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The Future of Arid Grasslands:

Identifying Issues, Seeking Solutions

Tucson, Arizona

October 9 – 13, 1996

Abstract

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This conference was designed to provide a non-confrontational setting for a variety of people from differing viewpoints to discuss the threats facing arid grasslands of the Southwest. Participants included ranchers and other private economists, scientists, and students. The sessions were organized around the major themes of understanding grasslands, identifying grassland issues, managing grasslands, and seeking solutions to grassland issues. Many of the sessions were in the form of panel discussions or informal presentations.

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The Future of Arid Grasslands:
Identifying Issues, Seeking Solutions

Tucson, Arizona and
Selected Ranches in Southern Arizona,
Southwestern New Mexico, and Northern Sonora

October 9 – 13, 1996

Editors:

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Conference Sponsors

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The Malpai Borderlands Group

The Arizona Nature Conservancy

Tucson Audubon Society and Huachuca Audubon Society

The Arizona–Sonora Desert Museum

Western Sod / Western Sere

Charles Hummel

Drexel Jones

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Preface

Barbara Tellman[1] and Diana Hadley[2], Conference Coordinators

THE PURPOSE OF THE CONFERENCE

Grasslands in many parts of the Southwest and northern Mexico are facing serious threats - from urbanization and subdivision development to spread of invasive plant species to conflicts over grazing policy. The conference organizers wanted to get a wide variety of people together to discuss the major problems facing grasslands in arid and semi-arid regions of the U.S. and Mexico and to seek solutions to those problems. The need to resolve conflicts in non-confrontational ways was stressed.

Target groups for participation included ranchers and other private landowners, non-profit groups such as The Nature Conservancy, government agencies with responsibility for grassland management, environmental advocates, economists, scientists, students, and others. The plan was to offer a non-confrontational atmosphere in which people could freely discuss issues and advantages and disadvantages of a whole range of solutions to common problems. The emphasis was on practical, hands-on management methods, including spending considerable time in grasslands managed under a variety of techniques.

More than 250 people attended some portion of the conference including: landowners and ranchers from Arizona and New Mexico; county planning department staff: state agency representatives from Arizona and new Mexico; representatives of the U.S. Forest Service, Natural Resources Conservation Service, Bureau of Indian Affairs, Fish and Wildlife Service, Bureau of Land Management, Agricultural Research Service; Tribal representatives from the Tohono O'odham Nation, San Carlos Apache Tribe, and the Navajo Nation; non-profit group representatives from The Nature Conservancy in several states, Trust for Public Lands (Santa Fe, NM), Real Estate Conservation (Helena, MT), the Land Institute of Kansas, Southwest Center for Biological Diversity, The Wildlands Project, Wildlife Damage Review, the National Audubon Society, and others; academics, including wildlife biologists, economists, rangeland management experts, and others from Arizona, New Mexico, California, Colorado, Texas, Utah, and Sonora, and students from New Mexico, Colorado, Mexico and Arizona.

HOW THE CONFERENCE WAS ORGANIZED

The first day was devoted to understanding grasslands and grasslands issues. The conference began with plenary talks to set a basis for understanding grasslands, or as one speaker preferred "savannas." Concurrent sessions on major problem areas were: Wildlife, Tourism and Urbanization; Fire Management and Grazing; Water Supply and Sustainability; Watersheds and Water Quality; Wildlife Corridors; and Exotic Plant Species. Problems of grassland management on tribal lands and on Mexican lands were another focus. Wes Jackson of the Land Institute of Kansas talked about sustainability problems on grasslands.

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[1] Water Resources Research Center, University of Arizona, Tucson AZ.

[2] Arizona State Museum, University of Arizona and the Audubon-Whittel Research Ranch Foundation, Tucson AZ.

The second day was spent looking at management of grasslands in Southern Arizona. One group visited a publicly owned grassland, managed for grazing, riparian proteciton, and recreation. A second group visited several privately owned ranches and learned about the history of the area and threats to its continued use as a ranchland. A third group visited two privately owned ranches with very different grazing styles and the Audubon-Whittel Research Ranch, where grazing was eliminated 20 years ago. All three groups ended up at the Research Ranch for lunch prepared by the Santa Cruz County Cowbelles, and for mini-workshops on paleontology, native plants, mammals, snakes, insect research and other topics. Some participants joined a preconference field trip to the Gray Ranch in southwestern New Mexico.

