ARS
Jornada Experimental Range
Las Cruces, NM 88003

Drs. Herrick and Rango:

The purpose of this letter is to express my willingness to collaborate on your project Management Technologies for Arid Rangelands. Over the last few years we have had numerous occasions to build an understanding about issues of common interest. I am confident that we can build on that experience over the coming years. The SWRC can contribute understanding of erosion and hydrologic processes on arid watersheds from our experience at the Walnut Gulch Experimental Watershed and across the transition area between the Sonoran and Chihuahuan deserts in Arizona.

Specifically, within your goal of developing "an integrative assessment and monitoring approach for vegetation structure and composition, soil stability, watershed function, and biotic integrity of spatially and temporally heterogeneous rangelands at landscape, watershed, and regional scales," I look forward to collaborating on your objective to develop conceptual models to describe the states and transitions of rangelands in response to variation in climate and soils. I also expect to contribute to the Jornex Experiment and other work at the Jornada linking remote sensing for rangeland health and mapping ecological sites and states.

Lastly, I am an advisor to the ARS equivalent organization in Mexico, INIFAP. As part of a national watershed project, there is a need to strengthen the scientific foundation for rangeland management. I hope we can collaborate to better understand the dynamics of similar, but in some cases more stressed, rangelands in central and northern Mexico.

Sincerely,

[Signature]

Philip Heilman
Research Biologist

Southwest Watershed Research Center
2000 L. Allen Road, Tucson, AZ 85719-1590
Voice: (520) 670-6201 x1411 Fax: (520) 670-5550 E-mail: phheilman@tucson.ars.ag.gov

Agricultural Research - Investing in Your Future
May 14, 2007

Dear Ms. Gamboa;

Since 2003, I have been collaborating with scientists of the USDA ARS, Jornada Experimental Range, on the ‘Management Technologies for Arid Rangelands’ project.

During this time, we have co-produced valuable data collection and analysis tools, and, now that the software has matured and is beginning to reach its intended national audience, we are pleased that this collaboration is proving to be a success.

The goal of our project, to develop various management and monitoring tools that assist land stewards in conserving natural resources in a cost-effective manner, is being met. With these tools, land managers are better able to quantify such indicators as Soil Composition, Compaction and Stability, Invasive species conditions, Riparian health, Plant densities, and overall Vegetation Structure.

As data is collected over time using our tools, we hope that land managers will be able to develop long-term strategies for improving conditions, and minimizing the risk of rangeland degradation.

Over the next couple of years, we anticipate further development and extension of the software, and I look forward to a continuing process, to add value to the system.

Yours truly,

Barry R Lavine
May 8, 2007

Deb Peters, Lead Scientist
Jornada Experimental Range
Box 30003 MSC 3JER
Las Cruces, NM 88003

Dear Ms. Peters:

On behalf of the New Mexico Department of Agriculture (NMDA), I am pleased to write this letter in support of continued collaboration with the scientific team at the USDA ARS, Jornada Experimental Range (JER) for the Management Technologies for Arid Rangelands Program located in Las Cruces, New Mexico. NMDA has been a long time collaborator with the scientific team at the JER and we value our partnership. In our work as a state agency, we are fortunate to have cultivated a relationship with the JER staff which allows us to utilize important scientific information in making key policy decisions for statewide natural resource issues. Each of the five research objectives described in the JER research project plan have potential to inform and assist with landowner land management and policy decisions.

NMDA looks forward to future collaboration with JER scientists and support staff for mutual benefit. If you require more detailed information regarding past or future collaboration between NMDA and the JER, please contact me at (505) 646-2642.

Sincerely,

Julie Maitland
Division Director
AgriTech Electronics LC

4144 Pennsylvania Avenue
Kansas City, Missouri 64111
(816) 410-7202
(816) 410-7201 FAX

May 23, 2007

Jornada Experimental Range
c/o Bernice Gamboa
Box 30003 MSC 3JER
Las Cruces, New Mexico USA 88003

Dear Ms. Gamboa:

This is in response to your letter of May 7, 2007 regarding future collaborations between Agri Tech Electronics and your scientist, Dean Anderson.

We look forward to continuing to work with Dr. Anderson to develop GPS-based livestock control systems and conduct tests using those systems. We believe that this technology continues to offer substantial promise to address a variety of grazing management and animal control needs.

We look forward to continuing our collaboration with Dr. Anderson.

Very truly yours,

Robert E. Marsh, Manager

REM/ pdv
07 June 2007

Kris Havstad
Supervisory Scientist
Jornada Experimental Range
P.O. Box 30003, MSC 3JER
New Mexico State University
Las Cruces, NM 88003

Dear Dr. Havstad:

I am very pleased to prepare this letter stating my continued interest to collaborate with scientists at the USDA ARS Jornada Experimental Range under their Management Technologies for Arid Rangelands project.

My past collaborations with scientists (Havstad, Herrick, Peters, and Bestelmeyer) at the Jornada have been very fruitful. Currently, I am collaborating with Dr. Peters by contributing a section on the Santa Rita Experimental Range in her Trends publication describing long-term trends in ecological parameters. Another current collaboration is with Dr. Bestelmeyer, where we are refining ecological site descriptions by examining both the inter- and intra-site variation in soil parameters and long-term vegetation composition dynamics.

