Reflections on a Century of Rangeland Research in the Jornada Basin of New Mexico

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Abstract—A historical analysis can generally take one of three formats: 1) narrative, 2) context, or 3) analog. As narrative, the analysis is limited to a description detailing events. As context, historical analysis explains the present state based on interpretations of its varied history. As analog, the analysis attempts to support predictions regarding future conditions. The narrative format is the safest in that it typically involves the least interpretation and assumption, especially if the historical record is well-documented. The context format can be the most enlightening. The analog, though, is the most useful, and the most precarious, and shares the central premise of scientific experimentation, the desire to make predictions about the future. The Jornada Experimental Range's history overlaps that of the discipline of rangeland management. Reviewing the history of the range should not be a parochial exercise, but should have a wider generic application to the history of the discipline. The history of research at Jornada has six often overlapping and evolving themes: classic range management, animal husbandry, ecology, range improvement, interdisciplinary sciences, and ecosystem science.

Inception of the Experimental Range

Elmer Otis (E.O.) Wooton was appointed in 1890 as the plant taxonomist for the New Mexico College of Agriculture and Mechanical Arts. Though Wooton specialized in taxonomy, his scientific interests were highly diverse (see Allred 1990). His botanical excursions throughout the New Mexico territory at the turn of the century helped form a well-based assessment of rangeland conditions in the region.

Wooton, in 1908, published a New Mexico Agricultural Experiment Station Bulletin that detailed his assessment of these range conditions. Based on his observations and surveys of ranchers' opinions throughout the region, his assessment was bleak. He reported greatly diminished carrying capacities for rangelands throughout the Southwest. Surprisingly, 67% of the surveyed stockmen attributed their deteriorated conditions to overstocking. Wooton estimated that a 20% increase in carrying capacities could be realized with implementation of grazing controls and good management practices. These practices included fencing, stock water development, livestock rotation, weed control, and erosion control.

Wooton also stated that proper stocking rates would have to be determined through research and that many of these practices and research results would have to be demonstrated to stockmen throughout the region. It was this conclusion that prompted Wooton to later propose the formation of the Jornada Range Reserve. Wooton had initiated research with cooperative ranchers in the Southern New Mexico Territory by 1904, but desired a more fixed and permanent location for his studies.

Established in 1912, the Jornada Range Reserve was formed within the USDA's Bureau of Plant Industry. Wooton, who had left New Mexico in 1911 to join the USDA was appointed the first director of the Reserve.

In 1915, the Reserve (later named the Jornada Experimental Range) was transferred to the Forest Service, which quickly developed long-term research objectives and implemented scientific investigations under the direction of C.E. Fleming. The initial objectives as detailed in the 1915 Memorandum of Understanding between the Forest Service and Charles T. Turney, the cooperating rancher who stocked the reserve, were to:

1. Develop a range management plan to minimize stock loss during drought.
2. Establish a system of forage utilization consistent with growth requirements of forage species and which will build up depleted range and minimize non-use losses.
3. Identify advantages of controlling stock and the range for improving stock performance.
4. Quantify carrying capacity of native range under control and comparative capacity of these lands without control.
5. Identify costs of handling stock under controlled conditions compared to uncontrolled conditions.
6. Quantify loss of stock under controlled conditions compared to uncontrolled conditions.
7. Identify number and distribution of stock watering places necessary to secure proper use.
8. Examine the possibility of range improvements by introduction of new plants, seed planting, conservation of runoff, etc.

Obviously, implicit in the original goals of the Range Reserve was to demonstrate the advantages for both stock and the land of controlling the grazing use of the open range.

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Historical Narrative

Range Management

A key problem for range management was quickly identified as inaccurate judgement of carrying capacity (Wooton 1915). The Jornada Experimental Range's (JER) research program focused on quantifying proper utilization levels of the principle species. Jardine and Forsling (1922) established early guidelines for carrying capacities of black grama (Bouteloua eriopoda) rangelands. Subsequent research during ensuing decades has reinforced the accuracy of these guidelines, as Campbell and Crafts (1938), Paulsen and Ares (1962) and Holechek and others (1994) have reached strikingly similar conclusions. These authors all concluded that proper utilization of black grama should be less than 40% of current year's growth.