The third day was spent in sessions looking for solutions to problems identified on the first day. Plenary speakers discussed new approaches to grazing policy and management. Major areas explored in sessions were: Monitoring; Land Conservation Options (including conservation easements, land trusts, tax law opportunities and zoning); Public and Private Land Management Techniques; Cooperative Partnerships; Conflict Resolution: and Rangeland Reform.

The final day again featured field trips to nearby grasslands in southern Arizona and northern Sonora.

THE CONFERENCE PROCEEDINGS

This volume follows the general organization of the conference, although the agenda is not exactly duplicated herein. Section One includes presentations on the subject of understanding grasslands, including the keynote speeches. Section Two includes presentations on the subject of managing grasslands. Section Three deals with identification of issues and problems facing grasslands. Section Four looks at solutions to the identified problems. Posters and abstracts of posters are integrated into the sections as appropriate.

Many of the sessions were in the form of panel discussions or informal presentations. Some of these were difficult to reproduce in the proceedings format. Some of the articles in this proceedings follow the traditional format of prepared papers, complete with technical graphics. Others are summaries of sessions by recorders, or transcriptions from tape recordings of presentations. The recorders and transcribers are clearly identified in those sections. Two major sessions - Monitoring and Conflict Resolution - were summarized in detail by the organizers of those sessions. The variety of formats reflects both the character and flavor of the symposium, and the intention of the organizers to bring together individuals and groups who have only recently shown strong interest in meaningful dialog.

THE GRASSLANDS BIBLIOGRAPHY

Available also to readers of the proceedings is a grasslands bibliography on computer disk. This bibliography contains almost 4,000 references to works relating to grasslands in the arid and semi-arid regions of the western United States. It was compiled by graduate students at Arizona State University and the University of Arizona from a large number of sources. It contains the standard technical works on grasslands research, as well as materials on the various subjects represented at the conference such as conservation easements, conflict resolution, and even grasslands history and poetry. The disk can be accessed by anyone with either DOS or Windows and does not require any other program for use. It will be sent free to all conference participants. Others may order a copy from the Tucson Audubon Society Gift Shop, 300 E. University Blvd., #11, Tucson AZ 85705. Please enclose $7 per copy to cover reproduction, shipping and handling costs.

Chapter I
Understanding Grasslands

The conference and this proceedings were structured first to understand the nature of grasslands, then to look at major issues involved in grassland protection, then to look at management matters, and finally to identify possible solutions to the problems identified.

In this chapter five plenary speakers set the framework for the conference by describing features of the grasslands from Texas west to California and from Sonora north to Nevada and Utah. This opening session was chaired by Mitch McClaran. Tony Burgess presents arguments that 'savanna" is a more appropriate name for the grasslands of these areas and describes those areas and raises issues about human use of them. Kris Havstad takes a look at grasslands in the northern Chihuahuan Desert. Alberto Burquez uses the case study approach to talk about grasslands in northern Mexico. Finally Jane and Carl Bock look generally at factors controlling the structure and functions of desert grasslands.

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Northwestern Apacherian Savannas: A Description, and Review of Issues Concerning Human Inhabitation

Tony L. Burgess[1]

ABSTRACT

I have focused on Apacherian Savannas in Arizona and adjacent areas, but it should be emphasized that related communities occur to the east as far as Abilene, Texas and south at least to Durango, Mexico. My reasons for proposing the name 'Apacherian savannas' to replace the term 'desert grasslands' are presented after a general description of their ecology. Trends in human influences upon these communities are summarized. I close with suggestions to integrate the preservation of ecological integrity with provisions for human opportunity.

ECOLOGICAL LIMITS

Ecological communities are organized around constraints on the growth and reproduction of their organisms. Apacherian savannas are defined by the nature of their adversities. Their landscapes are recognizably similar because the vegetation has been shaped in similar ways by climate.

The region is located on the polar edge of the arid subtropics, where it is heavily influenced by turbulent dynamics of jet streams (Neilson 1986, 1987). This situation produces recurrent droughts and unstable climate patterns. The complex basin-and-range topography presents a wide range of elevations. This context produces local, fine-scale patterns of microclimates and soil moisture regimes. Along elevational gradients, frequency and severity of frost range from subtropical to temperate values; so that cold damage to plants varies considerably from year to year and place to place.

