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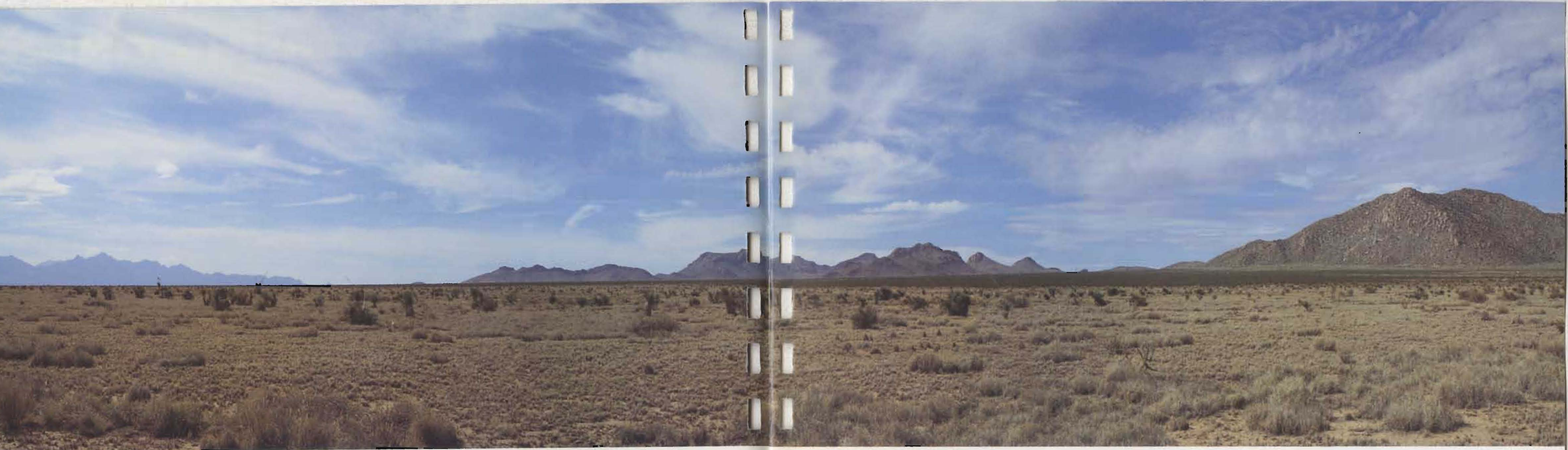


how to make a desert

You don't need to destroy all the plant life you see—just rearrange it a little. Then let nature do the rest.

BY CARL ZIMMER

Photographs by David Hamilton

AT TIMES THE DESERT CAN MAKE PEOPLE SEEM SMALL AND INCONSEQUENTIAL and even foolish. Bill Schlesinger feels that way today. With spikes and tape measure, he and co-worker Jane Raikes have staked out some 100 square yards of desert land in the Jornada Basin, 15 miles north of Las Cruces, New Mexico. Their claim includes some low-slung olive-drab creosote bushes, a clump of wispy tan snakeweed, and a lot of bare soil. Some ants roam the ground. A palm-size Texas horned lizard tries to stay cool in the shade of a creosote. It is a patch of desert that looks pretty much like countless other patches of desert in North America. ▪ Why anyone—even someone like Schlesinger, a biogeochemist from Duke University in North Carolina—should bother to mark and study this particular patch of desert is hard for an outsider to divine. Schlesinger is aware of this. So, as he calls out pairs of numbers to Raikes, he is not surprised by the puzzled looks he gets from passing weekend horseback riders. Raikes goes to the corresponding coordinates in the plot, armed with a rock hammer and a metal pipe. She drives the pipe two inches into the ground, the blows ringing out in the silence. Then she pries the pipe out and taps the clogged soil into a Ziploc bag. "I can see it in the press now," says Schlesinger. " 'They banged a pipe in the dirt many times and found it exciting.' "

Despite his habitual self-mockery, Schlesinger knows that the tablespoons of soil he and Raikes are collecting may help reveal a profound secret of the desert. If Raikes and Schlesinger had come to this spot 150 years ago, they would have been surrounded by almost uninterrupted grasslands stretching across the basin. Somehow the Jornada has since changed, and Schlesinger, Raikes, and the other researchers who work here think they know why. In many cases, they believe, a desert is like a living organism. Like a cactus or a sidewinder, it needs parents to give it birth, but once kicked into the world it can grow and thrive on its own. Deserts aren't necessarily the product of outside forces like decreasing rainfall, they say. Rather, it's the internal ecology of the desert itself—its web of plants, animals, and soil—that drives its growth to maturity and stability. Nor does the transformation of a grassland to a desert necessarily mean the creation of a place where life is more scarce—only one where life is rearranged.

"The ranching industry doesn't like us at all. They'd love to say that cows make no difference, that it's all drought or climate change or

able to absorb water. Rain flowed over this soil rather than into it, forming channels. No longer lingering in the upper soil, where grass roots grew, the water instead either escaped downstream or percolated through the channel bottoms, down to where only the deep-rooted shrubs could get to it. Hoofprints gave rise to pools of water that infiltrated the soil, creating spots for a seedling to take root and thrive. Water was no longer evenly spread over the basin, but now concentrated in scattered places.

By the time the giant herds left the Jornada, they had pushed it over a critical threshold. Now the ecology of the desert itself took up where outside influences left off. Thanks to patchiness, shrubs established a foothold, and they made the patchiness even greater.

"The shrubs are deeply and widely rooted," explains Schlesinger, "so they're obtaining nitrogen from a big area of the desert. It's at low concentrations out there, but they're getting it and concentrating it in their tissues. Then as the shrubs drop their leaves, the leaves fall under the shrub. It's like a pumping mechanism. They're sucking nutrients in from far and wide and dumping them under their canopies. The leaves decompose under the shrub and the nitrogen gets circulated. The bulk of the nitrogen is what gets circulated from under the shrub, but every year there's new nitrogen that's also being added from these roots."

The shrubs rearranged the nitrogen in the basin from a smooth layer to concentrated and increasingly isolated "islands of fertility." Wind and rain began to make these islands grow faster. Gusts scoured the bare patches, carrying away nutrient-rich dust, but when they hit the canopies of creosote and mesquite, they broke into whirling, weakened eddies, dropping their dust—as well as dead leaves and other organic matter—to the base of the shrubs. When a raindrop hit unprotected soil, it shoveled up the topsoil and carried it away in the overland flow of water, and when the water hit the downslope edge of the patch, it carved away even more soil. But the shrub roots protected their islands from the flow, and their leaves broke the fall of raindrops, which dribbled gently to the spongy ground below.

The mesquite and creosote also brought animals adapted to them, which in their own ways helped the islands grow. Termites and kangaroo rats collected food from a wide range and stored it in their nests, which they often made under shrubs. In this way they brought a lot of organic matter into the islands and took it away from surrounding areas. Meanwhile, nests they established away from the shrubs often became ideal birthplaces for new seedlings.

Even the shape of an insect's mouth could help build the desert. "In a grassland, most of the processing is done by chewers," says Whitford, and the droppings of these grassland insects—the scientific term is *frass*—consist of tough, complex material that spreads over the ground before it finally breaks down. "But the insects you find on shrubs," he explains, "are predominantly guys with mouthparts like little hypodermic needles, and they're sticking them directly into the vascular system of the plant and siphoning off its sap. The frass is basically a simple sugar solution. When that hits the soil, you've got a ready source of energy for the microbes to use and break down into the soil, where it's available for growing plants."

According to the model, all these feedback cycles will eventually, over the course of millennia, reach an equilibrium in the Jornada. When a shrub dies, the island it leaves will be a nursery for a new one, which will be protected from fire by the distance from one island to the next. Neither hard, bare soil nor shrub-dominated islands will offer any hope to colonizing grass. And since the soil will hold less and less water, rain recycling will stop, making the desert even drier.

Rain erodes the bare, hard soil of deserts, but plants can offer some protection. To determine how much, researchers collect sediment washed from staked-out plots.

Ecology being such a slow science, the researchers knew that by proposing this model they were indenturing themselves for decades. Seven years after their first brainstorm, they sound hopeful. "Just about all the evidence we've collected so far supports it," says Reynolds. New Mexico State University biologist Laura Huenneke, for example, has been measuring the mass of the Jornada vegetation, and she finds that the central tenet of the model holds true: arid grassland and shrub-dominated desert contain about the same weight of plant material. It's just arranged differently.

The researchers even feel confident enough now to argue that the Jornada model explains desertification in other parts of the world. The grass may not be black grama and the shrubs may not be mesquite and creosote, but the basic process seems universal.

The model also ought to apply to the spread of deserts before humans began to change the landscape, with slow shifts of climate playing the role of grazing cattle. As a grassland experienced centuries of decreasing rainfall, this scenario goes, the upper level of the soil would dry out. Grasses, with their shallow roots, would suffer, but shrubs would still be able to tap the deep water that trickled into the ground from storm runoff, and they'd start building their islands. A simultaneous change in the composition of the atmosphere could speed the process. Grasses are much more efficient absorbers of carbon dioxide than are plants like mesquite and creosote, and so they can thrive on low levels of the gas. But when the atmospheric level of CO_2 jumped from time to time, grasslands lost their competitive advantage and became vulnerable to shrubs and patchiness.

With an average of only nine inches of rain a year, the Jornada is always in danger of drought. "Rain-out shelters" allow ecologists to see how well plants will survive.

As they test the model further, the researchers crawl over the basin like a swarm of locusts. Schlesinger and Raikes, for example, bang their pipes into the dirt and find it fascinating because they want to see how the distribution of chemicals in desert soil changes over millennia. The model predicts that the chemicals important to life get concentrated under vegetation, while unnecessary elements like lithium and bromine remain smoothly scattered. Schlesinger is collecting soil samples from Jornada grassland and shrub land and comparing them with samples from the Mojave Desert in California, where a dry climate has allowed creosote to build islands of fertility for 10,000 years. If the model is right, he should see a progression in the distribution of chemicals from young desert to old.

However, it is not these last stages of the model that are most controversial, but the first ones—in which grazing supposedly gives islands of fertility their start. The human causes of desertification and their cures have attracted vast amounts of money and prompted political wrangling. Billions of dollars have already been spent in various schemes to fight desertification, even though researchers are only beginning to understand how it works. Critics maintain that developing countries use the fear of spreading deserts as a way to guarantee a flow of aid. But the argument isn't limited to Third World nations. In the United States, environmental groups are urging Secretary Babbitt to increase fees for grazing on the 280 million acres of public rangeland. Cheap grazing rights, they say, degrade the land, drive species extinct, and lead to desertification. Ranchers claim that they've improved their grazing practices since the turn of the century, so that the only real effect of raising grazing fees will be their bankruptcy.

The Jornada researchers try their best to keep the hue and cry from affecting their work. "The ranching industry doesn't like us at all," says Schlesinger. "They'd love to say that cows make no difference, that it's all drought or climate change or kangaroo rats. But I don't see these things as mutually exclusive. There's no point in our singling out one thing at the expense of others."

"The debate has a hell of a lot less to do with science than emotion," says Whitford. "It's about economics, about whose ox is getting gored. Hopefully we can provide some factual information. We don't have unequivocal evidence that there are these links; that's why we're doing the experiments we're doing."

So far those experiments have given them results that are suggestive but not conclusive. In 1982 the Jornada ecologists closed off some plots from the USDA's cattle. Over the following ten years many of the plots that still had some grass in them dramatically improved, compared with unprotected grass nearby; meanwhile, shrub-dominated plots saw no change. Still, some of the plots untouched by cows also died out, suggesting that drought too must play a role in the long-term survival of grassland.

However, New Mexico State University ecologist William Conley has shown that droughts may not have been so important in the Jornada. Grass is indeed susceptible to drought, but only when it strikes during the summer growing season. The USDA's 80-year record of rainfall in the basin shows that droughts this century have actually hit the Jornada more during the winter, the growing season of mesquite and creosote. If any-

kangaroo rats. But I don't see them as mutually exclusive. There's no point in our singling out one thing at the expense of others."

Though desert has spread over most of the Jornada Basin, a few stretches of black grama grass remain. In the distance, however, is an encroaching swath of creosote.

thing, they should have helped the grassland survive. Conley also made a statistical analysis of the rainfall record that shows that the droughts were not freakish; they had probably hit the Jornada every few decades for centuries. If they had the power to desertify, the Jornada should have become a desert long before Mexicans first passed through it.

That leaves grazing as the most likely culprit. Only now, though, are the Jornada ecologists performing the experiment that can document the steps by which cattle may initiate islands of fertility. Almost dead center in the basin, a wave of mesquite is rolling over some of the last remaining black grama. In 1993, on the border between the two plant communities, USDA researchers set up 18 fenced enclosures, each about 750 feet square. In 9 enclosures they hacked down the mesquite and painted the stumps with herbicide; the other 9 sites were left untouched. Whitford, who has continued to study the Jornada since he joined the Environmental Protection Agency in 1992, cataloged all the plants and animals. Schlesinger, who with Reynolds now heads the Jornada Long-Term Ecological Research Project, measured the distribution of dozens of chemicals in the soil. Before this winter is over, Havstad will bring two dozen head of cattle into 6 of the corrals and let them graze for 24 hours, in which time they should devour two-thirds of the grass and trample the ground. This summer he will let them loose in 6 others, while the 6 remaining will stay unmolested. In the next five years the researchers will measure how the soil, plants, and animals change in response. Two of the grazed plots will be burned and 2 others will be covered in rain-out shelters to see how fires and droughts enhance or reduce the effects of grazing.