I look forward to much future collaboration with these colleagues because their contributions are always top quality and improve my work and the work of my colleagues and students.

Sincerely,

Mitchel McClark
Professor, School of Natural Resources
Director for Research, Santa Rita Experimental Range
United States Department of the Interior
BUREAU OF LAND MANAGEMENT
Las Cruces District Office
1800 Marquess
Las Cruces, New Mexico 88005
www.nm.blm.gov

MAY 25 2007

4100 (03000)

Kris Havstad, Supervisory Scientist
Jornada Experimental Range
Box 30003 MSC 3JER
Las Cruces, New Mexico 88003

Dear Kris:

This letter is being sent to you to express the Bureau of Land Management, Las Cruces District Office’s support of the USDA ARS, Jornada Experimental Range’s (JER) Management Technologies for Arid Rangelands project. We would also like to express our interest in continuing to collaborate with scientists in your unit on this project.

Four of the five research objectives that your unit developed directly relate to issues and concerns we face daily. The fifth objective is quickly becoming a concern within our district. We believe the work your unit is doing will provide us with the necessary information and tools to manage the public’s land to meet the needs of current and future generations during these times of limited personnel and budgets.

The Bureau is becoming increasingly involved with the use and development of native plant materials for use in restoration of public lands. Ongoing fungal endophyte research at JER supports this direction. We believe there is a need to expand research of native plant materials, particularly in the Chihuahuan Desert region, and invite you to explore avenues of this research with us.

We greatly appreciate and enjoy the opportunities to collaborate and work side-by-side with you and your scientists.

Please do not hesitate to contact us if we can provide any information or assistance in the future.

Sincerely,

[Signature]
Jirk C. McCormick
Assistant District Manager
Division of Renewable Resources
Dear Drs. Peters and Havstad:

I would like to express the intent of my soil-geomorphology program at NMSU to continue collaboration with the USDA ARS Jornada Experimental Range on the project “Management Technologies for Arid Rangelands.” Our involvement will mainly be under your research objective #2: “Identify factors such as landscape position, species composition, land use history, management strategies, or climatic variables that can be used to predict or minimize the risk of rangeland degradation.” Specifically, we will conduct research that concentrates on the following areas.

1. Identifying relationships between rangeland degradation and soil types.
2. Understanding broad scale geomorphic and paleoclimatic factors impacting vegetation change.
3. Testing hypotheses dealing with how arid rangelands sequester inorganic carbon.

The Jornada Experimental Range is ideally suited for these investigations. First, it has a quality group of scientists to collaborate with, as well as an excellent support staff, and the needed infrastructure. Second, it has a long history of research publications to build on and many valuable long-term data sets. Third, the Jornada Experimental Range is an excellent natural laboratory containing multiple environments with alluvial and eolian stratigraphic records of erosion and isotopes that quantify C4/C3 plant dynamics.

I look forward to my continued involvement and hope our soil-geomorphology research group will be as beneficial to the Jornada Experimental Range as it has been to us. If you have any questions please let me know.

Sincerely,

H. Curtis Monger
Professor of Soil and Environmental Science
May 21, 2007

USDA-ARS
Jornada Experimental Range
P. O. Box 30003, MSC 3JER, NMSU
Las Cruces, NM 88003-8003

Dear Drs. Havstad and Peters,

This letter is to state my intention to continued collaboration with USDA-ARS Jornada Experimental Range scientists in support of their ongoing project to develop Management Technologies for Arid Rangelands. Research conducted by ARS scientists in Las Cruces is complimentary to ongoing USDA ARS Southwest Watershed Research Center research on applied technologies for controlling rangeland erosion. Both research programs will be enhanced through collaborations to collect and interpret field data. Cooperation on this research will be beneficial to both parties and will provide much needed information for rangeland conservation projects.

I am looking forward to working with you.

Sincerely,

Mary Nichols

Mary Nichols
Hydraulic Engineer
USDA-ARS Southwest Watershed Research Center
2000 E. Allen Rd.
Tucson, AZ 85719

Southwest Watershed Research Center
2000 E. Allen Rd. Tucson, AZ 85719
Voice: 520.670.6380 x161 E-mail: mnichols@tucson.ars.ag.gov
Agricultural Research - Investing in Your Future
To: Deb Peters and Kris Havstad  
USDA ARS  
Jornada Experimental Range

From: Gregory S. Okin  
Assistant Professor

Re: Research Project Plan

May 30, 2007

Dear Deb and Kris,

It is my distinct pleasure to provide this letter of support for the five-year research project plan for the USDA-ARS Jornada Experimental Range entitled “Management Technologies for Arid Rangelands”.

I have been working at the JER since 1996 and in that time have interacted extensively with you and your colleagues at Jornada. I intend to continue to work with you and your group on developing management and monitoring tools for conservation of natural resources as well as identifying factors, particularly related to wind erosion, that can be used to predict or minimize the risk of rangeland degradation.

I am highly supportive of your project and the unit as a whole and look forward to working on our existing collaborations and finding new one.

