DESERTIFICATION: WEAVING TOGETHER THE COMPLEXITIES OF TIME AND PLACE

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On September 8th 1866, 19-year-old 2nd Lieutenant J. Henry Storey and 12 men from the 125th United States Colored Troops left Fort Seldon, New Mexico to "scout against" a party of Mescalero Apaches in the San Andreas Mountains. On the second day he arrived at San Augustine Springs, a place overlooking parts of the Mesilla Valley and Jornada del Muerto Basin. He found the sight quite remarkable. In his report he wrote, "In my opinion, San Augustine springs would be one of the best places in the Territory to establish a camp and Corral for Government stock. There is an abundance of water at the springs and grama grass in the immediate vicinity to graze 500,000 head of stock [sic]." As a recent immigrant from England to New York, Lieutenant Storey might have been naïve about deserts, but in the present day, even the most inexperienced among us would not make this claim. While patches of grass remain, shrubs surrounded by bare eroded soils dominate the area today.

Forty-two years later E. O. Wooton Botanist of New Mexico College of Agriculture and Mechanic Arts in his 1908 paper "The Range Problem in New Mexico" described the same area visited by Lieutenant Storey as having "very low capacity." Indeed, he described much of the New Mexico Territory as degraded due to overstocking by livestock. Largely due to the efforts of Wooton and local rancher C. T. Turney what is currently the 78,266 ha USDA-ARS, Jornada Experimental Range (JER) was withdrawn from the public domain in 1912 by executive order to devise animal husbandry and range management practices benefiting the livestock industry. With perhaps the exception of World War I (Fredrickson *et al.*, 1998) range scientists, many of which were the early pioneers of the field, managed the JER conservatively. Despite conservative management, the JER has undergone a conversion from grasslands to shrub-dominated rangeland (Figure 1) that has greatly reduced livestock carrying capacity (Figure 2)

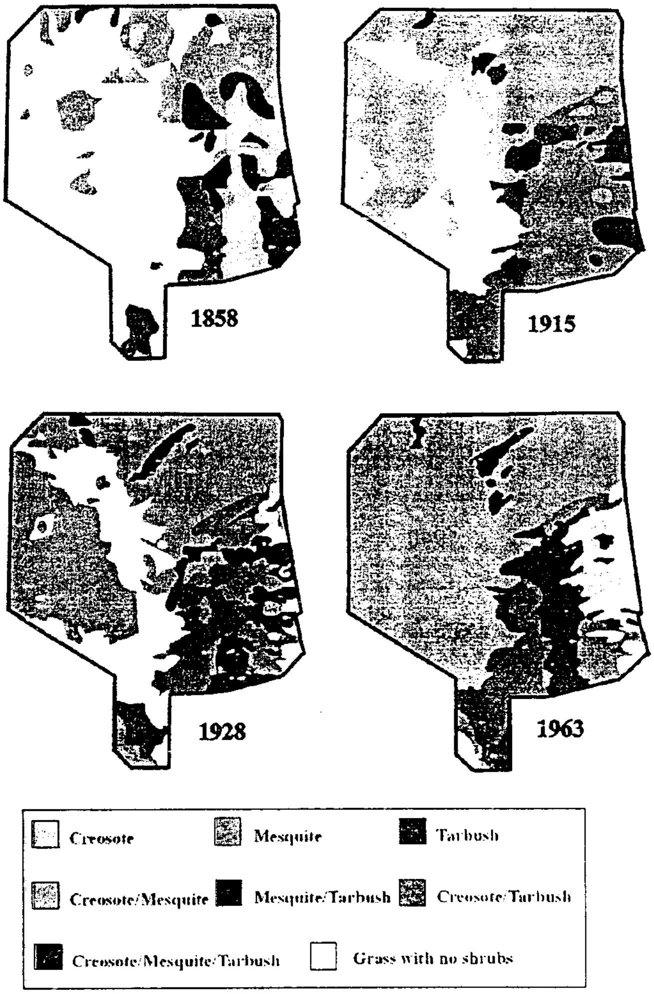

Figure 1. Vegetation change on the Jornada Experimental Range from 1858 to 1963 (Buffington and Herbel, 1965).