If the story of the Jornada does turn out to be the story of other deserts, then ecologists should be able to foretell the story of deserts not yet born. And that's a skill that may be in high demand in the coming decades. As we burn fossil fuels and add carbon dioxide to the atmosphere, we once again take away the competitive advantage grass has in a CO_2-poor world. Simulations also suggest that global warming may make continental interiors drier. Grasslands that now get comfortable levels of rain may become vulnerable to grazing, as the Jornada was in the nineteenth century.

For over 20 years Reynolds has been turning data collected in the Jornada into mathematical equations. By calculating 200 variables, he can now accurately simulate the year-to-year evolution of a few square yards of the Jornada, whether it's occupied by grass, an island of fertility, or bare soil. Now he's stitching these patches together into a quilt that represents the entire basin. Using its actual topography and weather, he lets the patches interact. Shrubs deplete the surrounding soil, and bare patches help erode neighboring topsoil as water flows from one patch to the next. By measuring the growth of creosote and mesquite in an isolated, CO_2-flooded area, Reynolds hopes to be able to predict how the basin will evolve in the near future.

Ultimately the simulation should be able to predict the fate of any grassland. An ecologist in Chile, for instance, could feed a computer data on the local topography, weather patterns, and patterns of vegetation and see how likely the land would be to shift over to desert. "We'll be able to say how sensitive places will be to grazing and climate change," says Reynolds. "We can say, this area is not beyond the threshold and it would be worth trying to restore it, but this other area has changes that are irreversible."

Irreversible is a tough word, but the Jornada model makes clear why most efforts to restore self-sustaining grasslands are futile. Take away the shrubs, and the landscape, full of islands of fertility, is still perfectly suited for new creosote and mesquite to invade. "We've talked about a homogenization experiment," says Reynolds, "in which we'd go out to some of the big dunes where it's really heterogeneous and just bulldoze those babies and see if when you distribute everything, the grasses would be successful again. This would just be an academic pursuit; it wouldn't be a restoration tool." Deserts do turn to grasslands naturally, but only when thousands of years of steadily increasing rainfall counteracts the power of the islands of fertility.

Perhaps the name Jornada del Muerto should now be changed to Jornada del Desierto. Just as people have journeyed across the basin for centuries, the land itself is taking a journey that these researchers are now able to trace. According to Whitford, history may provide a glimpse of its destination.

"Climatically, North Africa should be a grassland savanna," he says. "You can go back to historical records and read about the trees on the mountains and lush grass, about how they were the breadbasket for Rome, providing grain and meat to the empire. Well, now it looks like parts of Nevada. You put these things together and say, 'Well, the model probably worked there, and it looks like it followed the trajectory that we're following in places like the Jornada.' We're well on our way." D

Net Primary Production: Patterns and Implications

Project Coordinator: Laura F. Huenneke, Department of Biology, New Mexico State University

We have sampled vegetation at 15 sites (3 each in *Larrea*-dominated, *Prosopis*-dominated, and *Flourensia*-dominated shrublands, and 3 each in *Bouteloua eriopoda*-dominated grasslands and dry lake (playa) ecosystems) since spring 1989--an accumulation of 18 sample periods thus far. Analyses from the first several years of data indicate:

- mean aboveground biomass does not differ between ecosystem types.

- aboveground biomass is distributed in a more heterogeneous manner in the shrublands than in the grass-dominated systems, when measured at the scale of 1-m^2-quadrats.

- mean net aboveground productivity (NPP) does not differ between ecosystem types.

- productivity is more spatially heterogeneous in shrublands than in grasslands in some seasons.

As we gather enough data, we will test the prediction that grassland systems demonstrate greater temporal variation in productivity than do shrub systems, because of the greater reliance of grasses on shallow soil moisture.

Because the dataset separates biomass and NPP by species, we have a rich record of plant community structure and dynamics. Analyses indicate that our shrub systems are more species-poor (and display lower values for evenness) than the grasslands, and that the species assemblage of shrub-dominated sites is derived from an impoverishment of the grasslands (rather than from a replacement of one set of species by another). This research also shows the difficulties of evaluating the biodiversity of arid ecosystems, which experience great temporal variability.

The community data are currently being used to address a topic of major concern: the relationship between biodiversity and ecosystem function. We are interested in whether sites with different plant species diversity or growth forms display different levels of NPP and other measures of ecosystem function. Preliminary analyses suggest a tendency for the most species-rich ecosystems to have higher NPP--at least in some seasons (e.g., fall 1992 in Figure 1). However, the cumulative species number recorded for a site over the entire study is not correlated with mean annual NPP (Figure 2). We are particularly interested in whether higher diversity serves to buffer the severe fluctuations in NPP that characterize arid lands. To date, our data for cumulative species number are not correlated with simple measures of variation in NPP (Figure 3).

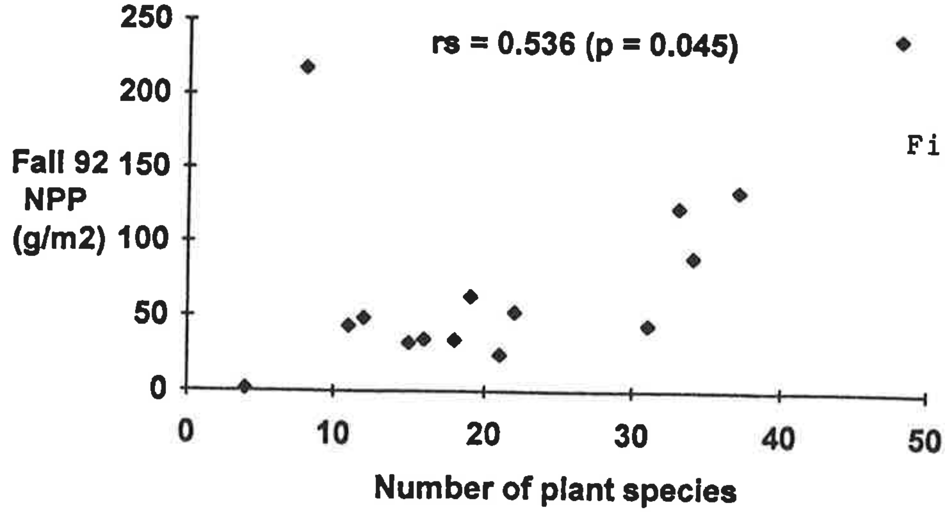


Fig.1

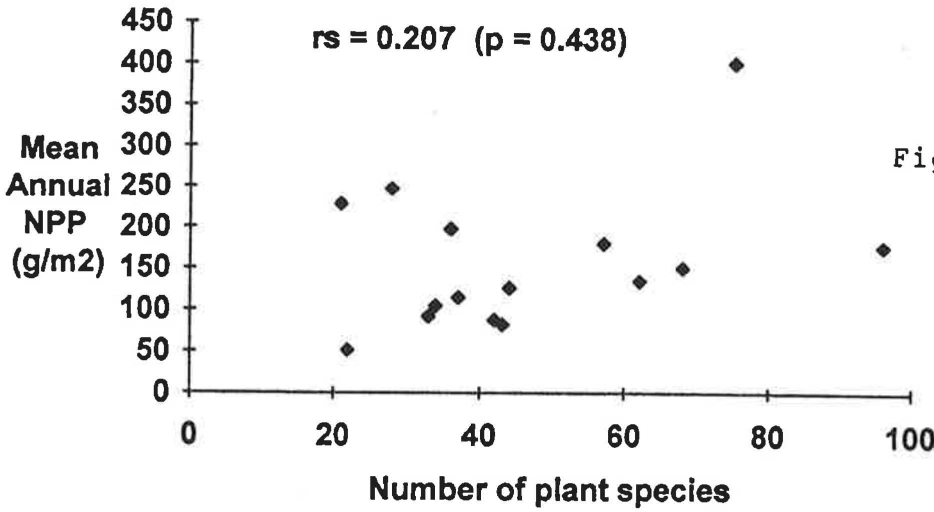


Fig. 2

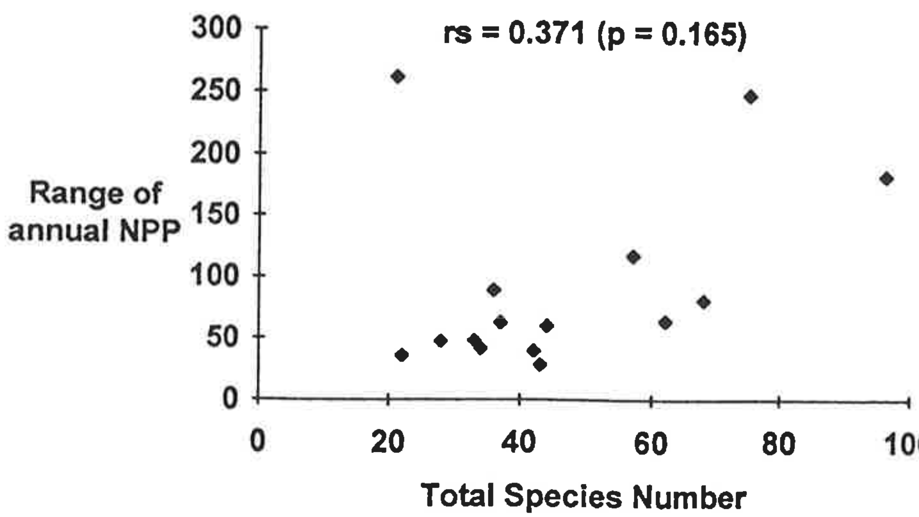


Fig. 3

Studies of Animal Communities

Project Coordinator: David C. Lightfoot, Department of Biology, University of New Mexico

Initiation of new studies of animal populations and modifications of existing (Jornada LTER-II) studies were completed over the 1994-95 academic year. Some existing lizard pitfall trapping plots have been moved to locations adjacent to plant production plots to better balance our experimental design. Each of the lizard sampling plots in each of the major habitats--creosotebush, mesquite, tarbush, and grassland-- is now associated with a vegetation plot. Lizard sampling for spring 1995 has just been completed at all sites.

Termite foraging measurements that are conducted on the lizard study plots are continuing. Termite foraging baits were placed on the study plots in January 1995. In addition, a new series of arthropod pitfall traps has been installed, and these have been operational since February 1995. The first series of samples was collected in April 1995. Pitfall traps that are specifically designed for ground-dwelling arthropods have also been installed in the major study sites. The arthropod pitfall traps employ the design used at the Sevilleta LTER site, to allow for cross-site comparisons of ground-dwelling arthropods in the Chihuahuan desert. Thus, we now have an integrated sampling program to collect data on plant production, various arthropod trophic groups, and predatory lizards--in major habitats of the Jornada basin.

Vegetation and soil measurement plots and rodent trapping webs for the new small mammal exclosure study were installed in February 1995 at grassland and creosotebush sites. The first series of rodent trapping and vegetation and soil sampling was completed in April 1995. Exclosure fences will be constructed during the 1995-96 academic year, after one year of pretreatment measurements on the study plots.

Spatial Distribution of Soil Resources

Project Coordinator: William H. Schlesinger, Departments of Botany and Geology, Duke University

We examined the spatial distribution of soil nutrients in various desert ecosystems of the southwestern United States to test the hypothesis that the invasion of semiarid grasslands by desert shrubs is associated with the development of "islands of fertility" under shrubs. In grasslands of the Chihuahuan desert of New Mexico, 35-76% of the variation in soil N was found at distances < 20 cm, which may be due to local accumulations of soil N under *Bouteloua eriopoda*--a perennial bunchgrass (Figure 4). The remaining variance is found over distances extending to 7 m, which is unlikely to be related to nutrient cycling by grasses. In adjacent shrublands, in which *Larrea tridentata* has replaced these grasses over the last century, soil N is more concentrated under shrubs and autocorrelated over distances extending to 1.0-3.0 m, similar to mean shrub size and reflecting local nutrient cycling by shrubs. A similar pattern was seen in the shrublands of the Mojave desert of California. Soil PO_4, Cl, SO_4, and K also accumulate under desert shrubs, whereas Rb, Na, Li, Ca, Mg and Sr are usually more concentrated in the intershrub spaces. Changes in the distribution of soil properties may be a useful index of desertification in arid and semiarid grasslands worldwide.