Rainfall is also erratic over time and space. Apacherian savannas experience less drought than those in an arid climate; hence they are usually more productive than desertscrub vegetation. On the other hand they get more drought than a humid climate; so they have less standing biomass than a woodland. The savanna vegetation is part of McAuliffe's "ecological confusion zone" (1995) sandwiched between arid desertscrub in lower basins and wetter woodland or forest on higher mountains. This zone is a mosaic of chaparral, grassland, savanna, woodland and desertscrub communities that have a prominent grass stratum sometimes in some places. Within this zone plant species composition and vegetation structure of a site are heavily influenced by two kinds of factors:

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[1] Biosphere II, Oracle, Arizona.

1) those that affect soil moisture availability, such as rainfall, topography, geology, and soil texture

2) those that affect disturbance or vegetation removal, the most important being fire, grazing, and drought.

Four important weather patterns can be recognized in this region:

1) The arid foresummer is a hot dry period usually centered in May and June. These are usually the driest months with the highest daytime temperatures.

2) Arizona monsoon storms signal the end of the arid foresummer. Wind patterns bring moist air into the region, and local convective thunderstorms form. Showers may be intense, but they seldom last long or cover wide areas. In most years these spotty storms are the major source of rain for Apacherian savannas.

3) Autumn tropical storms are unpredictable, but when they enter the region, they can provide large amounts of rain and trigger impressive vegetation responses. 'Autumn' is used in a broad sense, because these storms may occur from late summer through November.

4) Winter frontal storms bring widespread rain or snow along with cool temperatures. Winter storm systems, which may last two to five days, can be critical for recharging deep soil moisture that many trees and shrubs depend upon to survive the arid foresummer.

Among these four patterns the arid foresummer drought is most predictable, but its duration and intensity vary considerably from year to year. Plant growth in Apacherian savannas is governed by soil moisture, which is delivered as discrete pulses separated by intervals of drought. Each year differs in the relative amounts of summer, autumn and winter moisture received. Trends in the seasonality of rainfall may persist for a decade or more (Webb & Betancourt 1992).

Dry climate, erratic rainfall, and mountainous terrain with rocky or caliche soils do not create a setting for prosperous agriculture. But they create the context that makes ranching possible. Were it not for dry climate and unsuitable soils, ranchers would all be farmers, and the range converted to cultivated cropland, just as happened in the tallgrass prairie of Iowa.

DIVERSE PLANT GROWTH FORMS

Apacherian savannas support a variety of coexisting plant species, which provides rich potential for vegetation dynamics. Each species is adapted to exploit a particular regime of soil moisture and survive a given range of drought intensities. Modes of adaptation include tolerance to internal desiccation, root and shoot architecture, and the timing of growth and reproductive responses to weather events. Seedlings are more vulnerable than mature plants. Many species, especially those with long lives such as mesquite and ocotillo, rely on infrequent episodes when suitable climate and disturbance events converge to create opportunities for their seedlings to survive to maturity. Seedlings of each species differ in their requirements to establish; some are favored by winter storms, others by the Arizona monsoon. For this reason seemingly minor shifts in weather patterns, for example a sequence of dry winters, can ramify into substantial changes in vegetation.

Each species is unique, but three growth form groups can be recognized inhabiting Apacherian savannas, each group sharing general patterns of soil moisture exploitation (Burgess 1995):

1) Water-storers have shallow roots, rapid responses to rain, and relatively slow growth rates. Examples are prickly pear, sotol, yucca, and ocotillo. Plants with these growth forms are often called "cactus," even though many are totally unrelated to such true cactus as cholla and barrel cactus.

2) Extensive exploiters have extensive root systems which can use deeper soil moisture. These are woody plants with relatively slow responses to rain and potentially long life-spans. Mesquite, juniper, and catclaw acacia are examples. Plants with this growth form are often lumped together as "brush."

3) Intensive exploiters have dense shallow root systems that allow intensive exploitation of shallow soil moisture, rapid responses to rain, fast growth rates and rapid colonization on open land. For range management, two basic types of intensive exploiters can be distinguished:

3a) Grasses are represented by many species in Apacherian savannas. Although they all use shallow soil moisture, there is a range of life cycles and forms, from annuals such as red brome and six-weeks grama, to herbaceous perennials including tobosa and alkali sacaton, to half-shrub mimics including bush muhly and black grama.

3b) Half-shrubs, also called subshrubs or chamaephytes (Mueller-Dombois and Ellenberg 1974), are partly woody plants, usually less than knee-high, that often die back somewhat during cold or drought. Examples are burro-weed, broom snakeweed, and mariola. As is evident from their names, ranchers tend to call such plants "weeds" because their increase signals less profitable trends in savanna dynamics.