Displacement of perennial grasslands by shrubs typifies desertification and is a process that has occurred in many regions of the world (Huenneke *et al.*, 2002). According to 1990 estimates published by the United Nations Environmental Programme (UNEP, 1992 as cited by Mouat *et al.*, 1995) desertification affects one-sixth of the world's population with 76% and 73% of the drylands in North America and Africa respectively being in a degraded condition. For these lands, a loss in productive capacity due to desertification costs the world US$42 billion annually. Without a doubt, current and historic grazing practices are in part responsible for this transition; however, it is uncertain whether grazing is solely responsible or merely accelerated an inevitable shift in vegetation dynamics.

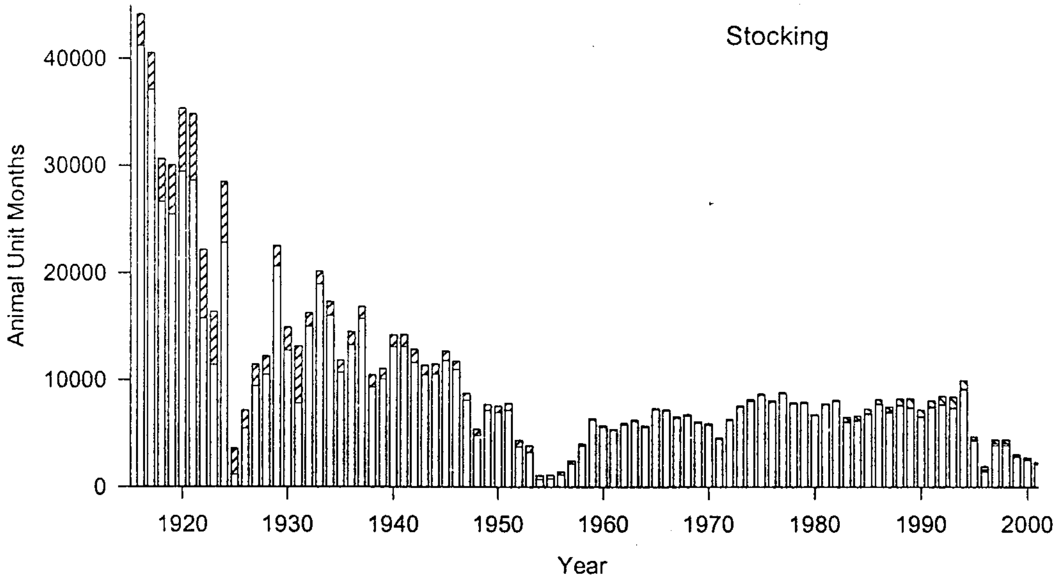

Figure 2. Livestock numbers on the Jornada Experimental Range 1915 to 2001.

To understand the vegetation changes in the northern Chihuahuan Desert it is necessary to go beyond institutional memory and examine vegetation changes over geological time. Allred (1996) provides an excellent summary of vegetation change over larger temporal scales. In his summary and that provided by Fredrickson *et al.* (1998) it is evident that vegetation patterns were in constant flux mostly driven by climatic changes that were at times abrupt. The recent Pleistocene ice ages (2.5 to 0.1 million years before present) typify these changes. During this time, approximately 20 glacial-interglacial periods occurred. With each glacial advancement and retreat, new vegetation assemblages arose as plants species would migrate, evolve, or become extinct. The last major glacial period ended about 10,500 years ago, with New Mexico and Northern Mexico becoming increasingly arid with climate favoring those plants adapted to summer rainfall. About 8,000 years ago, another shift toward arid conditions took place until about 2,500 years ago when a cooling trend occurred. Several times during these later transitions shrubland vegetation characterized by familiar plants such as honey mesquite (*Prosopis glandulosa*), *Opuntia* spp., and sotol (*Dasylirion* spp.) dominated the landscape. Long winters, high snowfall, and colder temperatures characterized the period from 1450 to the early 1800's (Scurlock 1995). Neilson (1986) proposed this "Little Ice Age" and the warm, dry trend that followed was largely responsible for the latest conversion of the northern Chihuahuan Desert from grasslands to desert scrub.

