Significant Accomplishments: This year has been a transition year for the Jornada LTER. The failure of the Jornada LTER renewal proposal prompted intensive and agonizing re-evaluation of study design, personnel, and relationship to other LTER projects. We have mounted an intensive effort to synthesize and publish the results of our initial five year effort. The synthesis and writing have required most of the time available to the Principal Investigator and many of the staff. However, we feel that this effort has produced some very significant results (see list of manuscripts, page 18). New initiatives started in late 1986, early 1987 were: (1) installation of and data collection from organic matter transport wiers and plots for study of deposition and transport of rabbit feces on the LTER watershed, (2) beginning model development for sediment transport by Dr. Tim Ward, (3) intensive but short term studies of soil disturbances by ants, rodents and termites. The new work is proceeding without major problems, and some of the short term work has resulted in manuscripts currently in review or summarized in presentations at the Ecological Society Meeting in Ohio.

W. Conley and M. Conley completed an analysis of the 1915-1984 meteorological records from the USDA Jornada headquarters. These analyses serve to frame the scope of inference for the studies of the LTER; for example, annual precipitation during 1978-1984 was unusually near the long-term mean for annual precipitation, exhibiting none of the extremely dry or wet years which have characterized similar periods of time in the past. Despite numerous suggestions by earlier authors of long term trends in precipitation, analyses revealed no significant
linear trends and very minor quadratic trends. Data for winter rainfall exhibits a significant three year autocorrelation, but this is not repeated in data from the nearby New Mexico State University weather station, and likely represents a data artifact. Of major importance is the demonstration that a severe drought in the area (generally defined as 1950-1956) that is credited with induction of shrubland replacement of Jornada grasslands, actually began in 1946, and featured a deficit in winter precipitation that was much more severe than the deficit in summer precipitation, the major growing season for perennial grasses (see Conley and Conley in papers submitted).

The previous design of termite studies was evaluated by an experiment comparing actual mass loss of baits with bi-weekly counts of foragers observed at baits. The two measures were poorly correlated (<50%), resulting in a revision to the study, substituting before-and-after bait measurements for the previous forager count method. Data from July-October 1986 indicate that termite activity was significantly higher in the basin slope zone on the transect receiving nitrogen amendments over the last three years. This pattern suggests that termite populations are capable of detecting and responding to spatial variations in organic matter input (in this case, associated with enhanced annual plant growth, which has been most apparent in the basin slope zone), and are acting as dispersing agents contributing to spatial homogeneity in organic matter.

Water-Nitrogen Availability Interactions: We are currently conducting a monthly sampling of a subset of locations along the control (once fertilized) and new (never fertilized) transects. The goal of this study is to test hypotheses concerning the influence of moisture
availability on N availability. Samples are collected quarterly from the treatment (annually fertilized) transect. Indices of mineralizable organic N and microbial N are determined for each sample. Sample locations were chosen to be representative of the center and transitions of the annual vegetation zones on the control transect, and the centers of vegetation zones on the new and treatment transects. Twenty-six bulked soil samples are collected monthly and 45 samples are collected quarterly. This study is designed to test hypotheses about water/N interactions. It complements process-level studies in the creosotebush zone that utilize irrigation and rain-out shelters to simulate wet and dry weather. The process-level studies will provide us with the knowledge of mechanisms necessary to predict N availability in the creosotebush zone. The LTER study allows us to test predictions and to determine how well they can be generalized to the other vegetation zones in the watershed. A major advantage of the LTER approach is that it allows hypotheses to be tested under a variety of real (as opposed to simulated) weather conditions.

Hypotheses: Studies of water–N availability interactions at the Jornada are organized around one central hypothesis: The processes of N assimilation and biomass production by plants are more moisture dependent than the processes of litter production, litter processing, and N mineralization.

J. L. Charley (1972) first proposed that plant and soil processes differed in their sensitivity to moisture to account for the accumulation of inorganic N under shrubs during dry periods and declining production during extended wet periods. Given contrasting sensitivities of plant and soil processes to moisture, it is possible to deduce that fluctuating moisture availability must result in peak rates
of N mineralization and N uptake that are out of phase. More specifically:

Drier than normal conditions should increase N availability as decomposition and mineralization occur more rapidly than N uptake.