The original philosophy was that proper utilization of the leaves and stems of the main forage plants was the basic principle of range management (Canfield 1939). General management guidelines published in the 1910's and 1920's are very similar to those promoted today. For example, nearly 80 years ago Jardine and Forsling (1922) recommended the following drought strategies: 1) limit breeding stock to carrying capacities during drought, 2) utilize surplus stock during good forage years depending upon market conditions, 3) adjust range use seasonally depending upon growth characteristics of key species, 4) establish permanent watering points no more than five miles apart, and 5) establish both herding and salting practices that achieve optimal stock distribution. Similar recommendations for drought conditions are outlined in one of the most current textbooks on range management (see Holechek and others 1995).

Husbandry

Initial research on livestock production also emphasized strategies for drought. Most of the original efforts focused on supplemental feeding programs, especially those that used locally available foodstuffs such as cottonseed products. For example, general recommendations were for 1 to 2 pounds of supplemental protein to augment range forage for maintenance (Forsling 1924), with slightly higher quantities suggested for growth of stockers (Jardine and Hurtt 1917). These general recommendations have persisted during ensuing decades. However, more recent research focuses on the use of protein and energy supplements for specific animal production stages to trigger specific physiological activities (see Gambill and others 1994).

More novel research has emphasized specialized practices for emergency feed conditions and management of poisonous plants. Soapweed (*Yucca elata*) was found to be a palatable emergency feed when fed chopped and fresh (Forsling 1919). Ensiling was not determined to be necessary. Other plant species were either deemed not suitable as emergency feeds (i.e., *Dasylirion wheeleri* and *Yucca macrocarpa*) or required spine removal (*Opuntia* spp.). Interestingly, burning spines from prickly pear cactus (in 1924 Forsling estimated that one person could prepare cactus feed for 200 to 400 hd of cattle in a day) was employed during the 1994-95 drought in the Southwestern U.S. However, even in the 1910's and 1920's the use of emergency feed practices was not viewed as responsible management for properly stocked rangelands.

As in other western rangeland regions, studies on poisonous plants provided both initial guidelines for livestock management and insight into the difficulties of plant control in a desert environment. For southern New Mexico drymaria (*Drymaria pachyphylla*) became a problem in response to overgrazing (Little 1937). For clay soils, drymaria was viewed as an early seral species (Campbell 1931). Avoidance of grazing in drymaria infested areas was the recommended management strategy. Various measures of control (fencing, burning, spraying, revegetation) were examined and determined to be either too expensive or ineffective. The recommended control practice was hoeing, but eradication was not viewed as a viable possibility. These general characteristics relative to management and control recommendations for poisonous plants persist today (see James and others 1993).

Development of techniques (such as esophageal fistulation) for animal nutrition research led to investigations of the interactions between plants and livestock. Early work identified foraging behaviors of different cattle breeds (Herbel and Nelson 1966), but irrespective of breed, cattle are generalists in this environment. A current research emphasis is identification of animal production capabilities most suitable to forage characteristics of desert rangelands (Walker and Winder 1993). Cattle genotypes with relatively modest performance traits, such as milk production, would be more successful in this nutrient sparse environment. It is possible that some desired characteristics will mirror those inherent to the original cattle breeds introduced to North America in the 16th century.

Research on plant-animal interactions now reflects the widespread distribution of shrubs in the Chihuahuan Desert. Foraging behaviors are strongly mediated by secondary plant chemistry (Estell and others 1994), and chronic ingestion may have post-ingestive consequences that further shape preferences (Fredrickson and others 1994). Remediation of shrub-dominated rangelands will require cost effective technologies. The use of livestock as bio-control agents for remediation will require detailed knowledge of this chemically mediated interaction in order to be an effective technology.

Ecology

One of the early objectives of the JER was to understand the role of management in natural revegetation of rangelands (Jardine and Hurtt 1917). By the late 1920's, patterns of succession were described (Campbell 1929; Campbell 1931). These observations were generally in areas where livestock numbers had been substantially reduced (or eliminated) and yearlong grazing had been adjusted to seasonal use. For example, on sandy soils five successional stages were described in the natural revegetation of sand dunes: 1) mat stage of low prostrate annuals, 2) inderal stage of large annual and perennial forbs, 3) snakeweed (*Gutierrezia sarothrae*) stage (viewed as critical), 4) dropseed (*Sporobolus* spp.) stage (regeneration of perennial grasslands), and 5) grama grass stage. These observations reflected the succession-and-climax paradigm of the period.