Herbivory too changed the landscape. Janzen (1986) proposed that many Chihuahuan Desert plants responded to the selective pressures of large herbivores such as sloths, camels, horses, and large bison by evolving spines and other physical barriers detering foraging animals. As plants and mammalian herbivores coevolved, plants also developed a large array of chemical deterrents (Freeland, 1991). Plants unable to deter or avoid foraging animals were likely removed from the system. Plants also developed special adaptations to use herbivores to disperse their seeds. Janzen (1986) in his paper further suggested that plants like *Opuntia* evolved fruits favored by herbivores and bearing indigestible seeds that when ingested were transported unharmed via the mammalian gut to safe places far from the parent plant. Plants like mesquite likely evolved a similar strategy. Possibly due to drought and over hunting by indigenous peoples (Martin and Klein, 1984), the large Pleistocene megafauna that coevolved with these plants disappeared approximately 10,000 years ago. With their disappearance, these same plants lost a primary mode of seed dispersal. This changed when livestock appeared in the North America deserts. In recent times, it is likely that livestock promoted reemergence of plant species with adaptations for seed dispersal by large herbivores. In the case of adapted shrubs, livestock both dispersed their seeds and removed plant materials that fueled frequent fires killing young emergent plants (Drewa and Havstad, 2001). This scenario is similar that described for the deserts of Australia and other regions (Walker and Janssen, 2002).

Indigenous peoples probably altered plant communities by dispersing and consuming seeds, hunting, and by their use of fire. Dobyns (1981) and later Bentancourt *et al.* (1993) claimed indigenous peoples greatly affected vegetation change in arid and semiarid regions of the southwestern U.S. They also remarked that the role of indigenous people in shaping landscapes is being greatly overlooked by ecologists trying to understand vegetation change.

The influence of modern society on desertification and aridland vegetation change is enormous but little understood. Human impacts now affect scales of complexity from biochemical processes to global biogeochemical cycles. Typically, ecologists were drawn to the field of ecology by an interest in "natural" landscapes and have shied away from studying human dominated landscapes; which, in reality, are nearly all terrestrial and aquatic systems. This trend is changing. Urban systems are now the focus of long-term ecological research programs and global change is a growing ecological discipline. One major area of interest is global warming. Global warming due to anthropogenic factors is estimated to range from 0.1 to 0.2°C per decade. Warming over landmasses is expected rise more rapidly than the global average with regions of North America expected to exceed the global mean warming by more than 40% (IPCC, 2001). Much of this increase is due to greenhouse gasses. Of these, atmospheric CO_2, primarily generated from burning fossil fuels, is the most studied. Since 1750 atmospheric concentrations of CO_2 has increased by 31% with substantial increases predicted during the remainder of this decade (Figure 3).

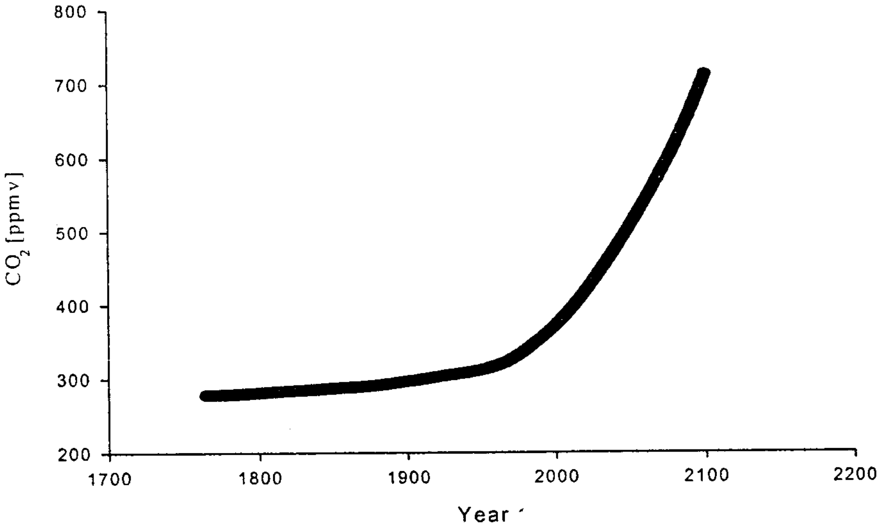

Figure 3. Estimated and predicted global yearly atmospheric CO_2 (Kittel et al., 1996).

Access to the dataset was provided by the Climate System Modeling Program, University Corporation for Atmospheric Research, and the Ecosystem Dynamics and the Atmosphere Section, Climate and Global Dynamics Division, National Center for Atmospheric Research.