Wetter than normal conditions should decrease N availability because plant growth rates exceed decomposition mineralization and available N is rapidly depleted to the point that N becomes limiting.

Soil Water Content:

An analysis was completed (Agronomy Abstracts 1986:250) of the variation in water content in six lysimeters placed along the two parallel transects. Comparisons were made between water contents in the lysimeters placed along the control and located along the treatment transects, and between soil water contents inside and outside (in-situ) the lysimeters. The lysimeters are 0.16 m in diameter, 1.5 m deep and are sealed at the bottom. Vegetation was allowed to establish itself on the lysimeters. The data show that in-situ soil water contents are higher than those in the lysimeters, but that moisture regimes show similar trends. Therefore, small lysimeters filled with disturbed soil seem to fairly represent the moisture regime in arid soils. The lysimeter data also indicate that, during three of the last four years, rainfall had very little or no effect on soil moisture content at the 130 cm depth. During a relatively wet year, however, rainfall increased the soil moisture content at a depth of 130 cm by 14%. Most of this moisture was subsequently lost from the lysimeters through evapotranspiration. The data also showed that the in-situ nitrogen amended soils are drier than the in-situ unamended soils at depths between 30 cm and 130 cm. Small differences in water content exist
between nitrogen amended and unamended lysimeters.

One of the main objectives of this Long-Term Ecological Research program is to determine the spatial and temporal variability in various soil and biological parameters. In a paper prepared by Nash et al. (1987), time series analysis techniques were used to study the relationships between rainfall and soil-water contents along the control transect. Autocorrelation functions were calculated between the rainfall and the mean soil water content at each soil depth for the whole transect, as well as for each segment.

The analysis of the data shows that for the period 1982-1986 (week no. 28-220), with the exception of the playa fringe, the mean water content varied very little with soil depth but varied extensively with distance along the transect. This variation in water content was related to soil texture, and ranged from 0.277 cm$^3$/cm$^3$ in the playa to 0.052 cm$^3$/cm$^3$ in the Upper Piedmont. Although the water contents were lowest in the upper piedmont, the temporal variability, as expressed by the coefficient of variation in water content, was highest in the upper piedmont. Thus, rainfall changed water contents to greater depths in the coarser textured Upper Piedmont soils.

As expected, water contents were more correlated in time than rainfall. Typically, rainfall is correlated over 2 lags or less while average soil water shows significant correlations in time of at least 4 lags (8 weeks). Highest temporal correlations were found for the playa soil (10 weeks).

Changes in soil water content lag behind rainfall events. The degree to which changes in soil water lag behind rainfall depends largely on soil texture. For example, from the cross correlation of the rainfall time series (97 two week periods), and soil water content time
series, we find a lag time of 2 weeks at the 130 cm soil depth in the playa soil, and of 6 weeks in the bajada soils. This means that on the average, a rainstorm reaches the 130 cm soil depths about 3 x faster in the playa soil than in the bajada soil. The upper piedmont soil has a coarse texture, lower storage capacity and high permeability. As such, rain penetrates faster and to greater depths than in, for example, the bajada soil. Relatively rapid changes in soil water content in the subsoil of the playa are most likely due to movement through cracks. The playa soil is a vertisol, which is characterized by shrinking and swelling, during respective drying and wetting periods. Water could move relatively quick through these cracks once the surface of the soil was flooded. This can happen during periods of intense rainfall and run-on from the surrounding area.

It is clear from the above that autocorrelation and crosscorrelation techniques are very useful in quantifying observations over time and space. Future analyses of the soil water data will include crosscorrelation and cokriging between soil water and vegetation. Cokriging allows the estimation of variables at locations where measurements are lacking, provided the time series of water content and vegetation are cross-correlated. The technique is especially suitable when observations are correlated in time.