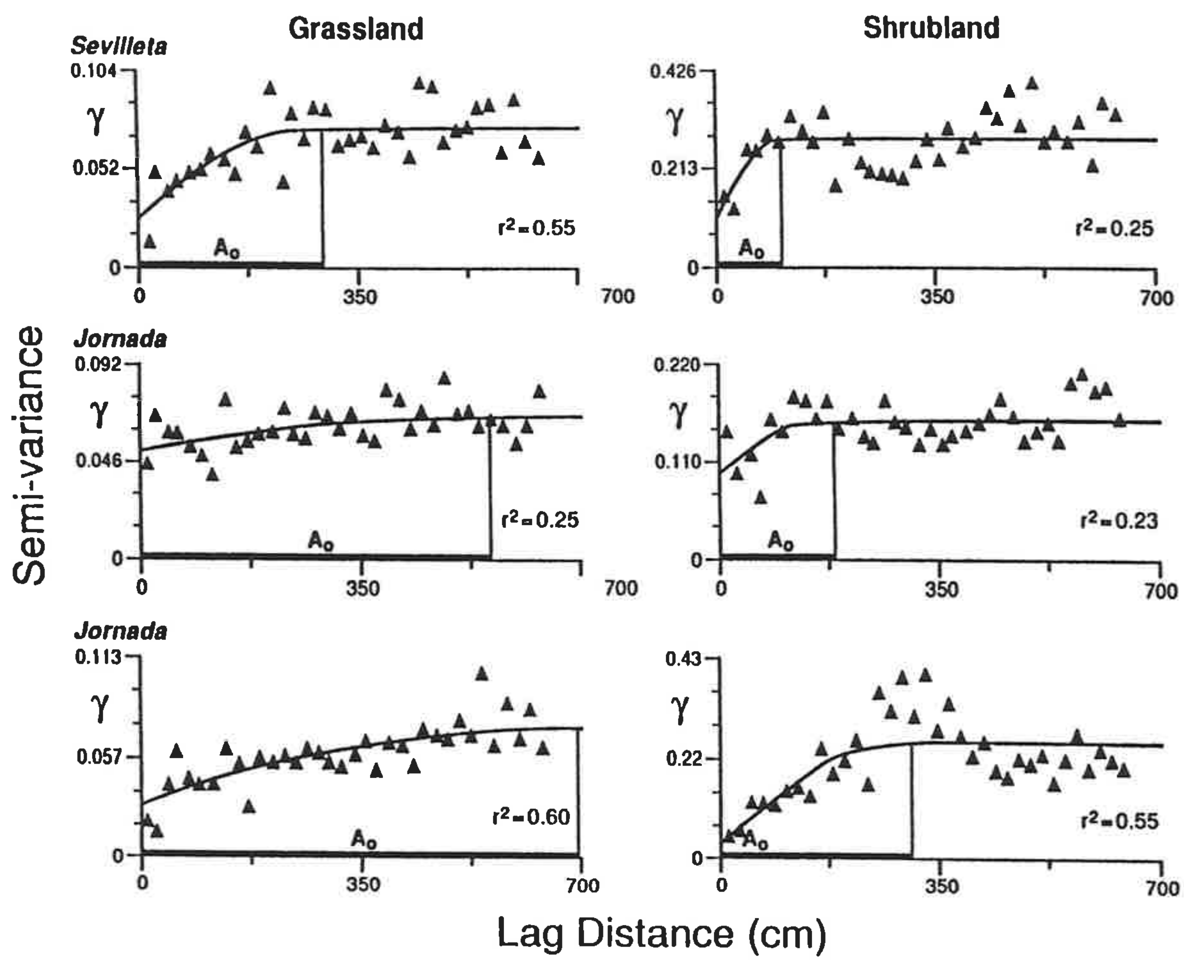


Figure 4. Spherical model semi-variograms for the distribution of soil N_{avail} in grassland and shrubland soils at the Sevilleta National Wildlife Refuge and the Jornada Experimental Range in the Chihuahuan desert of New Mexico.

Dynamics of Soil Organic Matter in Response to Vegetation Change

Project Coordinator: Ross A. Virginia, Environmental Studies Program, Dartmouth College

We are using the 13C/12C isotope ratio of soil organic matter and pedogenic carbonate to quantify changes in the soil carbon pools that are associated with the replacement of grasslands by shrublands at the Jornada. The grasslands are dominated by plants using C-4 photosynthesis, whereas the shrublands are characterized by C-3 plants--resulting in different isotopic ratios in the organic matter deposited in the soil.

The 13C isotope ratio of plant debris derived from mesquite and black grama are -25% and -15% , respectively. Preliminary results indicate that the C4-C3 community transition can be traced by isotopic analysis of soils (Figure 5). C-13 values for soil detritus in the black grama grassland suggest that 93% and 100% of the heavy and light fractions, respectively, at the soil surface are derived from C-4 plants. C-4 dominance declines to 72% at 90 cm in the light fraction and to 51% at 100 cm in the heavy fraction. This trend suggests that C-3 plants previously dominated this site; C-4 grasses arrived more recently. Detritus derived from C-3 plants is found in a calcic horizon at 100 cm, which may represent material that is considerably older than the organic matter immediately above the calcic horizon. This might be expected if calcic horizons protect ancient carbon from modern pedogenic processes.

The C-13 profile for carbonate indicates a relatively stable proportion of C3 and C4 plants over the period of carbonate formation. Average C-4 influence is approximately 55%, suggesting that this material formed early in the site's history.

Rapid C-13 enrichment with depth in recently deposited dune material serves as a marker for the modern C4 to C3 community transition. This enrichment exceeds typical profile variations seen in steady-state conditions. From the soil surface to 170-cm depth, the percent C3 contribution decreases from 72% to 16% and from 92% to 78% in heavy and light fractions, respectively. These differences, when compared to the grassland profile, indicate that mesquite detritus is present in the light fraction to 170 cm and in the heavy fraction to 140 cm. Differences between fractions may result from greater turnover rates associated with the light fraction. Comparisons of percent C-4 carbon in the A and Ab horizons of grassland and mesquite dune profiles, respectively, allow a calculation of the turnover of grass litter. Assuming a dune age of 80 years, the approximate turnover time of grass detritus is 98 years.

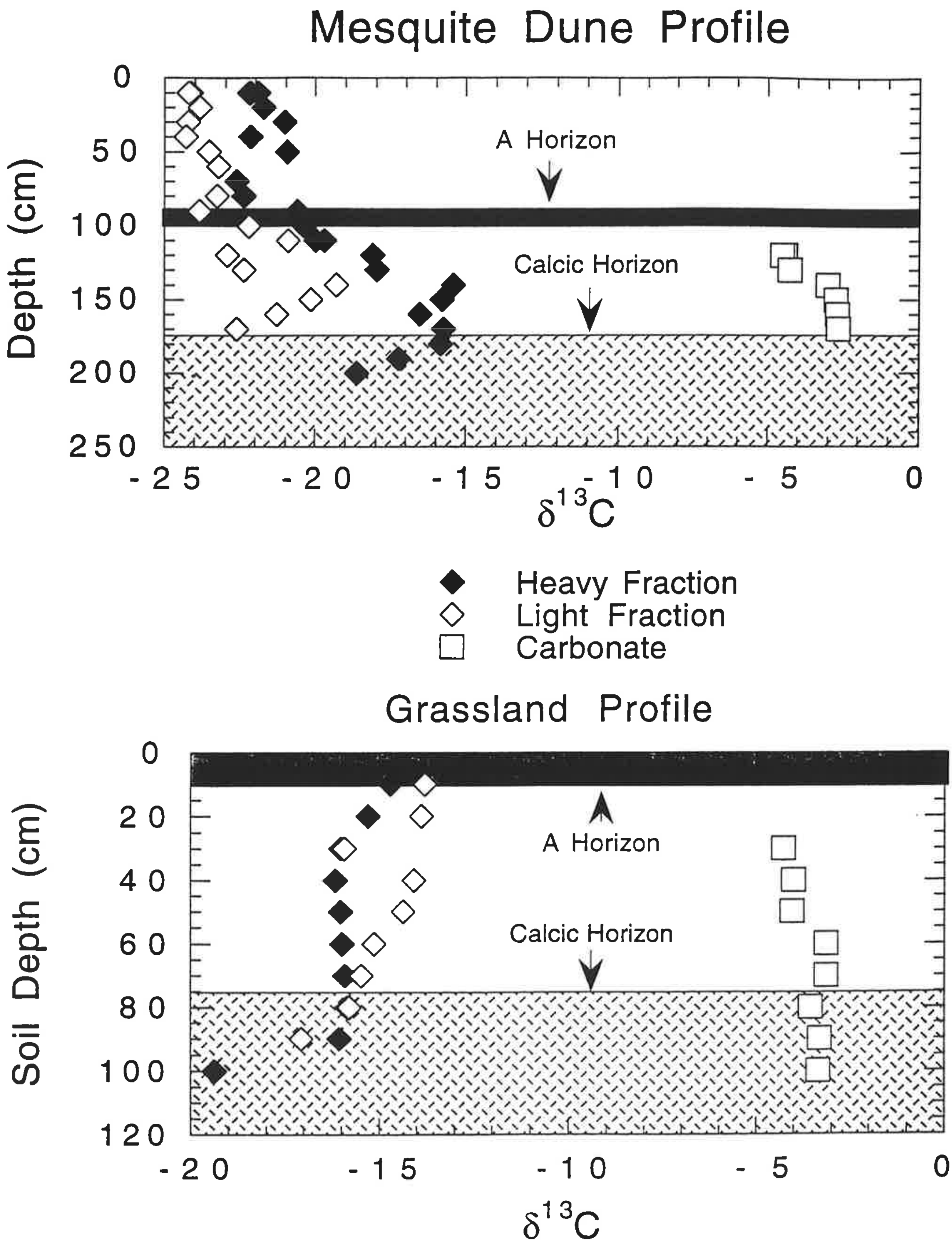


Figure 5. $\delta^{13}C$ profiles for two fractions of soil organic matter and pedogenic carbonate in grassland and mesquite dune soil profiles.

Studies of Soil Development in the Quaternary

Project Coordinator: H. Curtis Monger, Department of Agronomy, New Mexico State University

Human land use is closely linked to the modern trends of desertification in the Chihuahuan desert. Although remote sensing can monitor current desertification and old photographs and survey records provide estimates of desertification since the late 1800s, an understanding of the prehistoric trends in arid lands must rely on the sedimentary record. Detailed soil-geomorphic mapping reveals several cycles of erosion and sedimentation during the Quaternary. More recent studies indicate that paleosols contain isotopic evidence of desertification that is driven by changing climates and atmospheric carbon dioxide levels.

The goal of our pedologic studies is to refine our knowledge of natural desertification by mapping, dating and analyzing stable isotopes and fossil pollen in paleosols. Then by using sedimentation rates as a proxy for desertification, we hope to gain insight about the magnitude of human-induced desertification by comparing it to natural, historic desertification. In order to achieve this goal, detailed, comparative soil-geomorphic mapping is being conducted in the Chihuahuan desert in the Jornada basin, at Big Bend National Park, and at Boot Hill in southwestern New Mexico.

Although the mineralogy of arid soils has been studied using thin-section petrology the relationship between soil minerals, microbes and roots is not well known. Our petrographic studies are designed to observe the relationships of microbes--mainly fungi--with soil minerals and roots. The goal of this research is to help elucidate the role that microbes play in mining soil nutrients and water for desert plants.

Studies in microbial ecology - pattern and process.

Project Coordinator: R. Peter Herman, Department of Biology, New Mexico State University

There is little difference in the population of microbes in the Nitrogen Efficient Guild (NEG) in soil samples taken near plants compared to between-plants in grasslands, with a 10-40 fold rhizosphere effect limited to root-adhering soil. These results are consistent with predictions based on the resource island hypothesis. If soil nutrients are relatively evenly distributed in grasslands, one would predict that soil microorganisms would be relatively evenly distributed.

We have examined the resource island hypothesis further by measuring the NEG and "total heterotroph" populations in one example of each of the five major vegetation types found at the Jornada LTER. Soils were collected from the plant and interplant spaces in bajada and playa grasslands, as well as creosotebush, mesquite and tarbush shrublands. Total heterotrophs were enumerated by a most probable number (MPN) technique due to problems with swarming organisms on dilution plates. The NEG were enumerated by plate counts as previously described (Herman et al. 1994). Both heterotrophs and NEG members followed the distribution pattern predicted by the resource island hypothesis. There were no significant differences in heterotroph or NEG numbers comparing plant and interplant samples for both the playa and bajada grasslands. Further, populations were generally higher in nutrient-rich playa grasslands than nutrient-poor bajada grasslands.

In contrast, both heterotroph and NEG numbers were higher under shrubs than between shrubs in all three shrub sites. The ratios of counts taken under plants compared to those taken between plants clearly show much higher ratios in shrublands than in grasslands. These results are illustrated in Figure 6 and Table 1. They suggest that resource abundance in shrub islands predicts the distribution of heterotrophic bacterial numbers in desert soils (Herman et al 1995).

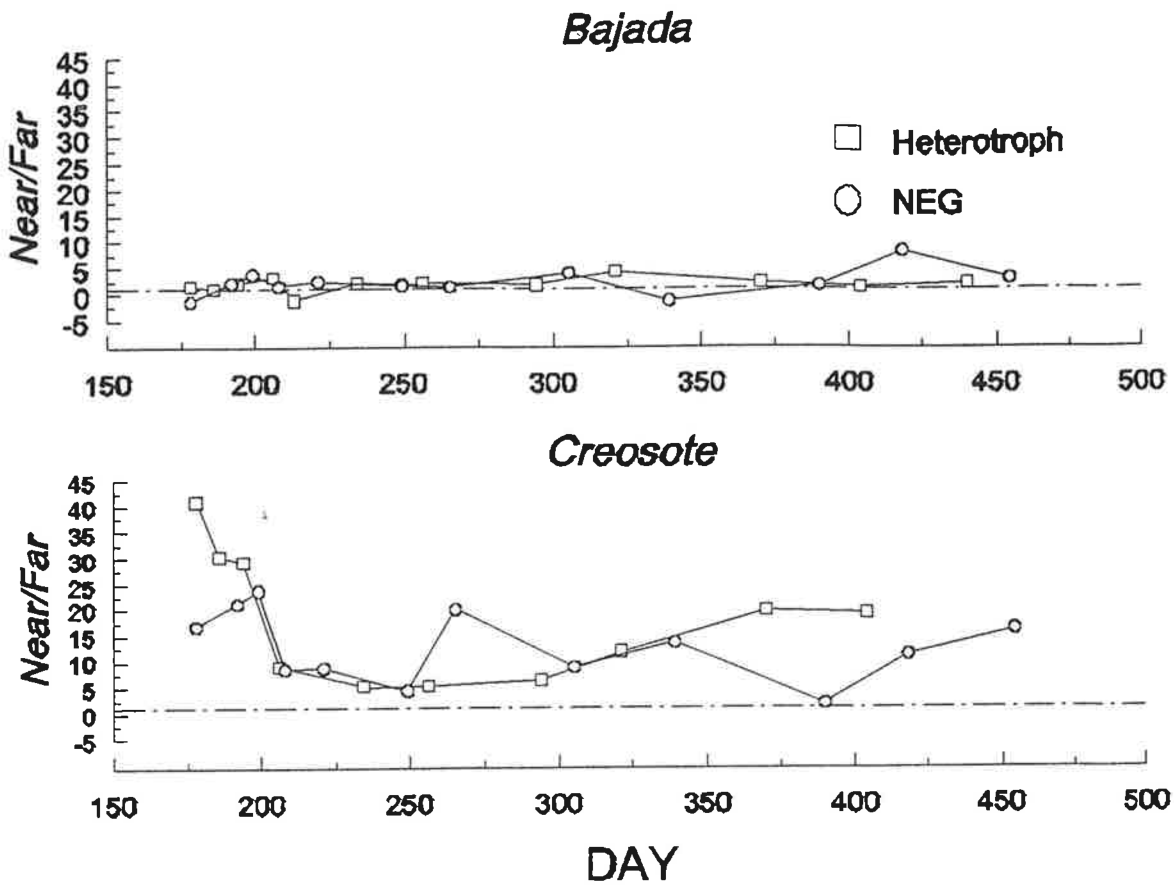


Figure. 6. The ratio of the near plant and far from plant sample numbers for Bajada Grassland (upper panel) and Creosote Shrubland (lower panel). Ratios for "total" heterotrophs (□) and NEG members (O) is shown for each site Day 1 is Jan. 1, 1993.