Current concentrations have not been exceeded during the last 420,000 years and possibly not exceeded during the past 20 million years (IPCC, 2001). Warming trends are predicted to affect precipitation patterns with some regions of the Chihuahuan Desert receiving more precipitation while others will receive less. Larger year-to-year variations in precipitation are very likely (IPCC, 2001). Global warming was once hotly debated among scientists, but this debate is waning and there is now a general census among scientists that global warming is occurring, and will continue to occur. Without a doubt, the Chihuahuan Desert and the forces affecting desertification will persist and perhaps even be amplified.

Biological systems are always undergoing irreversible change. It is unreasonable to think that change will cease merely by our presence. Indeed, we have become agents of change. We frequently act without knowing the consequences of our actions. Currently, science is unable to tease out those changes that would occur in the absence of man from those caused by man with a high degree of certainty. By looking at the history of deserts, we become aware that desertification is both a natural process, and a process caused by human activity. We also become aware that it is not possible to sustain any present or prior condition for any extended length of time without some cost.

Because biological systems are complex, chaotic, and often catastrophic we can at times predict small oscillations in biological change, yet, we are unable to predict changes in future conditions with any certainty. The question becomes, how do you deal with not knowing? How do you make decisions in a complex world? In a complex world what is the role of science, land managers, and society? Because quality of human of life, and our very existence, is inescapably linked to the quality of our environment these are essential questions.

As Simon Levin (1999) points out in his book "Fragile Dominion: Complexity and the Commons" one role of science is to reduce uncertainty. For this to occur we need to continue our efforts to better understand the dynamics of basic processes. We must then learn to link our knowledge of these processes to improve our understanding of increasingly higher order processes. Advances in disciplines such as physics and medicine during the last decade are both substantial and obvious. Necessarily, our ability to link basic processes has lagged behind. We must know one before we can know the other. Nevertheless, with the advent of computers, and a rapidly evolving theoretical framework from which to organize our knowledge, our progress is rapidly improving. As one individual exclaimed in a recent meeting on ecological complexity, "complexity is simplicity not found." With time, we will improve our ability to use our knowledge of ecological systems to play out different scenarios and identify those actions that reduce risk.

One area of ecological theory that promises to assist land managers and others is that of complex adaptive systems. Complex adaptive systems as defined by Levin (1999) is "A system composed of heterogeneous assemblages of types, in which structure and functioning emerge from the balance between the constant production of diversity, due to various forces, and the winnowing of that diversity through a selection process mediated by local interactions." Restated, and perhaps oversimplified, a complex adaptive system is an interacting set of diverse entities whose parts interact in such a way that they are more resilient to perturbations affecting the system and are better able to adapt to change. This theory applies to a number of hierarchal scales. For example, a pasture with a complex assemblage of linked species may be better able to withstand or adapt to forces normally leading to desertified conditions. A ranch owner or aggregate of ranch owners exploiting a diversity of potential income sources may be better able to tolerate drought, or be able to adapt to increasing aridity. Finally, a city, or region, with a diversity of interacting industries should be better able to adapt to climate or economic shifts. The idea of diversity is not new, but an examination of how diverse components interact and are allowed to adapt to change is relatively unexplored. Walker and Janssen (2002) analyzed commercially operated rangelands as a complex adaptive system of people and nature. In their analysis, conservative command-and-control conditions not only reduced short-term losses but also restricted learning and the ability to adapt to change. Conversely, a free-market environment led to severe degradation followed by a period of adaptation. They concluded that policies integrating aspects of both these systems are needed to prevent excessive degradation while promoting learning needed for adaptation.

Adaptive management is a process that can adjust to the uncertainties inherent in landscapes. Through a process of planning, implementation, monitoring, evaluation, and adjustment, adaptive management can help us better interact with changing environments. Adaptive management has evolved during the last 20 years. With increasing recognition by managers and policy makers that we in fact do live in an uncertain world, new management concepts will emerge to help us deal with uncertainty. Scientist and managers can work together to design management protocols that allow us to learn from management practices. Furthermore, scientists will continue to develop indicators of even subtle changes in the system that allows managers to adjust management before irreparable damage occurs. Lastly, we must learn to recognize what we can change and what we cannot.