Data Management: (1) Data Input Procedure. The investigator who wants data entered and archived in the Jornada LTER data base must fill out a standard data documentation form available from the data manager’s office. The completed form contains all the information the typist and the data manager need to file the data set. The documentation for each data set is stored on disc. The data are entered on a Zenith PC/AT
compatible microcomputer using a spread sheet package (LOTUS 123). A graph is plotted on the screen to check for obvious errors. When the data have been verified by the typist, a printout of the data set is given to the investigator for error checking and verification. The data are then corrected if necessary. Finally the data are copied to two other discs. One is returned to the investigator along with a final data printout. Data documentation is updated as additional data are entered into the data set.

(2) Data Storage Procedure. The data disc library contains the original discs used for data entry which contain the data sets and their corresponding documentation. A storage disc library contains back up copies of the same files on disc. When a study or experiment is completed, the data are downloaded to the mainframe and permanently stored. The names of all the files are available in an alphabetical list using a brief description of the files and the names of the investigators. A keyword list is also available (up to 10 keywords can be used to describe each file) to simplify searching for data sets of interest. A computer printout of both the data set and the corresponding documentation files are available upon request if further details about a particular file are needed.

Photograph quadrat data on the Jornada/LTER transects:

Permanent 0.25m2 quadrats (50 cm X 50 cm) were positioned at each of the sample stations located at 30m intervals along both the nitrogen amended and nonamended belt transects of the study area. Every two weeks each of these quadrats was photographed using a 35 mm camera and a specially fabricated stand that allowed each quadrat to be photographed from the same position. The color slides thus produced were intended originally to be a permanent record of the ground cover within each
quadrat and of the phenological stage of the ephemeral vegetation. It became apparent at the beginning of data collection in the LTER project that a slight modification of this approach would allow an assessment of standing crop of ephemeral plants at two week intervals from which production could be calculated. The only modification necessary was the addition of a height reference in the photographic frame. With this addition, canopy volume could be estimated from the photographs and related to biomass by regression equations obtained from destructive samples. A computer program was developed for digitizing the cover and height data from the photographs and appropriate regression equations were developed for calculating biomass for many of the more important ephemeral species.

Photographs were taken from August 1982 until May 1986. At that time we stopped taking the photographs on a regular basis because we felt that there were enough data to adequately represent the potential short-term patterns of ephemeral biomass and phenology as they might vary from year-to-year in response to varying weather patterns. If at some future date the line intercept data on ephemeral cover indicate that the more temporally intensive data would be advisable we can resume the collection of small quadrat data. We will probably use the less labor intensive Daubenmire Frame technique if this should be necessary. For the present, however, it seems that the line intercept data are adequate for assessing year-to-year and longer term changes in ephemeral plant cover and biomass.

Data from the photographed quadrats have been used to validate a simulation model of ephemeral plant phenology (Bachelet et al. in review) parameterized from an independent data set (Kemp 1983). They
have also been used to address specific questions relative to the effects of microtopography on the distribution of plants in the playa vegetation zone (Wondzell et al. in review). It is our intention to continue to use these data in much the same way in the future. That is, to use them to address specific questions relative to very small spatial scales and/or very short time scales that arise from our continued observations along the less frequent and larger spatial scale line intercepts. In this way we can take better advantage of our resources for collecting and analyzing data, referring to the more intensive data sets only when a specific need is defined.

Modelling: The major modelling efforts for the Jornada LTER focus on using LTER data as validation data sets for process models that were developed from data collected in short term process studies, examples; Jachelet, Wondzell and Reynolds (1987), Moorhead, Loring, Reynolds and Whitford (1987). The current modelling effort focuses on how desertification processes, i.e. changes in soil and vegetation resulting from overgrazing and climatic fluctuation, affect nitrogen availability and nitrogen cycling on Chihuahuan Desert watersheds. The conceptual models developed in this effort will be the basis of the Jornada LTER renewal proposal.

Significant Findings Relative to Spatial and Temporal Patterns of the Vegetation: The temporal (year-to-year) variations in relative plant cover are spatially variable and not directly predictable, as might be expected, from the seasonal distribution of rainfall. This can be seen from the relative cover responses of various photosynthetic pathway/life form plant groups in different years in different perennial vegetation ones. Many exceptions to this expectation have been found. C₃ semi-
shrubs and annual forbs increase in cover in response to summer as well as winter/spring rain in some, but not all of the vegetation zones. C₃ perennial forbs are very unresponsive to winter/spring rain in all vegetation zones. C₄ annual and perennial forbs and grasses increase in cover in response to summer as well as winter/spring rain in some, but not all of the vegetation zones. Winter/spring rains cause an increase in cover of C₄ perennial grasses in two of the three zones when they are dominant, but none of the other five zones. These are only some of the anomalous responses that have been observed.