Sincerely,

Gregory S. Okin
Dr. Robert R. Parmenter  
Preserve Scientist  
Valles Caldera National Preserve  
P.O. Box 359  
Jemez Springs, NM 87025  
Phone: 505-428-7727  
Fax: 505-829-4614  
Email: bparmenter@vallescaldera.gov

Date: 24 May, 2007

Dr. Kris Havstad, Supervisory Scientist  
USDA ARS, Jornada Experimental Range  
P.O. Box 30003  
MSC 31ER  
New Mexico State University  
Las Cruces, NM 88003-8003

Dear Dr. Havstad,

On behalf of the Valles Caldera Trust, I would like to extend our gratitude and enthusiastic support for your unit’s collaboration with us during the past 6 years, and convey to you our high level of interest in continuing our scientific relationship for many years to come. Your staff with the USDA ARS Jornada Experimental Range, through the Management Technologies for Arid Rangelands Project, has been extremely helpful to us in developing management strategies and monitoring programs for rangeland condition under various grazing programs for livestock and wildlife (elk) here in the Valles Caldera National Preserve. The Trust’s monitoring program for forage utilization, which you and staff continue to lead, has proven extremely useful in determining livestock densities, pasture rotations and rangeland condition. We are now using these data to calibrate satellite imagery (Landsat TM, Modis and AVHRR) for future monitoring of rangelands on the Preserve with remote sensing technologies. In addition, we have plans established now for expanding your monitoring methods to adjacent lands managed by the Santa Fe National Forest, Bandelier National Monument, and Los Alamos National Laboratory. As such, your efforts will soon be applied to the entire Jemez Mountains region, rather than just the Valles Caldera. These efforts will continue indefinitely into the future, as they constitute a major component of our science-based adaptive management philosophy for the Preserve, and we look forward to many years of collaboration with you and your staff.

Thanks again for all your activities, and please let us know if we can provide any additional support for your operations.

Sincerely yours,

Robert Parmenter, PhD  
VCNP Preserve Scientist
Professor Anthony Parsons
Department of Geography
University of Sheffield
Winter Street
SHEFFIELD
S10 2TN

9 May 2007

Telephone: 0114 222 7952  
Fax: 0114 222 7912  
Email: a.j.parsons@sheffield.ac.uk

To whom it may concern

I write in support of the project proposal Management Technologies for Arid Rangelands being submitted by USDA ARS, Jornada Experimental Range. I, members of my research group, and graduate students have been collaborating with Jornada scientists for more than a decade, and it is our sincere wish to continue that collaboration into the future. Our specific interests lie in the processes of land degradation, and particularly the complex interactions between rangeland vegetation and runoff, sediment and nutrient movement in the landscape. Through improved understanding of these interactions and their controls we believe that better management strategies and decision tools can be developed for arid-land managers. Our past collaboration with Jornada scientists has been fruitful in moving forward this research agenda and it is our intention to continue to collaborate with Jornada scientists in their new project.

Yours sincerely

[Signature]
United States Department of Agriculture

Natural Resources Conservation Service
Central National Technology Support Center
Grazing Lands Team
501 W. Felix St., FWFC, Bldg. 23
P.O. Box 8687
Fort Worth, TX 76115
Phone: 817-509-3211; Fax: 817-509-3337

May 23, 2007

Debra Peters
Kris Havstad
USDA-ARS
Jornada Experimental Range
New Mexico State University
MSC 3JER
P.O. Box 30003
Las Cruces, New Mexico 88003

Dear Ms. Peters and Mr. Havstad:

The USDA-NRCS-Grazing Lands Team has been collaborating with USDA-ARS-Jornada Experimental Range, for several years on activities related to Management Technologies for Arid Rangelands. Scientists at the Jornada Experimental Range have been very supportive in addressing NRCS rangeland research needs and development of inventory/monitoring/assessment strategies and tools for NRCS use. We are currently working with Jornada Experimental Range on rangeland activities such as remote sensing, ecological site descriptions, and inventory/monitoring/assessment tools and techniques.

We look forward to continued collaboration with scientists at the Jornada Experimental Range.

Sincerely,

George L. Peacock, Jr.
Leader, Grazing Lands Team

cc w/att:
Ronald C. Williams, Director, CNTSC, NRCS, Ft. Worth, TX
August 27, 2007

Dr. Debra Peters
USDA/ARS JORNADA EXPER RANGE
PO BOX 30003, MSC 3JER, NMSU
Las Cruces NM 88001

Dear Dr. Peters,

I am pleased to have this opportunity to reaffirm our commitment to continued collaboration between the USDA-ARS Northwest Watershed Research Center and the USDA-ARS Jornada Experimental Range on the "Management Technologies for Arid Rangelands" project. In particular, we are committed to the development and testing of monitoring and remediation technologies, as described under Objectives 1 and 2 of your project plan, and to supporting the development of decision support systems with rangeland hydrology and erosion models, as described in Objective 4.

Relative to Objective 1, our research unit is uniquely located to facilitate testing of monitoring technologies developed in the southern deserts of the United States in cool season grasslands, and in sagebrush and juniper-dominated communities (Objective 1). We plan to continue testing of monitoring methods developed by the Jornada in association with our fire experiments.