However, these early observations did not portend larger scale transformations that were documented over ensuing decades. Probably the defining publication from the first half-century of research in the Jornada basin was Buffington and Herbel's (1965) reconstruction of vegetative changes in the area between 1858 and 1963. The broad scale encroachment of shrubs was attributed to seed dispersal, heavy grazing and periodic droughts (Buffington and Herbel 1965).

Concomitant with the vegetation dynamics has been substantial change in surface soils. Gibbens and others (1983) documented effects of wind erosion of soil fractions as an ungrazed landscape changed from perennial grassland to coppice dunes dominated by mesquite. Both soil movement and the redistribution of sand, silt and clay factions were substantial.

Emerging from this reconstruction and associated research has been a key postulate regarding changes in ecosystem properties that accompany grassland conversion to shrubland (desertification). This central hypothesis is that the distribution of soil resources is altered from spatially homogenous, as seen in semiarid grasslands, to heterogeneous, as seen in shrublands, with desertification (Schlesinger and others 1990). Further, these emerging resource islands act as positive feedback to further the invasion and persistence of shrubs. This hypothesis has formed the basis for the research efforts of scientists affiliated with the Long-Term Ecological Research (LTER) program at the Jornada (fig. 1).

This hypothesis counters the earlier observations regarding the potential for disturbed lands in arid environments to naturally revegetate to semiarid grassland conditions. Current research in other arid regions would also support a hypotheses of nonlinear vegetation dynamics in these environments (for example, see Milton and others 1994).

Improvements

The first articles on classical techniques for improving forage production on desert rangelands were published in the 1940's (Cassady and Glendening 1940; Parker 1943). These research efforts primarily focused on reseeding practices and a variety of brush control methods. With the development of appropriate machinery (i.e., the rangeland drill) and herbicides, examinations of intensive improvement practices were a significant part of the research program for the next 45 years (Parker 1949; Herbel and Ares 1961; Herbel and Gould 1970; Herbel and others 1985). The principles of these intensive improvements have been well articulated (Herbel 1983), however, more recent economic assessments of these practices have not been wholly favorable. For example, Sherwood (1994) concluded that over 95% of the possible reseeding practices suitable for the Jornada basin would result in a negative economic return. Similar doubts have been raised regarding the cost effectiveness of chemical methods for brush control (Herbel and Gould 1995).

One of the original objectives of the Experimental Range was to identify a management system that brings about natural reseeding of desired species (Jardine and Hurtt