Nitrogen amendment has resulted in an increase in ephemeral plant cover. At the level of the entire landscape nitrogen amendment has led to responses in overall gradiant species diversity components, with decreases occurring in alpha, beta and gamma diversity due to a small number of ephemeral species increasing greatly in abundance.

The landforms of the Basin and Range Province have been hierarchically classified on the basis of scale, form, and genesis. Analysis of soils and vegetation on the LTER/Jornada site has shown strong relationships between perennial vegetative communities, and both landforms and geomorphic surfaces. We propose a causal hypothesis: Over geological time scales, geomorphological processes are fundamentally regulated by the underlying geologic structure and gross topographic relief of basin and range landscapes. The resultant landforms repeat across the landscape and occupy fairly consistent positions throughout the Basin and Range Province. However, over 10's to 100's of years the low frequency signal of landforming processes can be viewed as static while individual landforms regulate geomorphic processes. In turn, geomorphological processes control the transport of water, sediments, and organic matter across the landscape. Since biotic.
processes in arid and semi-arid environments are limited by water and nitrogen - the close correlation of vegetative communities to landform elements and geomorphic surfaces has resulted from differences in the transport of water and organic matter across and between landform elements.

(1) Reorganization of the Jornada LTER Research Group: Based on the realization that the original group of LTER P.I.'s was of marginal size and having lost several of those P.I.'s due to professional moves, it was essential to expand that group. Several ecologists with on-going projects on the Jornada enthusiastically agreed to assume the responsibility for the scientific leadership, for data collection and for developing inter-site synthesis efforts. The new structure consists of six principal investigators and a group of collaborating scientists as follows:

Co-Principal Investigators

Dr. Walter G. Whitford - Coordinator, Animal processes, soil biology
New Mexico State University

Dr. Gary Cunningham - Plant Ecology, New Mexico State University

Dr. Wesley Jarrell - Plant nutrition, nutrient cycling
University of California Riverside

Dr. James Reynolds - Modelling, San Diego State University

Dr. William Schlesinger - Plant ecology/biogeochemistry
Duke University

Dr. Ross Virginia - Plant ecology/nitrogen cycling
San Diego State University

Collaborating Investigators

Peter Wierenga - Soil Physics, New Mexico State University

Red Fisher - Nitrogen cycling, New Mexico State University
Tim Ward - Hydrology, New Mexico State University
Sue Bolin - Hydrology, New Mexico State University
Dominique Bachelet - Data management/modelling, New Mexico State University
Marsha Conley - Population ecology, New Mexico State University
John Zak - Microbiol ecology/mycorrhizae, Texas Tech
Tom Kieft - Microbiol ecology, New Mexico Tech
Barbara Hemmingsen - Microbiol ecology, San Diego State University
Diana Freckman - Nematode ecology, University of California Riverside
John Tenhunen - Plant physiological ecology, San Diego State University
Robert Gibbens - Plant Ecology, USDA, ARS Jornada Experimental Range
Carlton Herbal - Range ecology, USDA, ARS Jornada Experimental Range
Dean Anderson - Consumer behavior, USDA, ARS Jornada Experimental Range
Kate Lajtha - Biogeochemistry, Boston University

The group of six Co-PI's are responsible for the conceptual framework for the Jornada LTER studies, budget management, establishing priorities for data to be collected, etc. Collaborating investigators are encouraged to actively participate in all aspects of the LTER program including inter-site activities. This structure provides for efficient management while not restricting full participation by collaborating investigators and/or participation at any level of involvement with which an individual collaborating investigator is comfortable.