We are also committed to the collaborative development and testing of new remote sensing technologies, including LIDAR and the application of high resolution aerial photography and are committed to working with you to test the application of Unmanned Aerial Vehicles (UAV's) to monitoring in these ecosystems (Objective 1). We also look forward to developing ecological site-based approaches to remediation and the spread of invasive species. Finally, we are continuing to move forward on the development of the Rangeland Hydrology and Erosion Model (RHEM) in cooperation with the USDA-ARS Southwest Watershed Research Center and other ARS units and look forward to working with you to integrate it with new assessment, monitoring and decision support technologies (Objective 4).

Sincerely,

Frederick B. Pierson, Jr.
Research Leader

Pacific West Area
Northwest Watershed Research Center
800 Park Blvd., Plaza IV, Suite 105, Boise, ID 83712-7166
Voice: 208-422-0700, Fax: 208-334-1502, E-mail: fpierson@nwrc.ars.usda.gov

Agricultural Research - Investing in Your Future
Dr. Kris Havstad  
Supervisory Scientist  
ARS Jornada Experimental Range  
MSC, 3JER, P.O. Box 30003  
New Mexico State University  
Las Cruces, NM 88003

Dear Dr. Havstad:

The collaboration between the USDA Natural Resources Conservation Service (NRCS) and the Jornada Experimental Range has been most productive over the past decade and we are eager to continue that collaboration into the future. In particular, the Soil Survey and Resource Assessment area has benefited greatly.

The products of our work together that benefit soil survey have included field tools such as simple, cost-effective field measurement methods for survey, inventory, assessment, and monitoring and technical information materials for land managers and resource professionals. The planned Dynamic Soil Properties Sampling Guide will bring these materials together with new work in areas such as soil health and carbon sequestration to provide an important advance in how we communicate soils information to our clients.

The Jornada/NRCS collaboration has also greatly improved the measurement and monitoring of rangeland resources. The work on assessment that resulted in the Interagency publication Interpreting Indicators of Rangeland Health version 4 now serves as the basis for many conservation activities on rangelands. The work on quantitative inventory and monitoring that resulted in the NRCS-supported publication Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems contributed to an improved National Resource Inventory. That work has also resulted in a developing collaboration on a new effort, the Conservation Effects Assessment Program, which will provide an important means of measuring the impacts of publicly funded conservation programs on a range of ecosystem services that affect society.

Finally, the emergence of new concepts, applications and tools for the systematic and scientifically-based development of Ecological Site Descriptions as a result of the Jornada/NRCS collaboration have revolutionized an important aspect of rangeland management in the United States and around the World. The numerous workshops, symposia, publications and training sessions designed to reach a wide variety of rangeland users, scientists and policy makers have changed the language and the practice of rangeland technical assistance not only in our agency, but across the Federal Government. The continued collaboration linking vegetation relationships to their behavior in response to management and climate change promises to provide new insights into the continued production of rangeland ecosystem services.
Dr. Kris Havstad

In summary, the collaboration between NRCS and the Jornada Experimental Range has been highly beneficial to both parties in achieving our goals. But, most importantly, it has provided the public with new ideas and tools for the management of an important natural resource. I look forward to the continued progress and excitement this collaboration promises.

Sincerely,

WILLIAM E. PUCKETT
Deputy Chief
Soil Survey and Resource Assessment
May 11, 2007

Jornada Experimental Range
USDA, Agricultural Research Service
Box 30003 MSC 3JER
Las Cruces, NM 88003

To Whom It May Concern:

This letter is to inform you of the intent of my research group at the USGS Forest & Rangeland Ecosystem Science Center to continue our collaboration with scientists at the USDA, ARS, Jornada Experimental Range under their Management Technologies for Arid Rangelands project. The following are the specific objective within this project that we will continue to collaborate and consult among ourselves with the goal of providing useful products to sustain rangelands and their uses:

1. Develop management and monitoring strategies/decision tools that conserve natural resources while maintaining economic objectives.
2. Identify factors such as landscape position, species composition, land use history, management strategies, or climatic variables that can be used to predict or minimize the risk of rangeland degradation.
3. Develop monitoring and decision-support tools and management strategies for land managers.
4. Understand mechanisms of weed invasion and develop management strategies that can be used to restore rangelands that have been degraded by weeds or other disturbances.

Sincerely,

David A. Pyke
Research Rangeland Ecologist
28 August 2007

Dr. Deb Peters
Jornada Experimental Range
Box 30003 MSC 3JER
Las Cruces, NM 88003

Dear Dr. Peters,

I am pleased to be able to state that the National Park Service, Chihuahuan Desert Inventory & Monitoring Network (CHDN) is interested in continuing our collaboration with USDA ARS, Jornada Experimental Range scientists involved with the Management Technologies for Arid Rangelands project. During the past 2 years of collaboration, I believe we have forged an effective partnership on the development of monitoring strategies to use within the seven parks that comprise the CHDN. Thus, I see specific opportunities to work with the Jornada on two of four research objectives for your next 5-year planning cycle (2007-2012):

1. Develop an integrated assessment and monitoring approach for vegetation structure and composition, soil stability, watershed function, and biotic integrity of spatially and temporally heterogeneous rangelands at landscape, watershed, and regional scales, and

2. Identify key plant and soil processes, and environmental factors, such as landscape position, land use history, and climate, that influence the potential for remediation success.