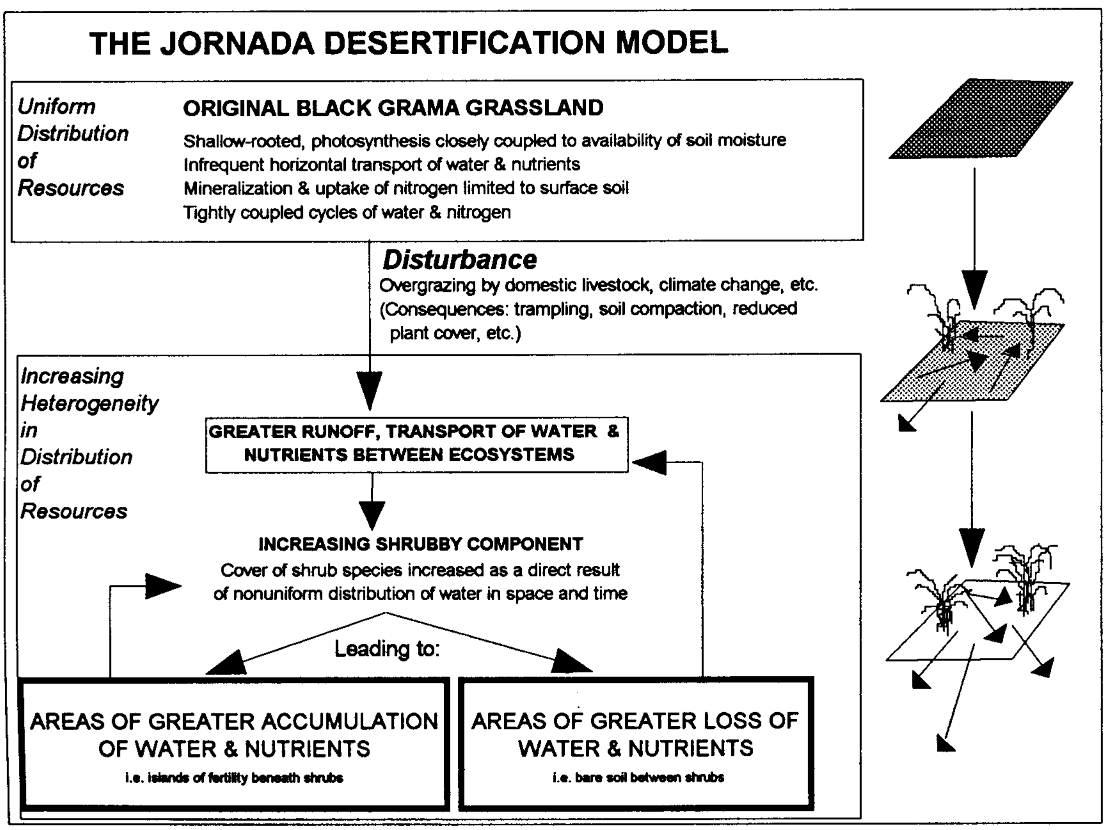

Figure 1

1917). With our emphasis on developing specialized intensive technologies we have not accomplished this original objective. Low-input techniques that are economical and effective are still required. Four premises need to be advanced: 1) biological integrity of both above- and belowground systems in addition to the short-term establishment of desired species, is necessary to buffer against future disturbances, 2) resource redistribution over time at the community and landscape levels plays an important role in both desertification and restoration processes, 3) restoration efforts should focus on fertile sites best suited for reestablishment of native species, and 4) planting technologies should be based on readily available "natural" dispersal systems (Herrick and others 1995).

Interdisciplinary Sciences

Interdisciplinary research began in earnest in the 1960's. Rangeland science has typically been presented as an applied, interdisciplinary field, but involvement of related sciences (other than animal science and other directly related agricultural fields associated with range livestock production) was slow to develop. The interactions with this new group of scientists occurred in conjunction with an expanding appreciation for the multiple uses and values of desert rangelands.

In the Jornada basin these interactions involved both biological and soil sciences. Gile (1966) provided new insights into soil horizon development processes in arid environments. In particular, descriptions of clay illuviation in high carbonate sediments greatly revised our understanding of argillic horizons in arid soils (Gile and Grossman 1968; Gile and Hawley 1972). These clay horizons develop slowly in deserts, and can be masked by subsequent accumulations of carbonate.

Whitford and others (1983) provided initial insights into the role of decomposers and herbivores on nutrient cycling in the desert. For example, cleverly designed field studies identified the mass of subterranean termites (*Gnathamitermes tubiformans*) in the Jornada at 30 kg/ha (MacKay and others 1989). Termites were estimated to recycle 11% of litter N and 13% of annual and grass standing crops (Schaefer and Whitford 1981).

Hundreds of studies in the past 25 years have expanded our knowledge on a range of topics, including soil biota (Virginia and others 1992), biogeochemical processes (Schlesinger and Peterjohn 1991), nitrogen fixation (Herman and others 1993), surface hydrology (Tromble 1988), primary production controls (Cunningham and others 1979), effects of lagomorphs (Gibbens and others 1993), and distributions of rodent populations (Hoover and others 1977).

Although many of these topics require further research, we still have two particular, and different, research needs. First, this body of work lacks effective synthesis. Without complete and detailed synthesis, the application of this information to the management of these desert rangelands is seriously curtailed. Second, there is an overwhelming need for research on the roles of soil biological systems in the recovery of degraded lands (Whitford and Herrick 1995).

Ecosystem Science

The creation of the International Biological Program (IBP) provided the impetus for an ecosystem framework for research. The Jornada basin was the location for the desert grassland site within the IBP. By the early 1970's scientists had assessed system variables as a foundation for model development and expanded insight into ecosystem processes. For example, Pieper and others (1972) quantified that 4% of captured energy was transferred from plants to herbivores in the desert.