(2) Synthesis of Desert and Grassland IBP data plus Jornada LTER - W. G. Whitford was on sabbatical leave from December 1986 - May 1987. The focus of that leave was the synthesis of data from the Jornada into a cohesive framework in the context of current views of desert ecosystems. That effort has produced a comprehensive outline for the
book (see appendix 1), four completed chapters (1st draft) and parts of five other chapters. A target date of 31 January 1988 has been set for a complete draft of the book. Springer-Verlag has expressed interest in publishing this book based on their evaluation of the outline and two sample chapters.

Intersite Research Efforts: (1) Desert-Grassland Transition: water-nitrogen limitation. In late 1986 Sala, Lauenroth (CSU) and Whitford began analysis of climate records to address the question of why primary production in the Chihuahuan Desert shows a greater response to nitrogen than to water while the adjoining short-grass steppe exhibits the reverse pattern. Lauenroth has requested release time to allow collaboration on a manuscript (draft has been completed) to be submitted to the American Naturalist. The hypotheses explored in this manuscript are centered around the effect of changes in precipitation structure upon the nitrogen cycle and its coupling with the carbon cycle.

During 1986-87, a study has been conducted by M. Conley in collaboration with Dr. Michael H. Smith, director of the Savannah River Ecology Laboratory (Aiken, S.C.), to examine patterns of genetic variability among rodent species across the habitat zones at the LTER site. Theories of population genetics have long suggested that levels of spatial and temporal variability in biotic resources or abiotic conditions should result in specific patterns of genetic variability. This study represents a unique extension of these theories into the realm of community and ecosystem ecology, and has utilized the extensive information base of the core LTER project in quantifying levels of spatial and temporal environmental variability. Results indicate that heteromyid rodents, which feature the greatest physiological adaptation
to desert conditions (and therefore experience less stress due to abiotic variations) exhibit lowest genetic variability. Genetic variability does not appear to be higher among species associated with any of the four habitat zones sampled, although we have evidence that some zones (i.e. basin slopes) exhibit high interannual variation in annual plant production. Overall, heterozygosity across species was positively correlated with average variance in plant cover measurements from the site where each species was captured; those species with highest genetic variability are "generalists" with respect to vegetative associations, but this does not correspond directly to species' distributions across vegetative zones (see Shugart et al. in papers submitted).

**Significant projects in association with LTER:** (1) Effects of termites on soil properties and vegetation in the Australian arid zone. W. G. Whitford initiated studies in collaboration with scientists at the Australian CSIRO Rangelands Research Centre to investigate soil processes for comparison with the Jornada-Chihuahuan Desert. These efforts have resulted in two manuscripts that are in review.

(2) A project examining the structure of mulga-woodland soil microarthropods has been undertaken in collaboration with Dr. James Noble, CSIRO Rangelands Research Centre, to provide comparisons with the extensive data available from Jornada studies.

(3) During 1986, William T. Peterjohn, a doctoral candidate at Duke University, completed preliminary sampling of desert soils for denitrification potential. While his work is centered at the Jornada, he seeks to compare the importance of denitrification in various desert ecosystems in the southwestern U.S., and he has conducted similar
sampling in the Mojave and Great Basin Deserts. This work is motivated by the observations of nitrogen limitation in many desert ecosystems, and high rates of denitrification that have been postulated by previous workers in an attempt to balance the nitrogen budget of desert soils. For example, West and Skujins (1977) suggest that denitrification losses accounted for 66% of the annual inputs in the Great Basin Desert of Utah. Estimated rates of 19 kgN/ha/yr are among some of the highest reported for terrestrial ecosystems (Bowden 1986). Little is known about the magnitude of N₂O loss during denitrification in desert ecosystems; a large flux could contribute significantly to the increasing global atmospheric content of this gas.

Peterjohn's work at the Jornada attempts to examine the spatial variation of denitrification potential along the landscape gradient from the mountain range to the basin playa. Estimates of potential will be extrapolated to regional estimates on the basis of kriging and other geostatistical methods. Field work during summer 1988 will allow a verification of the actual rates of denitrification in the field, and experimental manipulations to test for the important in situ control mechanisms.