Scientists at the Jornada are directly involved with the development of our long-term monitoring plan. CHDN is relying heavily on past and current Jornada research efforts on understanding the dynamics of soil function and stability, hydrologic function and vegetation dynamics as we assess what, where and how these types of vital signs (environmental indicators) will be monitored.

If you require any additional information, please do not hesitate to contact me (646.5294 or hildy_reiser@nps.gov).

Sincerely,

[Signature]
HILDEY REISER, Ph.D.
Chihuahuan Desert Network Coordinator

EXPERIENCE YOUR AMERICA
The National Park Service cares for special places so that all may experience our heritage.
June 12, 2007

USDA, ARS, Jornada Experimental Range
P.O. Box 30003, MSC 3JER
Las Cruces, NM 88003

Re: Letter of support for the Jornada Experimental Range

Dear Sir or Madam:

It has been my great pleasure to work with the staff of the USDA, ARS Jornada Experimental Range for the past two years. Our collaboration and interaction has resulted in significant technological advancement to NRCS, particularly in our west region.

With the many new challenges facing our clients (and our agency), it is imperative that we work closely with ARS in developing science and technology that benefits our western rangeland ecosystems and the people who benefit from them.

I have been involved in developing monitoring and decision-support tools and management strategies for land managers: particularly the Rangeland Database, Ecological Site Description database (including appropriate protocols for data collection), and forming science-based policy for NRCS in collection of ecological site description data. I will look forward to continuing a productive working relationship with the scientists involved in the Management Technologies for Arid Rangelands project.

Sincerely,

Jeffrey P. Repp
Rangeland Management Specialist
NRCS-WNTSC
(503) 273-2431
jeff.repp@por.usda.gov

cc: Bruce Newton, Director, WNTSC, Portland, OR
21 May 2007

Deb Peters
ARS-USDA Jornada Experimental Range
P.O. Box 30003 MSC 3JER
Las Cruces, NM 88003

Dear Dr. Peters:

I am writing to affirm our ongoing cooperative efforts with research that the Jornada Experimental Range is conducting under the USDA-Agricultural Research Service project entitled “Management Technologies for Arid Rangelands.” We are cooperating with Dr. Albert Rango on using remote sensing and modeling for evaluating hydrologic and energy fluxes and landscape states. We are working with Dr. Jeffery Herrick to study soil and constituent redistribution processes across semiarid landscapes. We have cooperated in many field experiments that have been conducted on the Jornada Experimental Range and at the Sevilleta LTER at Socorro, New Mexico.

We plan to continue this cooperative relationship with the Jornada Experimental Range and look forward to collaborating on future new research plans.

Sincerely,

s/n Jerry C. Ritchie

Jerry C. Ritchie
Soil Scientist
Dear Colleagues,

The purpose of this letter is to provide my comments on scientific collaboration between the Department of Ecology, Agronomy and Aquaculture, University of Zadar, Croatia, and USDA ARS, Jornada Experimental Range in Las Cruces, New Mexico.

I would like to emphasize that I have some experience in management and ecology of the arid rangelands in the western U.S., because I was a Fulbright scholar at Utah State University, Department of Rangelands Resources in 1997/98. Further I collaborated with US scientists on a research project in Croatia (2000-2004) focusing on the ecological aspects of grazing of Mediterranean shrubs by sheep and goats.

As professor and head of department, I invited Dr Kris Havstad to visit my institution, where he gave a seminar titled “Challenges and advances toward sustainable utilization of arid land resources in the USA” in 2004. In February of the next year I visited the USDA ARS Jornada Experimental Range, and gave a seminar on “Rangelands in the Mediterranean Zone of Croatia.” I am familiar with the majority of the Jornada Experimental Range scientists. Scientific collaboration between my research team and scientists from USDA ARS Jornada Experimental Range, especially with Dr. Richard Estell, has been very successful and productive. The research articles we have published are key contributions to understanding plant animal interaction and managing with small ruminants in shrubland ecosystems. I have enjoyed and benefited from our past collaborations in research, and I look forward to future collaborations.

As I can see from your proposed project - “Management Technologies for Arid Rangelands” the research objectives are part of the ARS National Program in Rangeland Pastures and Forages. The objectives that you propose are crucial because they reflect both national research priority pertaining to rangelands, and the capacities of your research units and your collaboration to address these objective.

I enthusiastically support your proposed project (Management Technologies for Arid Rangelands); especially in the framework of our recent scientific interactions on these problems and I look forward to a continuation of our future research collaboration.

Please feel free to contact me if clarification of these statements or further information is required.

Sincerely,

[Signature]

Jozo Rogosic

Professor and Head Department
May 14 2007

Dear Planning Committee:

I am writing to indicate my intent and interest to continue my collaboration with Dr. Dean Anderson, and more broadly the staff at the USDA ARS Jornada Experimental Range within the scope of the Management Technologies for Arid Rangelands program. We have a productive collaboration aimed at developing tools for managing rangelands. I am especially interested in collaboration towards the following objectives:

1. developing management and monitoring strategies/decision tools that conserve natural resources while maintaining economic objectives
2. identifying factors such as landscape position, species composition, land use history, management strategies for climatic variables that can be used to predict and minimize the risk of rangeland degradation
3. developing monitoring and decision-support tools and management strategies for land managers
4. developing immediate and lifetime animal productivity, well-being, and product quality relative to management strategies.