Grasses and half-shrubs often compete for soil moisture and space. Disturbances by fire and grazing, and weather sequences favoring seedlings of one group or another, can create a dynamic alternation of dominance between grasses and half-shrubs.

Plants in the three growth form categories differ in their life cycles, and hence in the duration of their influence on the landscape. Long-lived shrubby trees, for example mesquite, are the most stable elements of savannas. In contrast, annual plants respond rapidly to seasonal weather and disturbances. Populations of trees, shrubs and many water-storers change over decades to centuries. Perennial grasses and half-shrubs seem to respond on time scales from years to decades; however Robert Webb's recent study of a century of change in the Grand Canyon (1996) indicates that even individual grass clumps can be remarkably long-lived if they are protected from burros and other grazers.

What types of vegetation do these plants create?

Much of the Apacherian savanna is currently used for cattle production. Some areas have grasses mixed with arid-adapted shrubs, half-shrubs and water-storers on the wet edges of the northeastern Sonoran Desert, the northern and western Chihuahuan desert, and the southern fringe of the Great Basin Desert, especially on coarse-textured soils (Schmutz et al. 1991). An example is the grassy scrub of black-grama and white-thorn acacia on limey slopes of the San Pedro Valley. Grasses can also be found mixed with shrubby trees on the dry margins of pinyon-juniper woodland and Madrean oak woodland. Savannas and grasslands occur on mountain piedmonts or bajadas, especially where soils have high clay content (McAuliffe 1995). Clayey soils support savannas of velvet mesquite and curly mesquite grass on ancient alluvial fan remnants in many parts of southeastern Arizona.

These grassy plant communities and landscapes have been grouped together under labels of 'semidesert grassland,' 'desert grassland' or 'shrub steppe' (Burgess 1995). I prefer to call them Apacherian savannas. They support mixtures of desert, woodland and chaparral species, but they have characteristic species whose ecological distributions are clearly centered within these landscapes. These indicator species include tobosa grass, black grama, mesquite, sotol, soaptree yucca, and burro-weed. Half-shrubs are usually important components of Apacherian savanna. Here mixtures of succulents, shrubs, grasses and half-shrubs are normal, producing a diversity of coexisting plant growth forms much higher than expected in typical grasslands.

Vegetation structure created by coexisting growth forms is inherently unstable. A sequence of disturbances or weather events can change the landscape from open savanna to dense brush or low half-shrub scrub, and vice versa. Diverse species composition confers ecosystem resilience through dominance shifts. If conditions are not favorable for grasses, the half-shrubs and shrubs increase to fill in gaps left as grasses decrease.

Why do I call it savanna instead of desert grassland? To wake us up, and help us rethink its nature and potential.

The term desert grassland is a legacy of Frederick Clements, who had a prairie grassland bias from his first work in Nebraska. He recognized the unstable dynamics of this vegetation, but it did not conform with his Stable Climax Theory; therefore these communities could not be recognized for their integrity - they were to be considered an unstable ecotone between desert and grassland; thus the name 'Desert Grassland' (Clements 1963). From my perspective this vegetation has floristic and structural integrity that was denied by the desert grassland label, and these landscapes should not be viewed as transitional or ecotonal.

Calling these landscapes 'grassland' focuses on grasses and pasturage. This emphasizes the production of agricultural commodities, especially cattle. It also promotes comparisons with temperate grasslands, especially those of the Great Plains, which may not be the most appropriate models for understanding these places. If a landscape is considered 'grassland,' non-grasses tend to be viewed as 'invaders.' Accordingly, a landscape with shrubs or cactus is 'degraded' and need to be 'restored.' Cost-effective 'restoration' may require the introduction of exotic grasses. If a place is thought of as grassland, even an exotic grassland may seem somehow more appropriate than a landscape dominated by native shrubs or cactus.

In a savanna, coexistence of different growth forms is expected. The most stable plant components, trees and shrubs, are integral parts of a savanna community along with the grasses. The term 'Apacherian savanna' promotes comparisons with tropical savannas, where plant growth rhythms are governed more by rainfall than by temperature, and dynamic shifts in vegetation structure are expected (Knoop and Walker 1985, Laycock 1991, Walker et al. 1981, Walker and Noy-Meir 1982). In the drought-prone Southwest, such comparisons seem appropriate. A more inclusive ecosystem concept, embracing the possibilities of different vegetation conditions over time, provides mental models suitable for adaptive management (C. S. Holling 1996, Westoby et al. 1989) with flexible goals and methods.