Table 1.
Mean At-Plant/Inter-Plant Ratios for Heterotrophs and Nitrogen Efficient Guild Members in the Five Vegetation Types

Vegetation	Heterotrophs		NEG	
Bajada	2.28	± 0.29	2.59	± 0.60
Playa	2.63	± 1.16	1.52	± 0.48
Creosote	17.11	± 3.32	12.91	± 1.97
Tarbush	5.81	± 1.19	4.93	± 1.13
Mesquite	5.96	± 1.34	5.91	± 0.83

Population variability in water-use characteristics of creosotebush (*Larrea tridentata*)

Project Coordinator: Vincent P. Gutschick, Department of Biology, New Mexico State University

Individual plants of *Larrea tridentata* vary in transpiration rates, water-use efficiency, and drought tolerance. These characteristics determine plant water status, competitive water use and ultimately fitness. We are sampling the variability in stomatal control that underlies many of these traits.

In regional hydrologic and general circulation models of global climate, evapotranspiration is typically predicted from remotely-sensed stand structure, plus knowledge of stomatal conductance as a function of microclimate and physiological control parameters. A plant's stomatal conductance, CO2 assimilation rate, transpiration rate, and water-use efficiency are determined by fundamental processes, of which stomatal control at various stages of shoot development is the least well understood. Among factors affecting stomatal control, we focus on surveying variation in the Ball-Berry slope, m, in leaf investment in carboxylation capacity, and in resultant water-use efficiency traits, especially leaf internal CO2 concentration. We believe that C_i and related physiological traits vary among plants as a function of local variation in soil texture, topography (areas of runoff or runon), neighbor density, and current plant stature.

For these studies, we have chosen 50 plants along a well-described (i.e., soil characteristics) transect in the Jornada Experimental Range. We make repeated measures of soil and leaf water potentials to measure plant water status in the field. To measure underlying stomatal control parameters, we measure leaf gas exchange over day-long intervals. A novel aspect of our work is the use of process models to reconstruct the diurnal course of leaf performance in free air from 3 to 4 measurements in cuvettes. We are testing our predictions of time-averaged C_i against those derived from carbon isotope discrimination in recent photoassimilate extracted from leaves. We are using hierarchical analysis of variance to examine variations in stomatal control among plants in different growth situations.

We have a special interest in assessing whether thermal damage and photoinhibition during drought affect the assimilation capacity of creosotebush. We have begun a comprehensive effort to measure photoinhibition and to measure and model the microclimatic histories of each leaf that might determine its potential for photoinhibition. To this end, Dr. Gutschick will visit M.C. Ball of Australian National University during the summer of 1995, where he will make comparative field tests near Bungedore, NSW. This effort is supported by ancillary funding obtained from the International Programs Division at NSF.

Hydrologic and Mass Transport Studies in the Jornada Basin

Project Coordinator: Athol D. Abrahams, Department of Geography, State University of New York at Buffalo.

A conceptual model of the hydrological behavior of the bajada surface has been developed, taking into account the flow concentration and dispersal mechanisms. These routing mechanisms are poorly understood and have not been implemented in other recent models. Accordingly, parts of the bajada below Mount Summerford were surveyed and 6 flumes were installed in January 1995 to investigate whether there is a link between the topographic parameters of slope and planform shape and the erosional controls of flow routing. These links are currently being developed into an algorithm for bajada flow, so that initial testing and validation of predicted patterns of flow may be performed. This testing will use the Digital Elevation Model (DEM) for the Mount Summerford area. Eventually more extensive testing and analysis of the model will be conducted over a larger area.

The record of runoff from natural precipitation events will be supplemented by studies using simulated rainfall on small runoff plots during June and July 1995. This work will encompass:

- an analysis of the movement of solutes in overland flow on grassland and shrubland.

- an investigation of runoff and sediment yield from the grassland and shrubland sites, coupled with an evaluation of the ability of WEPP (The Water Erosion Project Model) to predict these fluxes.

- a study of the impact of digging by small rodents on runoff and sediment yield.

- an investigation of the hydrological consequences of shrub canopies in intercepting and redistributing rainfall.

In addition, laboratory experiments are being carried out at SUNY-Buffalo with the goal of developing a sediment transport equation to predict overland flow on irregular hillslope surfaces under different rainfall regimes.

Wind Erosion: Relation to crusting in barren soils.

Project Coordinator: Dale A. Gillette, Air Resources Laboratory, National Oceanic and Atmospheric Administration, Research Triangle Park, N.C.

In the absence of protecting vegetation or clastic cover, resistance of the soil to wind erosion comes about by crusting of the surface. This crusting is caused by physical and chemical processes and by the presence of nonvascular plants. Experimental work is aimed at identifying soil crusts at the Jornada Range and to measure the stresses required to destroy these crusts with respect to wind erosion.

Samples of soil crust were obtained from 3 barren sites with visible soil crusting at the Jornada Experimental Range, over a period of about 1 year. During this period, there were no major wind erosion events although the crusts were wetted and reformed following precipitation events. These strong crusts required disturbance by animals or humans to lower the threshold velocity, allowing erosion by observed winds. Simultaneously, wind erosion thresholds were exceeded at the nearby Jornada USGS Geomet site, but the barren, sandy soils at that site were protected from wind erosion by shrub vegetation--not by crusting. Thus, barren soils are potentially protected from wind erosion by a variety of mechanisms in the Jornada basin.

In the past year, a permanent study site has been located, where crusting is present but the soil is abradable by wind. Three automated meteorological towers are being erected at this site and the in-situ history of the crust will be monitored. The three towers measure wind speed at 4 heights (0.2, 0.5, 1.0 and 2.0 m) and wind direction. The towers have been placed in the direction of the strongest winds, so that detailed 20-minute averaged measurements may be obtained for individual wind erosion events. In addition to wind, particle flux measurements are obtained at 4 heights--5, 10, 20 and 50 cm. The towers are powered by solar panels and record data on a DOS-based POQUET computer located in weather-proof data logger shells on each tower. Other measurements include soil moisture and air temperature taken at 2 heights. Collections of airborne soil particle fluxes are made using the BSNE collectors for 7 locations (3 of them corresponding to the towers) at 6 heights each--10, 20, 30, 50, 60 and 100 cm.

These studies are being made in parallel with similar measurements at Owens Lake, California, where environmental conditions at the NOAA/USGS cooperative Geomet tower have been monitored since May 1992. Several breakages in the surface crust have been recorded by the automated towers, allowing us to determine the conditions that produce active wind erosion at that site.

Disturbance: Patterns of Herbivory on the Jornada Experimental Range

Project Coordinator: Kris Havstad, Agricultural Research Service, U.S. Department of Agriculture

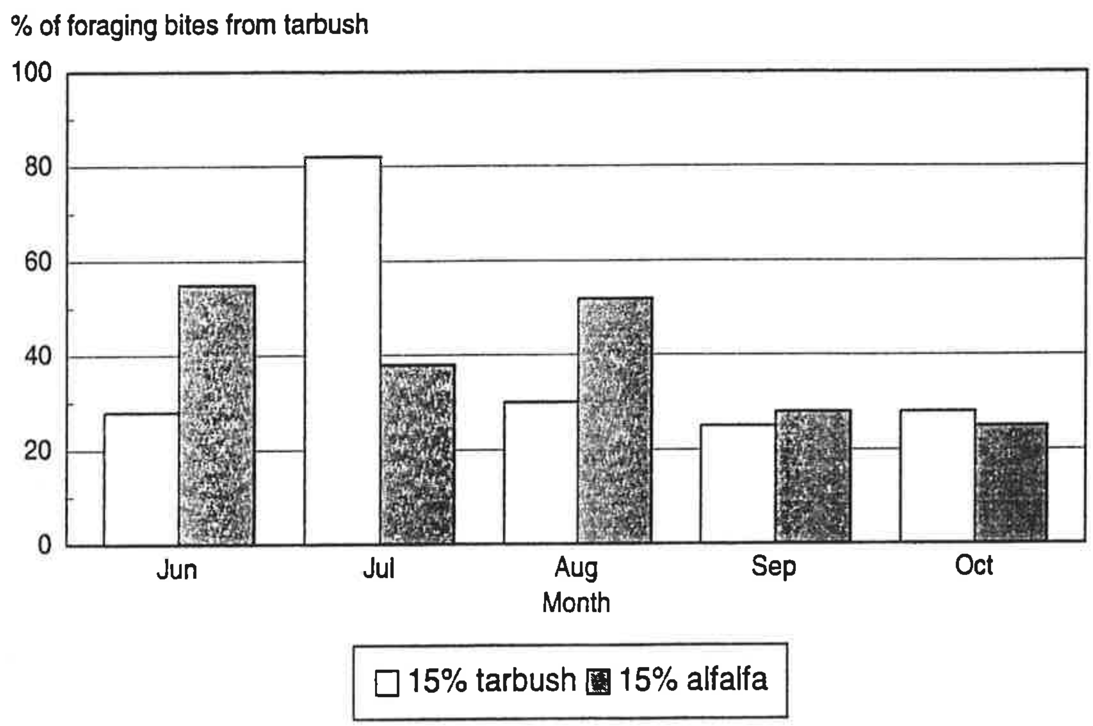
During 1994-95 we established the first of two sites designed to study the effects of acute defoliation stress on the dynamics of desert ecosystems. Each site consists of eighteen 0.5-ha exclosures; the first site was fenced and the main effect manipulation--shrub removal--was applied in 1994. The second site will be constructed by August 1995 and the shrub treatments will be applied in early 1996. The area selected for the second experiment is pictured in the color composite (page 27) included with this report.

Preliminary data, including vegetation composition and basal cover, have been collected across the exclosures of the first site. In addition, initial winter grazing and burning treatments have been applied, and 6 exclosures were winter-grazed by livestock in 1995. Approximately 80% of the aboveground perennial grass biomass was removed in a 24-hour grazing period. Small plots (3 x 4 m) in each of the 18 exclosures were burned in 1994. Baseline analyses of carbon and nitrogen in plant and soil samples from all treatments are being completed. Vegetation responses to these treatments will be first assessed in fall 1995.

We have studied the mediation by plant secondary chemistry of the selection of desert shrubs by grazing livestock. Diet selection by ruminants, including domestic livestock, can be described as a learned hedyphagia with euphagic consequences. We have focused on tarbush (*Flourensia cernua*), and hypothesize that diet selection is a function of preingestive sensory perceptions and postingestive feedbacks. We have converted lambs to tarbush consumption through early life exposure to feed mixtures containing tarbush leaves (Figure 7).

It is recognized that ruminants will reduce their ingestion of potential toxins to nontoxic levels, and we observed that postingestive malaise can control the intake of tarbush. We will continue these studies of animal feedbacks on diet selection from desert rangelands during 1996.

Figure 7. Foraging use of tarbush under rangeland conditions by lambs that had been raised in pens on pelleted feed. Two groups of lambs were raised on pellets that differed only in containing either 15% tarbush leaves or 15% ground alfalfa. Tarbush leaves had been harvested from entire plants in the previous August. Lambs received the pelleted ration for the first 120 days following birth. Only in July did lambs raised on tarbush use tarbush to a significantly greater extent. However, adverse weather conditions in July severly limited total grazing time for both treatments.



Patch and Landscape Models of Desertification

Project Coordinator: J.F. Reynolds, Department of Botany, Duke University.

During the past year, we have continued to develop the Patch Arid Lands Simulator (PALS) and the REgional General Arid Lands Simulator (REGALS). We developed 3 soil water models for use in PALS to evaluate the extent to which variation in plant growth form, plant cover, and soil texture interact to affect relative rates of evaporation and transpiration. These models incorporate the 1-dimensional distribution of water in the soil and have functions to make explicit calculations of transpiration and soil evaporation. PALS-SW includes soil water fluxes and emphasizes physiological control of water loss by different plant life forms; 2DSOIL emphasizes the physical aspects of soil water fluxes, and SWB is a simple water-budget model that has no soil water redistribution and simplified schemes for soil evaporation and transpiration by different life forms.