I look forward to our continued collaboration. Please do not hesitate to contact me if you have further questions.

Sincerely,

Daniela Rus
Professor, EECS
Co-Director, CSAIL Center for Robotics
MIT
10 May 2007

Dr. Kris Havstad
Supervisory Scientist
USDA ARS, Jornada Experimental Range
Box 30003 MCS 3JER
Las Cruces NM 88003-8003

Dear Dr. Havstad,

I am pleased to write this letter in support of your effort to plan research under the Management Technologies for Arid Rangelands project for the period October 2007-September 2012.

Collaboration with the USDA ARS, Jornada Experimental Range has been invaluable to my research over the past four years. I focus on the management and land use histories of arid and semiarid rangelands in the US-Mexico borderlands, in the states of New Mexico, Arizona, Chihuahua and Sonora. I hope to contribute historical and ethnographic approaches and insights to your efforts, particularly under objectives 1 and 2: developing management and monitoring strategies, and identifying factors that can be used to predict or minimize the risk of rangeland degradation.

In the coming five years, I plan to continue to collaborate with Jornada scientists to improve our understanding of the causes and dynamics of ecological change in the region and, in the process, to develop more effective ways of involving landowners and managers in these efforts.

I commend you and your unit for the path-breaking work you have already done, and I look forward to working with you further in the coming years.

Sincerely,

[Signature]

Nathan F. Sayre
Assistant Professor
June 1, 2007

Dr. Deb Peters  
USDA/ARS Jornada Experimental Range  
Las Cruces, NM

Re: Research Collaboration

Dear Dr. Peters,

We wish to continue our research collaboration with the scientists at the Jornada Experimental Range. We have been studying the how remotely sensed data can help us understand the dynamics of the landscape at the Jornada for the past ten years. Because of the high probability of getting clear sky observing conditions, the Jornada is an excellent site for remote sensing research. My own work has concentrated on determining the accuracy with which we can determine surface temperatures using satellite observed radiances. These temperatures will be used in models to estimate the surface energy fluxes. These can be compared with those observed by eddy correlation flux systems operating at the Jornada.

We look forward to continued collaboration with Jornada scientists.

Yours truly,

Tom Schmugge  
Gerald Thomas Professor of Water Resources  
New Mexico State University
May 15, 2007

Kris Havstad, Supervisory Scientist
USDA-ARS
Jornada Experimental Range
Las Cruces, NM 88003

Dear Kris:

It has been my pleasure for the last several years to work closely with many members of your staff. I believe that this association has been mutually beneficial for our agencies and furthered the long range goals and objectives of both. I highly value the professionalism and high quality work being done there.

It is my intention to continue to collaborate with scientist at the USDA-ARS, Jornada Experimental Range in several projects. The project encompassing Management Technologies for Arid Rangelands includes several objective of interest to me and to USDA-NRCS. Those include development of management and monitoring strategies, identifying factors that can be used to predict or minimize risk of rangeland degradation, and animal productivity and well being.

I look forward to continued cooperation and collaboration with your unit. In fact we have scheduled several opportunities to work together to achieve these objective in the next few months.

Thanks you again for your support of USDA-NRCS and our mission to "Help People Help the Land"

/s/ Pat L. Shaver

Pat L. Shaver
Rangeland management Specialist
USDA-NRCS
West National Technology Support Center
Portland, OR

Helping People Help the Land
An Equal Opportunity Provider and Employer
June 14, 2007

Jornada Experimental Range
c/o Bernice Gambos
Box 30003 MSC 31RR
Las Cruces, NM 88003

Re: Statement of collaboration with USDA ARS Jornada Experimental Range Management Technologies for Arid Rangelands

I am currently engaged in collaborative research with USDA ARS Jornada Experimental Range scientists. I am an economist, and a faculty member at New Mexico State University, Department of Agricultural Economics and Agricultural Business, New Mexico Agricultural Experiment Station. I have been affiliated with the Jornada Long Term Ecological Research (LTER) project for two years.

My research collaboration with USDA ARS Jornada Experimental Range scientists involves investigation into the social-ecological system dynamics of the Southwestern United States with particular interest in the socio-economic characteristics of rangeland cow-calf producers. This collaborative research is addressing objective #3 of the ARS National Program in Rangelands, Pastures and Forages. We are identifying socio-economic factors that can be used to predict or minimize the risk of rangeland degradation. We are researching linkages between socio-economic and ecological factors related to rangeland management.

This research has been made possible for me as a result of collaboration with USDA ARS Jornada Experimental Range scientists. This research also meets the objectives of the Jornada LTER project, and is consistent with my New Mexico Agricultural Experiment Station research responsibilities.

I look forward to a long and productive research relationship with USDA ARS Jornada Experimental Range scientists.

Sincerely,

Rhonda Skaggs

Rhonda Skaggs, Ph.D.
Professor
Dear Bernice

Collaboration with SAC

This letter is to confirm that USDA-ARS Jornada Experimental Range (JER), is collaborating with SAC on a European Union Framework 7 project submission entitled 'Future tracking technology for ecological management of extensive farming systems'.