As the IBP dissolved in the late 1970's, the LTER program emerged in the 1980's as its evolved successor. The LTER, now in its second decade, has five core research efforts: 1) pattern and control of primary production, 2) spatial and temporal distribution of populations selected to represent trophic structure, 3) pattern and control of organic matter accumulation in surface layers and sediments, 4) pattern of inorganic inputs and movements of nutrients through soils, groundwater and surface waters, and 5) pattern and frequency of disturbances. Research in these core areas has provided a basis for modeling efforts. In particular, modeling has linked transport processes to the spatial and temporal dynamics of soil resources, a key premise of the Jornada model. Based on these efforts the regional stability of desert ecosystems has been described as a function of resource distributions among smaller scale (patch) mosaics within the larger landscape (Reynolds and others 1995). Understanding the cascading effects (both positive and negative) of both management and remediation practices in the desert will require the continued development of larger scale ecosystem models.

Context of Research History

Two prevailing themes arise from an analysis of the history of research conducted in the Jornada basin. These themes are degradation and utilitarian environmentalism. The JER has its roots in the deteriorated range conditions of the region during the later decades of the 19th century. Much of its research effort throughout the 20th century was devoted to developing range management practices suitable for degraded lands or intensive technologies for their improvement. Even today a central postulate of our research is based upon a hypothesis of degradation processes (the "Jornada model"). Yet, if there is one key deficit to these research accomplishments, it is the failure to identify usable technologies for remediation of degraded conditions.

This failure is probably more a function of the dynamics of our environment, our economy, our attitudes, and our expectations than from an inefficient use of the scientific method. We now believe that remediation has to be accomplished in a more extensive fashion and based on a more complete knowledge of the basic ecological processes that occur in desert rangelands.

Since its establishment, the JER research program has included a significant element devoted to ecological studies. Livestock production and an understanding of the principles for managing the forage on which the range livestock industry is based was the initial emphasis. However, the emerging principles have an ecological basis. Though an increasing emphasis is now placed on the study of ecological principles, livestock grazing as a viable use and tool for landscape management is still central to the research. This can best be labeled as a utilitarian environmentalism, a concern for the long-term capacity to harvest food and fiber from a highly variable (transient) environment. Our terms for this goal, such as "proper use" and "sustainability", have not withstood rigorous examinations. The theme, though, has been and will continue to be how to use this resource based on a thorough understanding of our surroundings and our interactions with those surroundings.

History as Analog

The history of research results from the JER supports three emerging postulates from the broader body of rangeland science in recent years. These postulates are: 1) many ecological processes have thresholds below and above which they become discontinuous, chaotic or suspended, 2) ecological character is reflected by dominant species, and 3) species are interdependent and many of these interdependencies form highly specialized interactions.

Many of the observations in the Jornada basin during this century have documented surprisingly rapid changes across the landscape. Yet, our frustrations in effecting change, even with intense inputs, supports the second postulate. Remediation within this ecosystem will require specific knowledge of species interactions, which may have to be regenerated before corrective management actions will be effective. Needless to say, we can predict from our observations that simply abandoning the landscape will not promote recovery, or prevent further deterioration.

Within this context, livestock grazing must be managed so as to neither disrupt species interactions nor drive impacted processes beyond the thresholds. The average annual carrying capacity for this hot desert is 9.5 AU/section. This would require the annual harvest of approximately 10-20g of forage per m^2 with even distribution of grazing use. We have the basic management techniques for controlling grazing for this level of defoliation. However, we still need the ability to effectively monitor that use over large areas, detect impacts of use on key processes, more rapidly recognize seasonal forage dynamics and develop methodologies for using the animal to effect desired changes.

Conclusions

Much of the research conducted during the early 20th century is still applicable to today's management issues. Though the experimental designs employed in the 1910's, 1920's and 1930's might not entail the sophistication serviceable by current statistical analyses, the thoroughness and detail of the early field research more than compensates. In addition, the length of the research record itself becomes a powerful tool for insight and scientific speculation.

One perception that surfaces from a review of the research record of the Jornada basin is the complexity of this arid ecosystem. This complexity cannot be easily communicated. Yet, these desert rangelands will continue to provide critical resources to a significant portion of the human population. It is important that we not oversimplify our understanding of this system in our attempts to communicate our knowledge to interested segments of our society. Solutions to today's management problems are generally not simple, and we should not create false expectations. We need to use the full scientific history of experimental stations like the Jornada to create more complete understanding. This should be a prominent objective within our research programs. In fact, using the Jornada Experimental Range as a demonstration for our knowledge of desert rangelands was an original objective of the U.S. Forest Service in 1915 and it is still valid today.

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