Model predictions were compared to observed soil water distributions at 5 positions, representative of different plant communities along the LTER topographic gradient from the base of Mt. Summerford to the playa. All models predict soil water distributions reasonably well (Figure 8), with similar trends in the fractions of water lost as evaporation vs. transpiration. Transpiration was lowest (ca. 40% of total ET) for the creosotebush community. The fraction of ET lost as transpiration increased with increasing plant cover, with 2DSOIL predicting the highest transpiration (60% of total ET) for the mixed vegetation community with 60% cover on relatively fine-textured soil, and PALS-SW predicting highest transpiration (69% of ET) for the mixed vegetation community with 70% cover on relatively coarse-textured soil. Community type had an effect on the amount of water lost as transpiration primarily via differences in the depth and distribution of roots. In this respect, PALS-SW predicted the greatest difference among stations as related to differences in plant community types. However, since PALS-SW did not fit the soil moisture data as well as 2DSOIL, differences in the morphology and physiology of life forms may be secondary to the overall control of water loss by the primary factors accounted for in 2DSOIL--the vertical distribution of soil moisture, canopy cover, and the evaporative energy budget of the canopy. Soil texture interacted with the amount and type of plant cover to affect evaporation and transpiration, but the effect was relatively minor.

We conducted a theoretical study of the definition and quantification of heterogeneity to aid us in understanding landscape ecology. The central hypothesis of the Jornada LTER

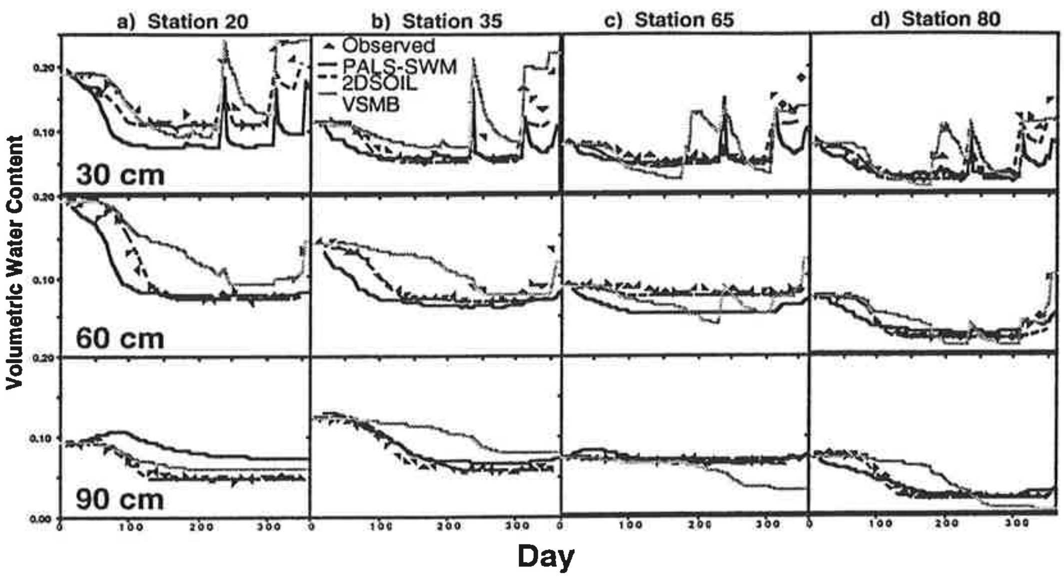


Fig. 8 Predicted volumetric soil water contents during 1986 for 4 stations along LTER transect at 3 depths using 3 soil water models in **PALS.** Points are observed water contents.

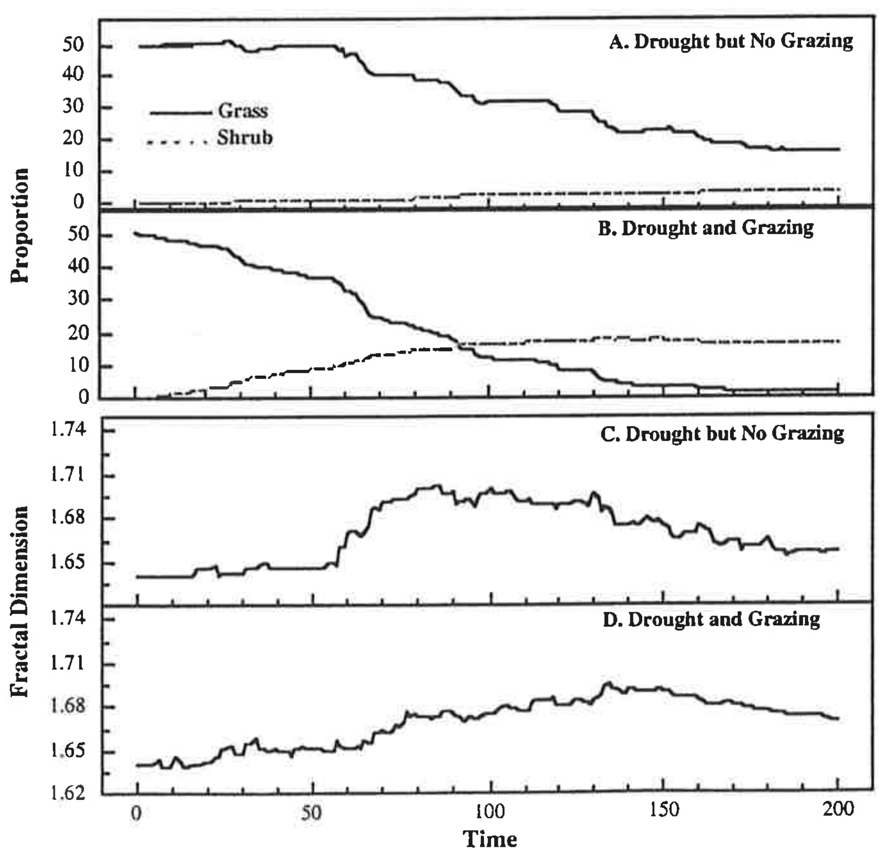


Fig. 9 Landscape dynamics with or without grazing simulated by **REGALS** (vers.CAM.1 model:

A and B: Changes in proportions of grass and shrub covers,
C and D: Changes in fractal dimension.

Ms. Barbara Nolen acts as our full-time expert in Geographic Information Systems (GIS) and remote sensing applications. Her efforts jointly support the LTER and the USDA research programs on the Jornada Experimental Range, including such 1994-95 milestones as:

- collection and archiving of satellite and aerial imagery.

- GPS survey of the research sites and associated human features on the landscape (e.g., fences and wells) to expand our on-line GIS database.

- processing a level-2 Digital Elevation Model for the area near Mt. Summerford.

- maintaining the following software on a PC platform for use by various local and visiting researchers: ARC/INFO for GIS layers, ERDAS for satellite imagery, Trimble Pathfinder for GPS surveying, ARCVIEW for viewing all data layers, and Adobe Photoshop for image manipulation.

- intersite cooperation with the University of Wisconsin's Remote Sensing Center for the archiving of LANDSAT-TM images on CD-ROM.

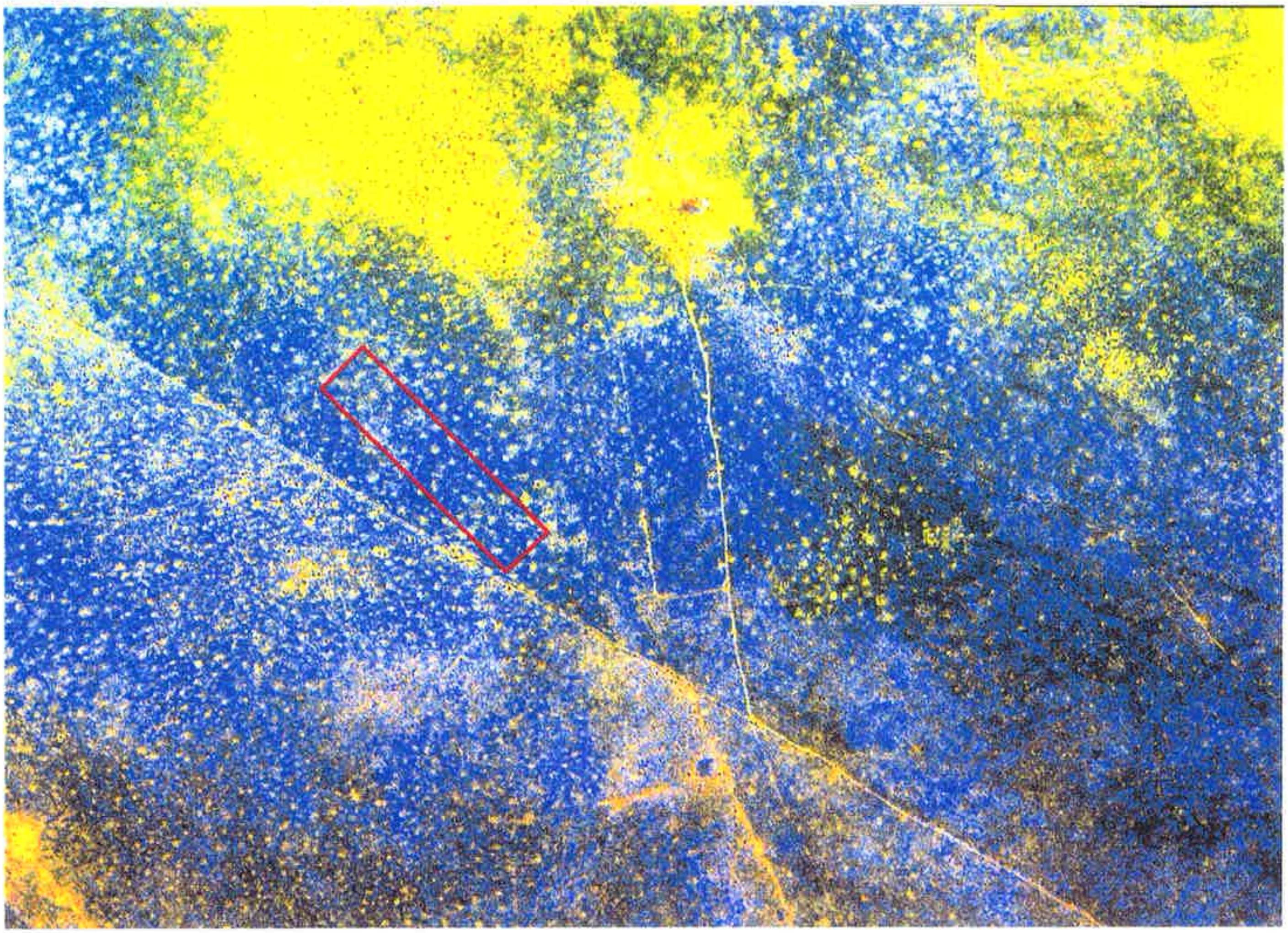
- acquisition and availability of Daedalus Imagery for some areas of the Jornada basin, courtesy of the Environmental Protection Agency's Environmental Monitoring Systems Laboratory, Las Vegas, N.V.

N.B. Figure 10 (overleaf) shows the Daedalus image of the area in which the second large "stressor" experiment is under construction. (See core area 5). The wavebands in microns are:

Band 6	0.60 to	0.65
Band 9	0.80 to	0.89
Band 11	8.0 to	13.5

Vegetation appears blue and bare ground as yellow.

LTER III Stressor Site
Daedalus Image 9- 17- 94
bands 9 6 11 3 m resolution



This imagery supplied courtesy of the US-EPA Environmental Monitoring Systems Laboratory-Las Vegas

Mr. Kevin LaFleur, the Jornada LTER data manager, accomplished a number of milestones during the past year, including:

- updating of all LTER-II data set documentation (metadata), and historical documentation of projects at the Jornada LTER.

- updating of all data sets with data header information, which describes the data fields and the various codes used in the data sets.

- revision and updating of data set keyword listing and catalog listings.

We now have an Insight Pentium 90 MHz IBM-Compatible PC with CD-ROM drive, 7 GB of hard disk storage area, 14.4 fax/modem and 8 GB WangDat tape drive. The Insight PC acts as a file server, storing and allowing on-line access to data sets and remote sensing images. The Insight PC will also act as a print server, allowing local users access the high speed HP LaserJet 4M+ printer, HP DeskJet 1200c color printer, and an Epson LQ-1500 dot matrix printer. The Insight PC is currently running Novell Netware v4.10, and access to the server is limited to the five computers in the LTER office. Currently all of the necessary software applications are being transferred from individual PCs in the office to the file server, and menu systems are being developed to allow easy access to the software, while maintaining security.

Current access to the campus network is by remote access as dummy terminals or dial-up communications. Efforts are being made to connect the Insight Novell server to the campus network and allow TCP/IP access to the server utilizing FTP, Telnet, Gopher and World Wide Web (WWW). The TCP/IP utilities will allow remote access to datasets that are placed on line as well as enhanced communication in both local and wide-area networks without logging onto the campus network.

N.B. The following tables show a list of long-term datasets maintained and a list of the requests received by our data management office during the last year and how, and how quickly, we were able to accommodate them.

JORNADA Long Term Data Sets

X Indicates study is listed in Long-Term Ecological Research Network Core Data Set Catalog.