The project application was submitted to the EU on 2 May 2007. To date, we have yet to learn if this project submission has been successful in winning the requested funds for the European partners concerned in it.

The main role of JER is to collaborate on two work packages within this project (a) WP2 (technical development) and (b) WP3 (animal behaviour studies).

The main contact point at JER will be Dean Anderson.

I hope this letter provides sufficient information for your review.

Yours sincerely,

[Signature]

Dr Michael L Smith
Research Manager
July 6, 2007

TO: Dr. Deb Peters, Lead Scientist,
USDA-Agricultural Research Service, Las Cruces, NM

FROM: Dr. Tony Svejcar, Research Leader
USDA-Agricultural Research Service, Burns, OR

SUBJECT: Cooperation during 2007-2011 project plan cycle

Our research group is very willing to continue the cooperative relationship we have developed with ARS Las Cruces over the past 15 years. The sharing of knowledge and expertise has been of value to both units. The ability to share notes and experiences on ecological relationships and vegetation responses to climate and management has been especially useful. Of particular interest to us is the use of state-and-transition models in our cold desert environment. We hope to share our approaches to biologically-based invasive plant management with your staff. The cooperation between groups allows us to conduct an informal comparison of hot desert/cold desert settings. Should you or your staff ever need to use any of our equipment, data, or field sites, we would be more than happy to accommodate.
7 June 2007

Deb Peters, Lead Scientist
United States Department of Agriculture
Jornada Experimental Range
P.O. Box 30003, MSC 317, NMSU
Las Cruces, NM 88003-3003

Dear Deb Peters,

The CSIRO collaborative project between the Livestock Industries Division (CLI) and Information Communication Technologies Centre (ICT) based at the J M Rendel Laboratory, Rockhampton wish to continue collaboration with the USDA ARS, Jornada Experimental Range under the Management Technologies for Arid Rangelands project. In particular we are interested in identifying areas of overlap between the USDA and CSIRO research groups that can add value to our strategic directives.

To build on the collaborative research efforts in plant animal interactions in rangeland environments the following activities are proposed:

1. Exchange of best practice to enhance research activities.
2. Identify opportunities to test specific hypotheses under a range of climatic, edaphic and vegetation ecotones.
3. Through modelling activities develop a shared view on a theoretical framework for understanding plant animal interactions.
4. Explore whether there are any opportunities for joint commercialisation of virtual fencing IP.
5. Identify opportunities to combine existing data sets to deliver shared scientific publications that address overarching science questions.
6. Consider submitting proposals for jointly funded projects.

We look forward to developing the collaborative activities and the opportunity to build on the existing USDA/CSIRO links.

Yours sincerely

[Signature]

Dave Swain
Dear Deb,

Re: USDA Agricultural Research Service (ARS) project plan for October 2007 – September 2012

Thank you for your letter regarding letters of support for the USDA Agricultural Research Service (ARS) project plan for October 2007 – September 2012.

I have no hesitation in offering my and GAP’s support to the plan, and very much look forward to continued collaboration between our organisation (and its many constituent members and partner organisations in the UK and Europe), and USDA. There is a great deal that we can learn from each other that will be mutually beneficial.

Please do not hesitate to call if you need any further information,

Yours,

Sincerely,

Jim Swanson, GAP Southern England Coordinator

cc. Kris Havstad, Dean Anderson
June 11, 2007

Project name: Management Technologies for Arid Rangelands
The United States Department of Agriculture
Agricultural Research Service
The Jornada Experimental Range
P.O. Box 30003, MSC 3JER, NMSU,
Las Cruces, NM 88003-8003

Dear Dr. Kris,

It is my pleasure to bring you the information about our present and expected collaboration with USDA ARS and the Jornada Experimental Range. We sincerely hope that our cooperation will continue with your support.

The collaboration of Research Institute of Animal Husbandry, Mongolia and the USDA, ARS research unit based at the Jornada Experimental Range has started since 2005. The collaboration has contributed to improved Mongolian rangeland scientist knowledge and studies of new research methodologies and techniques of rangeland. Nowadays, Mongolia’s main concern is grazing land management and degradation of rangeland.

We would like to continue our collaborations to address these objectives.

1. Develop management and monitoring strategies for rangeland resources while maintaining livestock productions.
2. Develop monitoring and decision-support tools and management strategies for pasture managers.
3. Develop technologies for improvement and restore rangelands.
4. Develop monitoring of thematic GIS layers for ecological-site based stratification and integration of ground-based rangeland health assessments, on-site monitoring, and remote sensing based monitoring.

RIAH scientists and ARS team will be of a great importance, as it will lead to good opportunities for exchanging and learning.

Thank you very much for expected collaboration.

Sincerely yours

S. Tserendash
Director of RIAH
June 14, 2007

Subject: Letter of Support for ARS National Program in Rangelands, Pastures and Forages.