If Lieutenant Storey stood at his vantage point at San Augustine Springs today, he would be amazed at the changes that have occurred in the landscape stretching out in front of him. If people living in 1866 were able to see the changes that Lieutenant Story now sees, would they have behaved differently? Will we behave differently knowing that change of a similar magnitude can occur within the next 100 years or less? I think we will. With this in mind, we need to renew our focus on developing the science and tools necessary to effectively deal with desertification and a constantly changing desert environment.

REFERENCES

Allred, K. W. 1996. Vegetative changes in New Mexico rangelands. New Mexico Journal of Science 36:168-231.

Betancourt, J. L., E. A. Pierson, K. A. Rylander, J. A. Fairchild-Parks, and J. S. Dean. 1993. Influence of history and climate on New Mexico piñon-juniper woodlands. In: E. F. Aldon and D. W. Shaw (Eds.), Managing piñon-juniper ecosystems for sustainability and social needs. U. S. D. A. Forest Service General Technical Report RM-236.

Buffington, L. C., and C. H. Herbel. 1965. Vegetational changes on a semideset grassland range from 1858 to 1963. Ecological Monographs 35:139-164.

Dobyns, H. F. 1981. From Fire to Flood: Historic Human Destruction of Riverine Oases. Ballena Press Anthology Papers. No. 20. Ballena Press, Socorro, New Mexico.

Drewa, P. W., and K. M. Havstad. 2001. Effects of Fire, Grazing, and the Presence of Shrubs on Chihuahuan Desert Grasslands. Journal of Arid Environments 48:429-443.

Fredrickson, E. L., K. M. Havstad, R. E. Estell, and P. W. Hyder. 1998. Perspectives on desertification: southwestern United States. Journal of Arid Environments 39:191-207.

Freeland, W. J. 1991. Plant secondary metabolites: biochemical coevolution with herbivores. In: R. T. Palo and C. T. Robbins (Eds), Plant Defenses against Mammalian Herbivores. CRC Press, Inc., Boca Raton, Florida. Pp. 61-82.

Huenneke, L. F., J. P. Anderson, M. Remmenga, and W. H. Schlesinger. 2002. Desertification alters patterns of aboveground net primary production in Chihuahuan ecosystems. Global Change Biology 8:247-264.

IPCC. 2001. Climate Change 2001: The Scientific Basis. Contribution I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. J. T. Houghton, Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. A. (Eds.), Cambridge University Press, Cambridge, United Kingdom. 881 pp.

Janzen, D. H. 1986. Chihuahuan Desert nopaleras: defaunated big mammal vegetation. Annual Review of Ecology and Systematics 17:595-636.

Kittel, T.G.F., N.A. Rosenbloom, T.H. Painter, D.S. Schimel, H.H. Fisher, A. Grimsdell, VEMAP Participants, C. Daly, and E.R. Hunt, Jr. (1996) *The VEMAP Phase I Database: An Integrated Input Dataset for Ecosystem and Vegetation Modeling for the Conterminous United States.* CDROM and World Wide Web (URL=http://www.cgd.ucar.edu/vemap/).

Levin, S. 1999. Fragile Dominion: Complexity and the Commons. Perseus Publishing, Cambridge, Massachusetts.

Martin, P. S., and R. G. Klein. 1984. Quaternary Extinctions. University of Arizona Press, Tucson.

Mouat, D. A., C. F. Hutchinson, and B. C. McClure 1995. Introduction. Environmental Monitoring and Assessment 37:1-4.

Neilson, R. P. 1986. High-resolution climatic analysis and southwest biogeography. Science 232:27-34.

Scurlock, D. 1995. Environmental history. In: D. M. Finch and J. A. Tainter (Eds.), Ecology, diversity, and sustainability of the middle Rio Grande basin. U. S. D. A. Forest Service General Technical Report RM-GTR-268. Pp. 12-28.

UNEP. 1992. World Atlas of Desertification. United Nations Environmental Programme, Edward Arnold, London.

Walker, B. H., and M. A. Janssen. 2002. Rangelands, pastoralists, and governments: interlinked systems of people and nature. Philosophical Transactions of the Royal Society of London. Series B. 357:719-725.

Wooton, E. O. 1908. The range problem in New Mexico. Agricultural Experiment Station Bulletin No. 66, New Mexico College of Agriculture and Mechanic Arts, Las Cruces.