	RESEARCH PROJECT	PERIOD	DESCRIPTION
X	Animal Transects	89-now	Biweekly; flush transects: birds, lizards, rabbits
X	Jornada LTER Weather Station	83-now	Meets Participation Level 2 & 3, Standardized Meteorological Measurements for LTER sites
X	Jornada Precipitation	81-now	Tipping bucket and graduated gage precipitation
X	Hydrology (LTERI)	83-92	Soil surface rainfall runoff and sediment transport data from termite exc
X	Hydrology (LTERII)	89-now	Soil surface rainfall runoff and sediment transport data from desert shru
X	Net Primary Production	89-now	Yearly; Winter,Spring,Fall biomass measurements
X	Pit Fall Traps - Lizard/Arthropod	89-now	Quarterly; lizards-mark/release; arthropods-collection
X	Soil Water Content - NPP	89-now	Monthly; 10 depths; 30-300cm
X	Soil Water Content - Transect	83-now	Monthly; 5 depths; 30-150cm
X	Termite Baits	89-now	Yearly; termite foraging activity
X	Vegetation - Fenceline (LTERI)	82-now	Every 5 yrs, spring & fall; vegetation response to grazing release
X	Vegetation - Transect (LTERI)	83-now	83-88 yearly then every 5 years; spring & fall; vegetation spatial & temporal pattern
X	Wet-Dry Precipitation Chemistry	83-now	NO_3, NH_4, Cl, SO_4, Ca, Mg, Na, K, total N, total P

USDA Jornada Experimental Range Long-Term Data Set

Abiotic
- precipitation, monthly, 29 locations, 1915-present
- precipitation, daily, 27 locations, 1976-present
- precipitation (summer), intensity, 27 locations, 1976-1986
- soil movement, 5-yr measurements, 160 sample points along 2 transects, 1933-1990
- soil moisture, weekly (soil moisture blocks), numerous sites, 1956-1976

Biotic
- basal cover, annually, 104 1m*2 quadrats, 1915-1979 (intermittent later years). Quadrats grouped within vegetation types and along grazing gradient.
- vegetation production, annually, clipping methods, variable locations, 1941-1988
- vegetation utilization, annually, transects, plant height measurements, 1939-1989
- vegetation composition, annually, transects, grouped by soil type, intercept measurements, 1957-1977

Livestock
- stocking, animal days, by pasture, 1920's-present
- performance, annually, various measures, 1972-present

JORNADA LTER DATA REQUEST LOG

SentBy: JA = John Anderson KL = Kevin La Fleur

RecBy	Date of Request mm/dd/yy	DateSent mm/dd/yy	RequestBy	RequestDescription	FileSize	FormatSent	SentBy
KL	10/03/94	10/07/95	Matt Hohmann Ohio St. Univ.	Transect Plant Line Intercept OCT82, OCT83, SEP84	395	floppy	KL
JA	10/21/94	10/21/94	Ted Floyd Penn St. Univ.	Monthly air(min,max,avg), precip Apr-Aug 93 & 94	2	email	JA
JA/KL	10/20/94	10/25/94	Leslie Sieger Colorado St. Univ.	Jornada LTER keyword listing Jornada bibliography	125 191	email email	KL KL
JA	11/21/94	11/21/94	Kay Gross KBS	Jornada LTER plant species list Listing: alpha and family	114	email	JA
JA	12/06/94	12/09/94	Bob Waide r_waide@upr1.upr.clu.edu	Long term data set list	2	email	JA
KL	01/02/95	01/06/95	Walt Whitford EPA	Data set doc for Animal Transect, Lizard and Arthropod pitfalls	77	floppy	KL
JA	01/10/95	01/10/95	Mike Atchley	Air temp & precip Jun-Sep 92-94	10	floppy	JA
KL/JA	01/25/95	01/30/95	Peter Herman NMSU	Transect soil H20 content & soil H20 potential	9	email	JA
JA	01/30/95	02/06/95	Kirk Maloney Iowa State Univ.	Jornada bibliography	191	ftp/ binary	JA
JA	01/31/95		Ben Sherman University of WI	Jornada bibliography [Waiting for Sherman response on file format and destination]			
JA	02/03/95	02/07/95	Adrienne Pilmanis Duke	Monthly summary climate data 1983-1994	18	email	JA
KL	02/03/95	03/14/95	Debbie Hartell Holloman AFB	USDA/NOAA evap pan 1962-1974	220	floppy	KL
JA	03/07/95	03/07/95	Chris Tripler Idaho St. Univ.	Jornada bibliography	191	email	JA
JA	03/14/95	03/14/95	Jeff Straka Iowas St. Univ.	Jornada playa invertebrate citations	3	email	JA
JA/KL	03/15/95	03/16/95	Wes Jarrell Graduate Research Inst. Beaverton, OR	Transect SWC (soil water content)	8889	floppy	KL
JA	04/03/95	04/04/95	Judith Lancaster Desert Research Institute Univ of NV	Pub: LTER in the U.S. - A Network of Research Sites 1991		hardcopy	JA
JA	04/25/95	05/01/95	Anne Hartley	Precip @ Upper Trailer Jun-Sep 92-94	18	email	JA
JA	04/28/95	04/28/95	Keith Killingbeck Univ of RI	Precip for U.T. (85-95) & C-CALI (89-95)	26	floppy	JA
JA	05/15/95	05/16/95	Sarah Valentine McBeans@io.com	Jornada LTER plant list	61	email	JA

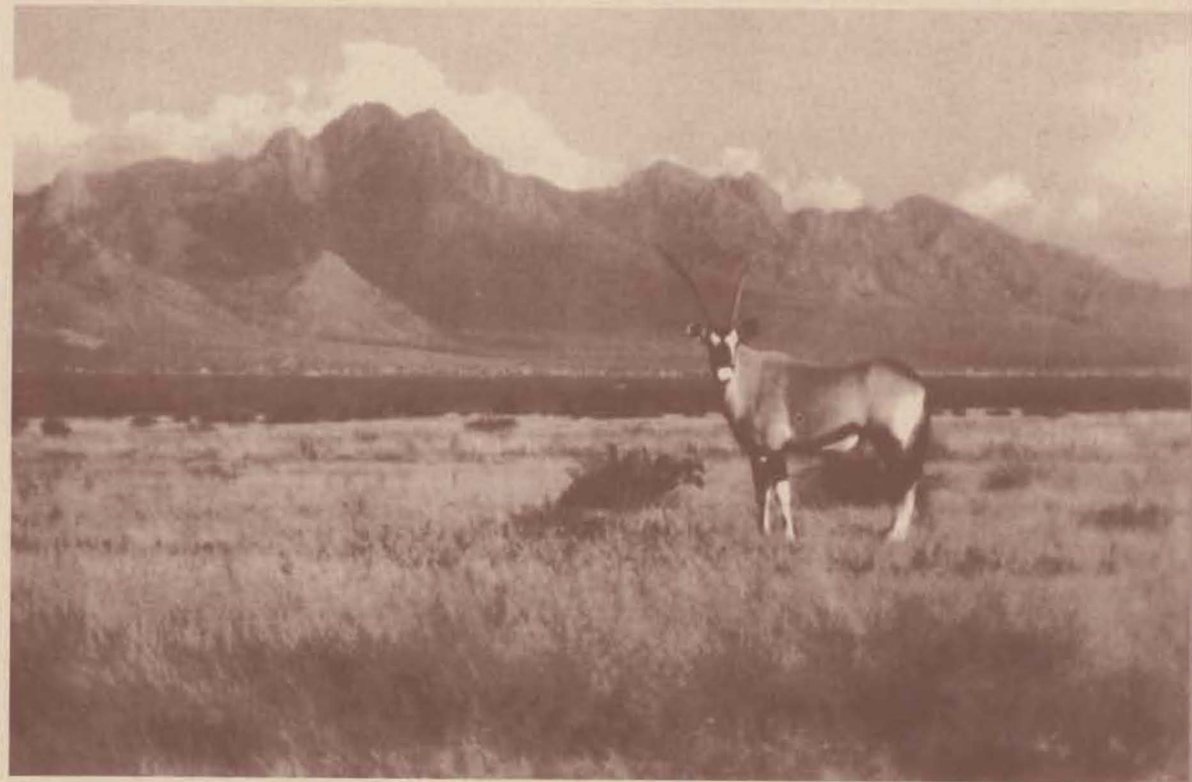
New Mexico State University

ANNOUNCES

THE NINTH

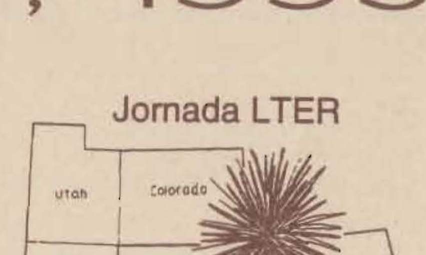
Wildland Shrub Symposium

Shrubland Ecosystem Dynamics in a Changing Environment



May 23–25, 1995

Hilton Hotel
Las Cruces, New Mexico



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Jornada Experimental Range/Long-Term Ecological Site

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Jornada Experimental Range/Long–Term Ecological Site

Program Committee

E. Durant McArthur
Jerry R. Barrow
Robin J. Tausch
Ronald E. Sosebee

Registration

May 23, 24 and 25, 1995
7:30—9:00 a.m.
Las Cruces Hilton Hotel
705 S. Telshor
Las Cruces, NM 88001

Shrub Ecosystem Dynamics in a Changing Environment

Ninth Wildland Shrub Symposium

Hilton Hotel
Las Cruces, NM
May 23 - 25, 1995

Schedule

May 23

Morning

PLENARY SESSION
SAN ANDRES BALLROOM (BALLROOMS 1 & 2)

MODERATOR	Robin J. Tausch, USDA Forest Service, Intermountain Research Station, Reno, Nevada.
9:00	**Welcome**, Dr. John Owens, Dean, College of Agriculture and Home Economics
9:10	E. Durant McArthur. **Shrub Research Consortium Status and Function**
9:20	Julio L. Betancourt. **Long and Short Term Climatic Influences on Southwestern Shrublands**
9:50	Herman S. Mayeux. **Potential Effects of a Changing Atmosphere on Southwestern Shrublands**
10:20	BREAK—Avenida (ballroom foyer)
10:50	William Schlesinger. **Understanding Global Desertification Processes Through Long-Term Ecological Research in the Jornada Basin**
11:20	Kris Havstad. **Reflections From Nearly a Century of Rangeland Research in the Jornada Basin**
11:50	LUNCH—on your own

Afternoon

CONCURRENT SESSION A, VEGETATION OVER TIME AND SPACE
TULAROSA AND SAN AGUSTINE BALLROOMS (BALLROOM 1)

MODERATOR	Dean M. Anderson, USDA-Agricultural Research Service-Jornada Experimental Range, Las Cruces, New Mexico
1:15	John A. Ludwig, David J. Tongway and Stephen G. Marsden. **Predicting Shifts in Australian Shrublands With Changing Climates and Land Uses**
1:35	Jack D. Brotherson. **Elevational Relationships of Introduced Woody Species on the Islands of Lanai and Hawaii**
1:55	M.H. Nichols, L.J. Lane, and R. Gibbens. **Time Series Analysis of Data for Raingauge Networks in the Southwest**
2:15	Laura Foster Huenneke. **Shrublands and Grasslands of the Jornada Long-Term Ecological Research Site: Desertification and Plant Community Structure in the Northern Chihuahuan Desert**
2:35	Ann L. Hild and David B. Wester. **Winterfat Shrubland Boundary Dynamics Under Different Grazing Histories**
2:55	Kimball T. Harper. **Invasion of Alien Annuals into Salt Desert Shrublands and Ecological Consequences Thereof in West-Central Utah**
3:15	BREAK—Avenida (ballroom foyer)
3:35	H. Curtis Monger, David R. Cole, and Brenda J. Buck. **Vegetation Dynamics During the Late Quaternary in the Northern Chihuahuan Desert Based on Stable Isotopes in Pedogenic Carbonates**
3:55	Kenneth D. Sanders and Lee A. Sharp. **Dynamics of a Shadscale Stand Without Influence by Man**
4:15	Jake F. Weltzin and Guy R. McPherson. **Will Global Change induced Precipitation Redistribution Cause Shifts In Lower Treeline?: Preliminary Data**
4:35	Scott C. Walker, David K. Mann, and E. Durant McArthur. **Plant Community Changes Over 58 Years Within the Great Basin Experimental Range, Manti-LaSal National Forest**
4:55	Lakhdar Benkobi and Daniel W. Uresk. **Thunder Basin National Grassland, Wyoming: Upland Habitat Type Ecological Classification Models**

Concurrent Session B, Shrubland Management Options

Soledad and Guadalupe Ballrooms (Ballroom 2)

Moderator Daniel J. Fairbanks, Brigham Young University

1:15 Robin J. Tausch. **Past Changes, Present and Future Impacts, and the Assessment of Community or Ecosystem Condition**

1:35 Dayna Ayers, Don Bedunah, and Michael Harrington. **Bitterbrush and Willow Response to Shelterwood Cutting and Prescribed Burning in Western Montana**

1:55 Stanley G. Kitchen and Derek B. Hal., **Community Stability in a Salt-Desert Shrubland Grazed by Sheep—the Desert Experimental Range Story**

2:15 J.D. Landsberg, A.M. Nissila, and R.E. Martin. **Response of Understory Vegetation to Prescribed Underburning**

2:35 M. Ishaque. **Literature Review on Two Acacia Species of Chihuahuan Desert Rangeland**

2:55 Gary McBryde. **Modeling *Prosopis-Acacia* Range to Determine Economic Characteristics of Managing a U.S.—Mexico Watershed**

3:15 BREAK—Avenida (ballroom foyer)

3:35 Thomas C. Merrill and Melanie A. Wetzel. **Applying ERHYM-II for Forage Forecasting and Hydrology Reports at Sites in the Great Basin**

3:55 Richard Stevens and Scott C. Walker. **Juniper-Pinyon Population Dynamics Over 30 Years Under Five Grazing Treatments Following Anchor Chaining**

4:15 Hossein Heydari, Bruce A. Roundy, Carolyn Watson, Steven Smith, Bruce Munda, and Mark Pater. **Summer Establishment of Four Sonoran Desert Shrubs Using Line Source Sprinkler Irrigation**

4:35 Todd Thompson. **It Can Happen to You**

4:55 Thorsten Wiegand, Suzanne J. Milton, and Christian Wissel. **A Simulation Model on Shrubland Ecosystem Dynamics in the Semi-Arid Karoo, South Africa**

Evening

Poster Session and Social Hour

San Andres Ballroom (Ballrooms 1 & 2)

6:15 to 7:30 p.m.