(4) Recent studies by William H. Schlesinger at sites in the Mojave and Chihuahuan Deserts have elucidated processes of soil development in arid regions and examined the importance of overland flow as an ecosystem process. Soil profile development, as examined along the Jornada LTER transect, shows a strong influence of overland flow in the movement of materials and the profile distribution of Ca and P (Lajtha and Schlesinger, in press). Areas that receive runoff from upslope have significantly higher net primary productivity (Ludwig 1986) and over twice the standing crop of shrubs (Schlesinger and Jones 1984).
Previous LTER workers have examined some of the factors that control the production of runoff from individual storms, however, there is little work that documents the absolute magnitude of this process in the field. We proposed a long-term program to examine these processes as they may affect the movement of material between geomorphic surfaces of the Chihuahuan Desert landscape.

During summer 1988, 2 x 2 m runoff plots similar to the plots currently being monitored by the LTER would be established in each of the four geomorphic surfaces along the LTER transect. We propose five such plots placed randomly in each area. When precipitation events produce runoff, the collections will be examined for total particulate content, and the elemental movement in dissolved and particulate form. Presumably this program will continue as a core of LTER studies beyond 1988.

Changes and additions in population studies:

Mark-recapture studies of small mammal and lizard populations were suspended at the end of 1986, and the labor was diverted into analysis of these data. This task has currently consumed >500 man-hours devoted to error checking >10,000 individual observations to identify inconsistencies in species identification, individual coding identification, reproductive diagnoses and other generalized errors. Integrative analysis of these data are now in progress and planned to continue as the major focus of this year's activities. In addition to continued monitoring of termite activities using the mass loss technique, the study of colony demography in selected ant species is being continued.

Two new studies involving animal populations are planned for the
coming year, each designed as a short term observational study to evaluate features which have arisen as potentially important in future LTER project foci. One of these will consist of observations of jackrabbits and cottontail rabbits to examine patterns and levels of habitat use through the seasonal cycle. This relates to an approach identifying animal species as either patch-creating or patch-dispersing in their effects on the nutrient-water resources of the system. We suspect that rabbits (in contrast to the less mobile small mammal species previously studies) may act in both roles - as patch creators through digging activities, and as patch-dispersers through selective foraging and waste deposition that may exhibit seasonal changes affecting organic matter input and movement between landscape units across the watershed. The second study will consist of an analysis of the effects of soil disturbance by gophers, a phenomenon which occurs in a small area of the current LTER site (upper piedmont grassland), and which appears to have very little effect on that plant community, in contrast to effects of gophers in other ecosystems.
PUBLICATIONS IN PRINT


PUBLICATIONS IN PRESS


Lajtha, K. and W. H. Schlesinger. The biogeochemistry of phosphorus cycling and phosphorus availability along a desert soil chronosequence. Ecology 68:


Whitford, W. J. Effects of harvester ant Pogonomymex rugosus nests on soils and a spring annual, Erodium Texanum. S. W. Nat. In press.


MANUSCRIPTS IN REVIEW


PUBLICATIONS IN PREPARATION

Cornelius, J. M.  Effects of fire disturbance in an northern Chihuahuan Desert black grama (Bouteloua eriopoda) semi-desert grassland. Ph.D. thesis, New Mexico State University, Las Cruces, NM


Sala, O. A., W. Lauenroth and W. G. Whitford. Shortgrass steppe to Chihuahuan Desert transition: Is it gradual or abrupt?

Silva, S. I. and J. M. Cornelius. Effects of fire disturbance on spatial distribution patterns of rhizosphere microarthropods and nematodes in a semi-desert grassland.

Silva, S. I., J. M. Cornelius and W. G. Whitford. b. A field ion exchange experiment to examine the role of microarthropods in determining nitrogen availability in the rhizosphere of fluff grass (Erioneuron pulchellum).

Silva, S. I., J. M. Cornelius and W. G. Whitford. c. A laboratory mesocosm experiment to examine the role of soil microarthropods and nematodes in determining nitrogen availability in the rhizosphere of fluff grass (Erioneuron pulchellum).


Whitford, W. G. Abiotic controls on the functioning of soil food webs.

Whitford, W. G. and J. Anderson. Stem flow, through fall relationships in a desert shrub: water channelization to roots?


PUBLISHED ABSTRACTS