William P. Wergin is Vice-President of Wergin Associates, Inc., a scientific consulting company that is engaged in research involving electron microscopy. He maintains a Cooperative Appointment with the Electron Microscopy Unit (EMU), Soybean Genomics and Improvement Laboratory, Agricultural Research Service (ARS), U.S. Department of Agriculture (USDA), Beltsville, MD 20705. The major instrumentation in the EMU includes a transmission electron microscope equipped with digital imaging features and a field emission scanning electron microscope that is interfaced with a low temperature stage for viewing frozen hydrated specimens. These instruments can be utilized for examining biota in snow and ice, as well as the structure-function relationships in weed and cultivated plant species. Wergin, who has had experience and published in both of these areas, believes his expertise would complement the research objectives that are stated in the ARS National Program in Rangelands, Pastures and Forages.

Resume: Dr. Wergin received his B.S. (genetics) and Ph. D. (plant cell biology) degrees from the University of Wisconsin – Madison. He worked with the Agricultural Research Service for the last 30 years where served as leader of the Electron Microscopy Laboratory/Unit. He has authored/co-authored 250 peer reviewed manuscripts and 150 abstracts. During the last 15 years, Wergin and colleagues developed the methodology and techniques for collecting and transporting snow and ice and imaging them with an SEM. Previously, light microscopy restricted scientists to examination of these crystals at magnifications of only a few hundred-fold. He demonstrated for the very first time that snowflakes, snow crystals, glacial ice and other types of winter precipitation could be examined and studied at magnifications of 50,000 or more in a modified SEM. These results are enabling collaborating research scientists in diverse fields such as hydrology, meteorology, ice physics, and glaciology to observe for the first time high resolution, three-dimensional images of newly precipitated and metamorphosed snow and ice crystals. The information is also being used in remote sensing, to determine the water equivalent present in winter snow pack which ultimately affects agriculture, flooding, hydroelectric power production and potential avalanche situations. Results from these studies were used or cited by numerous TV, radio and news programs including NOVA, National Geographic, National Public Radio, CBS News, Washington Post, Scientific American and Discover. He received best paper award for presentation of this data at the Eastern and the Western Snow Conferences, invitations for seminars at several universities including the Meteorology Dept, Penn State University and the annual meeting of the National Ski Patrol. The web page that pertains to this research, containing images of snow and ice, routinely receives over 30,000 "hits" per month during the winter period. Awards/appointments include: 1) USDA Certificates of Merit, 1994, 1995, 1996, 1997, 1998; 2) Presidential Scholarship Award from Scanning Microscopy International, 1994; 3) Research Professor of Biology, 1995-98, The American University, Washington, DC; 4) Best Oral Presentation at the Eastern Snow Conference, May 1996; 5) Research Grant from York Snow, Inc.; 6) Scientist of the Year, 2000 Beltsville Area, USDA; 7) National Excellence in Information Award, Agricultural Research Service, USDA, 2003; 7) Recognition Award, Foundation for Advancements in Science and Medicine, 2003 and; Best Oral Presentation at the Western Snow Conference, April 2006.
Texas A&M University  
College of Agriculture and Life Sciences  
Department of Ecosystem Science and Management

Dr. Deb Peters and Dr. Kris Havstad  
USDA ARS, Jornada Experimental Range  
P.O. Box 30003  
MSC 3JER  
Las Cruces, NM 88003-8003

Dear Dr. Peters and Dr. Havstad,

We are writing to express our strong support for your Management Technologies for Arid Rangelands project that is being conducted through USDA ARS, Jornada Experimental Range.

We believe that the research goals and objectives you have outlined for this project provide many avenues for collaboration and synergy that will be mutually beneficial to both of our organizations. Our continued collaboration on development of monitoring and decision support tools for carbon sequestration in the southwestern US, as well as our emerging collaboration on rangeland health monitoring in Mongolia offers opportunities to broaden the scientific knowledge and meet stakeholder needs in these important areas of study. We are keenly interested in your unit's work on ecological site state and transition modeling, remote sensing applications for rangeland monitoring, and methodologies for minimizing and/or predicting rangeland degradation. We hope to pursue avenues for collaborating on these critical issues in the near future.

Thank you for the opportunity to offer our support for your research project plan. We wish you the best in the implementation of this project and look forward to our continued and future collaborations.

Sincerely,  

Steve Whisenant, Professor and Head

College Station, Texas 77843-2138  Tel 979.845.5033  Fax 979.458.0158
USDA, ARS
Jornada Experimental Range
Box 30003 MSC 3JER
Las Cruces, NM 88003

May 9th, 2007

RE: Letter of Intent to Collaborate with JER

Dear Dr. Peters and Dr. Havstad:

The Department of Geography at New Mexico State University strongly wishes to continue our collaboration with the USDA, ARS, Jornada Experimental Range on their Management Technologies for Arid Rangelands project. Our department has worked with your unit for many years on this worthwhile research effort. Specifically, we wish to collaborate with you on your Objectives #1, #2, and #3 – all related to natural resource management, monitoring, and conservation. Our collaboration with you on studying land use and land cover change in the Chihuahuan Desert and Mesilla Valley region is an important and shared focus of our two units.

The Department of Geography stands ready to continue our research collaboration relationship for many years to come.

Sincerely,

[Signature]

Dr. John Wright, Head
Department of Geography
Box MAP
NMSU
Las Cruces, NM 88003
(505) 646-4806
jwright@nmsu.edu