Poster 1 L.L. Cadwell, J.L. Downs, and L. Fitzner. **Sagebrush Restoration in the Shrub-Steppe of Southcentral Washington**

Poster 2 J.L. Downs and R.E. Rossi. **Quantifying Spacial Variation of Shrub Habitat Characteristics**

Poster 3 Thomas A. Eddy. **Ecotonal Dynamics of High-Bush Blackberry in Eastern Kansas**

Poster 4 R.E. Estell, E.L. Fredrickson, D.M. Anderson, K.M. Havstad, and M.D. Remmenga. **Tarbush Leaf Surface Terpene Profile in Relation to Mammalian Herbivory**

Poster 5 D.J. Fairbanks, C.F. Ruas, P.M. Ruas, W.R. Andersen, and R.P. Evans. **A Male-Specific DNA Marker for Sex Determination Studies in the Genus *Atriplex***

Poster 6 Trista L. Hoffman and Carl L. Wambolt. **Growth Response of Wyoming Big Sagebrush to Heavy Browsing by Wild Ungulates**

Poster 7 Carl L. Wambolt and Myles J. Watts. **High Stocking Rate Potential for Controlling Wyoming Big Sagebrush**

Poster 8 David C. Lightfoot. **A Comparison of Grasshopper Species Composition and Population Densities in Northern Chihuahuan Desert Grassland and Shrubland Communities**

Poster 9 Steven O. Link, Gregg M. Petrie, and Lee E. Rogers,.**Estimation of Latent Heat Flux Using Quantitative Landsat Thematic Mapper Satellite Data in a Shrub-Steppe Ecosystem**

Poster 10 Steve Nelle. **The Management and Use of Browse in the Edwards Plateau of Texas**

Poster 11 E. Durant McArthur and Jeff E. Ott. **Potential Natural Vegetation in the 17 Conterminous Western United States**

Poster 12 Dana Quinney and Marjorie McHenry. **Management and Restoration of Native Shrubland in a Military Training Area**

Poster 13 C.R. Tischler, H.W. Polley, H.B. Johnson, and H.S. Mayeaux, Jr. **Effects of Elevated Concentration of Carbon Dioxide on Seedling Growth of Mesquite and Huisache**

Poster 14 J.R. Wight and C.L. Hanson. **Energy Budget Dynamics Within a Shrub-Dominated Watershed**

Shrub Research Consortium Executive Committee Meeting

Cimarron Room

8:00 pm

May 24

Field Trip

Transportation Buses will leave the Hilton at 9 a.m. and will return to the Hilton at approximately 8 p.m. and again at 9 p.m.

Food A box lunch will be provided. A barbecue will be served at 5:30 p.m.
There will be a social hour at the Jornada Headquarters when the tour ends at approximately 4 p.m.

Tour The tour will traverse the Jornada del Muerto Plain. It includes the NMSU College Ranch, the USDA-ARS-Jornada Experimental Range, and the NSF Long-Term Ecological Research Site (LETR) in the Jornada Basin.
Special emphasis will be placed on the long-term studies in grazing management and rangeland ecology being conducted throughout the basin. We will visit the 60,000-acre New Mexico State University Ranch, established in 1927, and the 192,000-acre Jornada Experimental Range, established in 1912.
The National Science Foundation long-term ecological research on the Jornada will be a focal point. This NSF research, initiated in 1984, greatly extended the earlier work of the International Biological Program (IBP).
Discussion will emphasize research by the Environmental Protection Agency on development of indicators for monitoring ecological dynamics of desert ecosystems.

Trip Leaders Reldon Beck, Department of Animal and Range Sciences, New Mexico State University
Laura Huenneke, Department of Biology, New Mexico State University
Bill Schlesinger, Department of Botany, Duke University
Walt Whitford, Environmental Protection Agency, Las Vegas, Nevada
Kris Havstad, USDA-ARS-Jornada Experimental Range

May 25

Morning

Concurrent Session C, Shrubland Ecophysiology

Tularosa & San Agustine Ballrooms (Ballroom 1)

Moderator Jannelle L. Downs, Batelle Pacific Northwest Laboratory, Richland, Washington

8:00 H.W. Polley, H.B. Johnson, H.S. Mayeux, and C.R. Tischler **Impacts of Rising CO_2 Concentration on Water Use Efficiency of Woody Grassland Invaders**

8:20 Walter G. Whitford. **Morphological Variation in Creosotebush, *Larrea tridentata*, Affects Ecosystem Processes**

8:40 Stanley D. Smith, Anna Sala, and Dale A. Devitt. **Evapotranspiration from a Saltcedar-Dominated Desert Floodplain: A Scaling Approach**

9:00 Rosemary L. Pendleton, Sheldon D. Nelson, and Ronald L. Rodriguez. **Do Soil Factors Determine the Distribution of Spineless Hopsage *(Grayia brandegei)***

9:20 Bruce N. Smith, Tom Monaco, and Dan Hemmin., **Comparative Metabolism and Growth of Accessions of Some Species of Shrubs, Grasses, and Forbs of the Great Basin**

9:40 Anne Hartley. **Nitrogen Trace Gas Emission from Grassland and Shrubland Soils in the Jornada Basin**

10:00 BREAK—Avenida (ballroom foyer)

10:20 Vincent P. Gutschick, Connie J. Maxwell, and Robert J. Core. **Physiological Control of Evapotranspiration By Shrubs: Scaling Measurements from Leaf to Stand with the Aid of Comprehensive Models**

10:40 Amrita G. de Soyza, Walter G. Whitford, Augusto C. Franco, Ross A. Virginia, and James F. Reynolds. **Effects of Summer Drought on the Water Relations, Physiology, and Growth of Large and Small Plants of *Prosopis glandulosa and Larrea tridentata***

11:00 Sean L. Connin, Ross A. Virginia, and C. Page Chamberlain. **Origin and Flux of Soil Carbon Following Shrub Invasion in the Chihuahuan Desert: Isotopic Analyses of Community Change**

11:20 Keith T. Killingbeck. **Tracking Environmental Change with the Desert Shrub Ocotillo *(Fouquieria splendens):* Prospects and Pitfalls**

11:40 Joneen S. Cockman and Rex Pieper. **Arroyo-Riparian Shrub Diversity Along a Transition Zone Between the Sacramento Mountains and Tularosa Basin, New Mexico**

Noon LUNCH—on your own

Concurrent Session D, Microbes, Seeds, and Satellite Monitoring

Soledad & Guadalupe Ballrooms (Ballroom 2)

Moderator	W. Kent Ostler, E. G. & G. Energy Measurements, Las Vegas, Nevada
8:00	Jamey Thompson and Laura Huenneke. **Regeneration Niches and Differential Germination in Shrubland Perennials**
8:20	Ed Klein. **Seed Quality and Testing**
8:40	Susan C. Garvin, Susan E. Meyer, and Stephanie L. Carlson. **Seed Germination of Shadscale *(Atriplex confertifolia)***
9:00	Jayne Belnap. **Effects of Soil Surface Disturbances on Semi-Arid Ecosystems**
9:20	Jerry R. Barrow and Bobby D. McCaslin. **The Role of Microbes in Resource Management in Arid Ecosystems I**
9:40	Bobby D. McCaslin and Jerry R. Barrow. **The Role of Microbes in Resource Management in Arid Ecosystems II**
10:00	BREAK—Avenida (ballroom foyer)
10:20	Don Vickrey, Barbara Barnett, and Al Peters. **Monitoring Semi-Arid New Mexico Rangelands Using Multi-Temporal Coarse Resolution Satellite Sensor Data**
10:40	David A. Mouat, Judith Lancaster, Robert O. Kuehl, and Walter G. Whitford. **Time-Series Satellite Data to Identify Mesquite Response to Stress as an Indicator of Ecosystem Health**
11:00	Marlen D. Eve and Albert J. Peters. **Detection of Temporal Changes in Shrub Densities Using Meteorological Satellite Data**
11:20	Barry Middleton and Albert Peters. **Monitoring Arid and Semi-Arid Shrub and Grassland Communities Using Coarse Resolution Satellite Data**
11:40	Peggy A. Livermore. **A Prescriptive GIS Model for Domestic Quail Management on Ladder Ranch**
Noon	LUNCH—on your own

Afternoon

Management Session

San Andres Ballroom (Ballrooms 1 & 2)

Moderator	Ronald E. Sosebee, Texas Tech University, Lubbock, Texas
1:20	D. Carl Freeman. **Developmental Instability as a Bioindicator of Ecosystem Health**
1:40	John E. Emlen. **Interaction Assessment: A Tool for Managing Ecosystems**
2:00	Ross A. Virginia and James F. Reynolds. **Experimental Studies of Shrub Resource Islands: Are They the Key to the Stability of Aridlands?**
2:20	James F. Reynolds and Ross A. Virginia. **Modeling Desertification: The Importance of Shrub Resource Islands**
2:40	Stephen B. Monsen and Nancy L. Shaw. **Occurrence of Rush Skeletonweed *(Chondrilla juncea)* Within a Mountain Big Sagebrush/Antelope Bitterbrush/Bunchgrass Community in Central Idaho**
3:00	Dotty Douglas. **Shrub/Douglas-Fir Seedling Interactions in Southeastern Idaho**
3:20	Raymond L. Franson, Matthew W. Fidelibus, and David A. Bainbridge. **Spacing Patterns in Mojave Desert Trees and Shrubs**

General Information

Registration — *Questions about registration?* Call the Office of Conference Services at New Mexico State University at 505/646-1011, Monday through Friday, from 9:15 a.m. to 2:30 p.m. Mountain Standard Time.

Registration Deadline — May 8, 1995

Registration Fee

Early Bird	$100
After May 8, 1995	$125

Registration Fee Includes

Plenary Session	Concurrent Sessions A, B, C, and D
Poster Session	Management Session
May 24 Field Trip:	Three refreshment breaks
Bus transportation	One evening social hour
Box lunch	Copy of abstracts
Steak barbeque	Copy of proceedings

Remember, the cost of registrations postmarked after May 8, 1995 is $125, so REGISTER EARLY.

Registration confirmations and packets will be available May 23, 24 and 25 from 7:30 a.m. to 9 a.m. in the south lobby of the Las Cruces Hilton.

Cancellations/Refunds — Cancellations received prior to May 8 will be refunded less a $25 service charge. No refunds will be made after May 8, 1995.

NOTE — Each conferee should complete a registration form. Photocopies of the registration form are acceptable.

Conference Location — Conference activities will take place at the Las Cruces Hilton. The hotel provides free parking for all registered guests. There is a restaurant, a lounge, and a gift shop in the hotel. The Hilton is located across the street from the Mesilla Valley Shopping Mall and is within easy walking distance of several restaurants.

Lodging — For your convenience, a block of rooms is being held at the Las Cruces Hilton. Make reservations at 505/522-4300. Identify yourself as a Wildland Shrub Symposium participant to receive the following special daily rates (single or double occupancy):

Standard Room	$62
Executive Room	$72
Poolside	$72

Reservations must be made by May 8, 1995, to receive this special rate.

Transportation

Air Travel — You can fly into the Las Cruces International Airport on Mesa Airlines or into the El Paso, Texas, International Airport on most major airlines. El Paso is about an hour's drive from Las Cruces.

Shuttle Service — The Las Cruces Hilton provides free shuttle service from the Las Cruces International Airport. You must make arrangements with the hotel for this service.

The Las Cruces Shuttle Service, a commercial enterprise, runs from El Paso to Las Cruces approximately every one-and-one-half hours from 5:30 a.m. until 1:45 a.m. Call 1-800/288-1784 to make arrangements.

Conference Registration Form

For information, call 505/646-1011, 9:15 a.m. to 2:30 p.m. MST, Monday–Friday.
Please complete one form for each individual attending.
Registration deadline is May 8, 1995.

NAME ______________________________ NAME FOR BADGE ______________
first / last

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INSTITUTION/COMPANY ______________________________

MAILING ADDRESS ______________________________

CITY ______________________ STATE ______ ZIP ______

BUSINESS TELEPHONE (______) ______________ FAX NUMBER (______) ______________

REGISTRATION FEE	Early Bird	$100
	After May 8, 1995	$125

PAYMENT
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Make check, money order or purchase order payable to SHRUB SYMPOSIUM, NMSU.

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Papers Published as Part of the Jornada LTER-III

15 October 1994 -- present

BassiriRad, H., D.C. Tremmel, J.F. REYNOLDS and R.A. VIRGINIA. 199x. Short-term patterns in resource capture by two desert shrubs following a simulated summer rain. Plant and Soil, in review.

Brisson, J. and J.F. REYNOLDS. 199x. Plasticity in the zone of influence during plant neighborhood interaction and its effect on plant population attributes. Manuscript.

de Soyza, A.G., A.C. Franco, R.A. VIRGINIA, J.F. REYNOLDS, and W.G. WHITFORD. 199x. Photosynthesis and water relations of large and small shrubs of *Prosopis glandulosa* in a sand dune habitat of the Chihuahuan Desert, U.S.A. American Journal of Botany, in press.

Fredrickson, E., J. Thilsted, R. Estell and K. HAVSTAD. 1994. Effects of chronic ingestion of tarbush (*Flourensia cernua*) on ewe lambs. Veterinary and Human Toxicology 36: 409-415.

Fredrickson, E.L., R.E. Estell, K.M. HAVSTAD, W.L. Shupe and L.W. Murray. 1995. Potential toxicity and feed value of onions for sheep. Livestock Production Science, in press.

Gallardo, A. and W.H. SCHLESINGER. 1995. Factors determining soil microbial biomass and nutrient immobilization in desert soils. Biogeochemistry 28: 55-68.

HERMAN, P.P., K.R. Provencio, J. Herrera-Matos and R.J. Torrez. 1995. Resource islands predict the distribution of heterotrophic bacteria in Chihuahuan desert soils. Applied and Environmental Microbiology 61: 1816-1821.

HUENNEKE, L.F. and I.R. Noble. 1995. Ecosystem function of biodiversity in arid ecosystems pp. xx-xx. In H.A. Mooney, J.H. Cushman, E. Medina, O. Sala and D. Schulze (eds.). *Functional Roles of Biodiversity: A Global Perspective*. John Wiley and Sons, New York.

Huenneke, L.F. and I.R. Noble. 1995. Arid Lands. In H.A. Mooney, J. Lubchenco, R. Dirzo and O.E. Sala. (eds.). Global *Biodiversity Assessment*. United Nations Environmental Program, Nairobi.

Kratz, T.K., J.J. Magnuson, P. Bayley, B.J. Benson, C.W. Berish, C.S. Bledsoe, E.R. Blood, C.J. Bowser, S.R. Carpenter, G.L. CUNNINGHAM, R.A. Dahlgren, T.M. Frost, J.C. Halfpenny, J.D. Hansen, D. Heisey, R.S. Inouye, D.W. Kaufman, A. McKee and J. Yarie. 1995. Temporal and spatial variability as neglected ecosystem properties: Lessons learned from 12 North American ecosystems. pp. 359-383. In D.J. Rapport, C.L. Gaudet, and P. Calow (eds.). *Evaluating and Monitoring the Health of Large-scale Ecosystems.* Springer-Verlag, N.Y.

Li, H. and J.F. REYNOLDS. 1994. A simulation experiment to quantify spatial heterogeneity in categorical maps. Ecology 75: 2446-2455.

Li, H. and J.F. REYNOLDS. 1995. On definition and quantification of heterogeneity. Oikos 72: 1-5.

Marion, G.M. and W.H. SCHLESINGER. 1994. Quantitative modeling of soil forming processes in deserts: The CALDEP and CALGYP models. pp. 129-145. In R.B. Bryant and R.W. Arnold (eds.). *Quantitative Modeling of Soil-Forming Processes.* Soil Science Society of America, Madison, Wisconsin.

Moorhead, D.L., R. Sinsabaugh, A.E. Linkins and J.F. REYNOLDS. 199x. Decomposition processes: Modelling approaches and applications. Science of the Total Environment, in press.

Nash, M.H. and W.G. WHITFORD. 1995. Subterranean termites: Regulators of soil organic matter in the Chihuahuan desert. Biology and Fertility of Soils 19: 15-18.

REYNOLDS, J.F., R.A. VIRGINIA, and W.H. SCHLESINGER. 199x. Defining plant functional types for models of desertification. pp. xx-xx. In T.M. Smith, H.H. Shugart and F.I. Woodward. (eds.). *Functional Types in the Analysis of Global Change.* Chapman and Hall, in press.

SCHLESINGER, W.H. 1994. The vulnerability of biotic diversity. pp. 245-260. In R. Socolow, C. Andrews, F. Berkhout, and V. Thomas (eds.). *Industrial Ecology.* Cambridge University Press, Cambridge.

SCHLESINGER, W.H., J.A. Raikes, A.E. Hartley, and A.F. Cross. 199x. On the spatial pattern of soil nutrients in desert ecosystems. Ecology, in press.

Thomas, P.M., K.F. Golly, R.A. VIRGINIA, and J.W. Zyskind. 199x. Cloning of mesquite rhizobial and bradyrhizobial *nod* gene regions and nucleotide sequence of the mesquite rhizobial *nodD* gene. Molecular Plant-Microbe Interactions, in press.

WHITFORD, W.H. 1995. Desertification: Implications and limitations of the ecosystem health metaphor. pp. 273-293. In R.J. Rapport, C.L. Gaudet and P. Calow. (eds.). *Evaluating and Monitoring the Health of Large-Scale Ecosystems.* Springer-Verlag, New York.

Articles in the popular press, television interviews, and other public media that interpret Jornada LTER research for a general audience

October 15, 1994 -- present

Publications:

"Science at Home on the Range," November 1994 article in *Agricultural Research*, a monthly magazine published by the by the U.S.Department of Agriculture for farmers and ranchers.

"Watching Desert Creep," December 1994 article in *Dialogue* a weekly newspaper published for the Duke University community.

"Students Study Growth in NM," December, 12, 1994 article in *The El Paso Times*,

"How to Make a Desert," February 1995 article in *Discover*, a national monthly science magazine published by The Walt Disney Company

"Success Secrets of Desert Plants," March 1995 article in *Agricultural Research* (see above)

Students Trained as part of the Jornada LTER-III

15 October 1994 -- present

Completed Degree Requirements:

Tiszler, J. 1994. Changes in soil nitrogen dynamics with the establishment of desert shrubs in a Chihuahuan black grama grassland. M.S. Thesis, San Diego State University (R.A. Virginia, advisor).

Horton, J.D. 1995. Using kriging to predict distribution of arid vegetation, with discussion of cokriging field data and satellite imagery. Ph.D. Dissertation, New Mexico State University (K.M. Havstad, advisor).

Thompson, J.B. 1995. Regeneration niches and nurse plant associations in Chihuahuan desert perennials. M.S. Thesis, New Mexico State University (L. F. Huenneke, advisor).

In Progress:

Baggs, J. M.S. Program, New Mexico State University (L.F. Huenneke, advisor).

Buck, B.J. Ph.D. Program, New Mexico State University (H.C. Monger, advisor)

Connin, S.E. Ph.D. Program, Dartmouth College (R.A. Virginia, advisor).

Encina-Rojas, A. M.S. Program, New Mexico State University (H.C. Monger, advisor).

Fernandez, R. Ph.D. Program, Duke University (J.F. Reynolds, advisor).

Gross, K. A.B. Program. Duke University (J.F. Reynolds, REU advisor, summer 1995).

Gurrola, J. A.B. Program. New Mexico State University (L.F. Huenneke, REU advisor, 1994-95).

Hartley, A.E. Ph.D. Program. Duke University. (W.H. Schlesinger, advisor).

Herrera-Matos J. M.S. Program, New Mexico State University (R.P. Herman, advisor)

Kipp, J.M. Ph.D. Program, New Mexico State University. (H.C. Monger, advisor).

Li, G. Ph.D. Program, State University of New York, Buffalo, (A.D. Abrahams, advisor).

McCabe, S. B.A. Program. State University of New York, Buffalo. (A.D. Abrahams, REU advisor, summer 1995)

Mooney, J. B.A. Program. Dartmouth College. (R.A. Virginia, REU advisor, summer 1995).

Najera, F. B.S. Program. New Mexico State University. (V.P. Gutschick, REU advisor, 1994-95).

Neave, M. Ph.D. Program, State University of New York, Buffalo. (A.D. Abrahams, advisor)

Pilmanis, A. Ph.D. Program, Duke University. (W.H. Schlesinger, advisor).

Provencio, K. B.A. Program, New Mexico State University (R.P. Herman, REU advisor, 1994-1995)

Wright, A. B.A. Program, New Mexico State University (R.P. Herman, REU advisor, 1994-1995).

Ancillary Grants Received as part of the Jornada LTER-III

15 October 1994 -- present

National Science Foundation, Division of Environmental Biology. $ 80,000 to Drs. Andrew Stephenson and James Windsor (PENN STATE) to support the project "Genetic and Environmental Factors that Influence Pollen Performance and Result in Non-random Fertilization."

National Science Foundation, International Programs. $ 13315 supplement to LTER-III to support V. Gutschick's (NMSU) comparative ecophysiological studies in the U.S. and Australia.

National Science Foundation, Division of Environmental Biology. $ 49605 EROL supplement to DEB-91-07481 to support investigations by Kay Gross (MICHIGAN STATE) at the Jornada and Sevilleta LTER sites.

U.S. Department of Agriculture, National Institute for Global Environmental Change. $101,069 to V.P. Gutschick to support the project "Predicting large-scale patterns in vegetated-surface conductance for CO2 and water vapor."

U.S. Department of Interior, National Biological Service, $365,000 to L.F. Huenneke (NMSU) to support the project "Plant community dynamics of northern Chihuahuan desert communities."

U.S. Department of Agriculture, NRCS. $30,000 to H.C. Monger (NMSU) to support the development of a video describing the evolution of the Rio Grande Valley and its soils, New Mexico.

U.S. Department of Agriculture. $100,000 to K.M. Havstad (NMSU) to support a postdoctoral fellowship for the project "New products from desert shrubs."

Environmental Protection Agency. $860,000 to K.M. Havstad for a cooperative program to study "Desertification, biodiversity and sustainable use of arid ecosystems." (Co-Pi with W.G. Whitford).

National Science Foundation, Long-Term Projects. $10,000 supplement to LTER-III to support Research Experience for Undergraduates (REU) at the Jornada, Summer 1995

U.S. Department of Agriculture. $5000/yr subcontract through Colorado State University to K.M. Havstad to maintain the Jornada's participation in the "Uv-B Radiation Monitoring Network."

Network Participation as Part of the Jornada LTER III

15 October 1994 -- present

October 1994	Schlesinger attended LTER-CC Meeting Dillard, Georgia (Cowetta LTER Site)
October 1994	Reynolds attended the 3rd Joint U.S.-Japan Workshop on Global Change
January 1995	Reynolds, Virginia, Huenneke attended a meeting at Sevilleta to develop a cross-site experiment (with SEV and CPER) examining grama grasslands in arid and semiarid environments
April 1995	Havstad attended LTER-CC Meeting Norfolk, Virginia (VCR LTER Site)
June 1995	Huenneke was an invited member of the arid lands working group at a workshop of the Americas Interhemisphere Geo-Biosphere Organization (AMIGO), Stanford, California

Presentations made at Scientific Meetings and Workshops as part of the Jornada LTER-III

15 October 1994-- present

International Symposium and Workshop on Desertification in Developed Countries, Tucson, Arizona, 24-29 October 1994

Keynote Address by W.H. Schlesinger, "Long-Term Ecological Research in the United States."

Poster by Al Peters, "Derivation and Temporal Analysis of Satellite-Based Vegetation Indices in Desert Shrub Communities of the Arid Southwest."

Contributed paper by H.C. Monger, "A Major Desertification Episode beginning about 8,000 years ago in the Chihuahuan Desert of southern New Mexico and western Texas."

Eighth Mogollon Archaeology Conference, El Paso, Texas, 21-22 October 1994.

Contributed papers by H.C. Monger, "Eolian geomorphology, survey intensity, and landscape patterning in the surface archaeological record," and

"Eolian geomorphology, artifact patterning, and assemblage composition."

Annual Meeting of the Geological Society of America, Seattle, 24-27 October 1994

Contributed Paper by S.L. Connin, R.A. Virginia, and C.P. Chamberlain. "Recent pedogenic carbonate formation in the southwestern United States from carbon isotope measurements."

Annual Meeting of the Soil Science Society of America, Seattle, November 1994

Symposium Paper by H.C. Monger. "Stable carbon and oxygen isotopes of carbonates as paleoenvironmental indicators in arid regions."

Annual Meeting for the Society of Range Management. Symposium on Alien Plant Invasions, Phoenix, Arizona, 17 January 1995

Symposium Paper by L.F. Huenneke, "Ecological Impacts of Plant Invasions in Rangeland Ecosystems."

Annual Meeting of the Soil Ecology Society of America. Fort Collins, Colorado, March 1995

Contributed paper by B.S. Bamforth, D.W. Freckman, and R.A. Virginia. "Early soil biogenesis."

Fourth Annual Professional Range Managers Forum, Brownwood, Texas, March 1995

Invited Symposium Paper by K.M. Havstad, "Long-term ecological monitoring technologies."

Ninth Annual Wildland Shrub Symposium, Las Cruces, N.M., May 23-25, 1995.

N.B. The Jornada was host to the 1995 meeting, and is pleased to include a symposiium program in its annual report.

Plenary Paper by K.M. Havstad. "Reflections from nearly a century of rangeland research in the Jornada basin."

Plenary Paper by W.H. Schlesinger, "Understanding global desertification processes through long-term ecological research in the Jornada basin."

Contributed Paper by L.F. Huenneke, "Shrublands and grasslands of the Jornada Long-Term Ecological Research site: Desertification and plant community structure in the northern Chihuahuan desert."

Contributed Paper by H.C. Monger, et al. "Vegetation dynamics during the late Quaternary in the northern Chihuahuan desert based on stable isotopes in pedogenic carbonates."

Poster by R.E. Estell, et al. "Tarbush leaf surface terpene profile in relation to mammalian herbivory."

Poster by D.C. Lightfoot, " A comparison of grasshopper species composition and population dynamics in northern Chihuahuan desert grassland and shrubland communities."

Contributed Paper by W.G. Whitford, "Morphological variation in creosotebush, *Larrea tridentata*, affects ecosystem processes."

Contributed Paper by A.E. Hartley, "Nitrogen trace gas emission from grassland and shrubland soils in the Jornada Basin."

Contributed Paper by V.P. Gutschick, et al. "Physiological control of evapotranspiration by shrubs: Scaling measurements from leaf to stand with the aid of comprehensive models."

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Contributed Paper by R.A. Virginia, "Experimental studies of shrub resource islands: Are they the key to the stability of aridlands?"

Contributed Paper by J.F. Reynolds, "Modeling desertification: The importance of shrub resource islands."

Annual Meeting of the Ecological Society of America, August 1995, Snowbird, Utah.

Contributed paper by L.F. Huenneke et al., "Plant biodiversity and ecosystem function in the northern Chihuahuan desert."

International Humic Substances Society, Atlanta, Georgia, 27-31 August 1995

Invited Paper by H.C. Monger, entitled, "Carbon in desert soils: Its nature and isotopic significance."

International UNEP Workshop on Combatting Global Warming by Combatting Land Degradation, Nairobi, Kenya, 4-8 September 1995

Invited paper by W.H. Schlesinger, entitled, "The carbon budget of drylands."