This is only one attempt to shift our preconceptions and promote creative insights. We came to this conference because we care about this region and its future. In landscapes as dynamic and complex as these, misunderstandings are likely. With our current technology and wealth, poorly conceived actions can produce ecological degradation, which reduces opportunities for people trying to live in these landscapes. Lots of different communities and landscapes are included under the category of Apacherian savanna or desert grassland. What are the best ways to know and live with these ranges? How can our culture incorporate and communicate this understanding? Where should this information be concentrated? Should knowledge of the range be restricted to owners and inhabitants, or should regional urban-dwellers be given access to the details of their surrounding ecosystems?

WHAT ARE MOST IMPORTANT ISSUES CONCERNING FUTURE HUMAN INFLUENCES UPON THESE LANDSCAPES?

These places are inhabited, and both human and non-human residents face an uncertain future.

The human population and its consumption demands will almost certainly increase. Urban dominance will continue: the Phoenix-Mesa area is expected to add 1,391,000 people between now and 2015 (Kiplinger Editors 1996). The general shift from commodity-generated income to information and service-generated income will probably continue. Sunbelt retirees will continue to support gated techno-oases along with rampant land speculation. The Colorado Plateau and Sky Islands may continue their transformations into theme parks, restructured and managed to provide pleasant experiences for urban vacationers. More large land holdings will become owned by the independently wealthy for use as exclusive retreats or pleasuring grounds, rather than as sources of personal livelihood.

Under strong pressure from land speculation, the lifestyle and the amenity value of land in this region often exceeds its value for producing agricultural commodities. Purchases by new residents are motivated more by lifestyle or intangible values than by the land's potential to generate agricultural income. Lifestyle value is driven by personal beliefs, thus it is more unpredictable and harder to measure than livestock production. These unstable, shifting value systems are changing the social fabric of rural communities.

Global climate models foretell substantial change, but it is hard to predict specific climate trends in the Southwest. The climate may become more unstable, or flip into a new stable behavior that could be drier or wetter in different parts of this region. Any change in weather patterns will produce substantial changes in vegetation and forage production. More critical for the region's economy will be whether the future climate will appear more or less comfortable than other parts of U. S., which will affect the relocation of retirees.

Urban growth and perhaps climate change will increase the value of water, especially in the Salt River watershed supporting Phoenix. There may be renewed efforts to increase runoff yield by denuding vegetation, in effect 'shrink-wrapping' the watersheds.

Perhaps the greatest value of our regional landscapes is in the ecological services they provide: air regeneration, water purification, soil formation, etc. Unfortunately these values are usually externalized: they have no accountability within our economic system. If the true worth of ecological services could be evaluated, the quality of ecological stewardship would become a major criterion for subsidizing rural ranchers.

What should happen to rural ranchers and landscapes? Is subdivision compatible with ecological integrity? Is ranching compatible with ecological integrity?

ANY SERIOUS DISCUSSION OF LAND TENURE MUST INVOLVE POWER.

In European culture, all rights to the land are acquired by purchase or conquest. Conquest is the reason Apaches are no longer the dominant culture. Purchase, either outright or through taxes and grazing leases, is how current owners or ranchers gain the right to hold their places. If current inhabitants are to retain rights to their land, they must maintain their power, especially economic and political power, within our urban-dominated society.

Traditionally power obtained from the land was used to secure the rights to use that land. This was thought to lead to the 'best use' of land, measured by the amount of wealth that could be created from extraction or cultivation. Under the social Darwinism paradigm of the Nineteenth Century, those who are most adept at accumulating and sustaining power should acquire rights to the land (Worster 1985). The social goal is to motivate individuals to accumulate wealth, which they share with the state. Beyond some threshold this system leads to extraction and impoverishment of the land's productive potential, and can also diminish human opportunities. Hence this paradigm is being reconsidered in our current situation of exploding human populations and accelerating technological power. It is not clear that economic health, as currently defined, is compatible with ecological health.

The landscapes we are concerned with, savannas, grasslands and scrublands too arid or rocky for industrial-style farming, pose special problems. The traditional solution to dryland inhabitation has been nomadic pastoralism, but our land tenure system has forced pastoralists into the fixed locations and defined boundaries of stable farms. This has sometimes led to unfortunate ecological consequences, especially during long droughts when owners could neither move nor sell their livestock.

The unstable economic yield of stock-raising in drought-prone climates does not mesh well with current economic expectations of the U. S. As agricultural commodity markets consolidate, and brokers and marketers will accumulate power, and small-scale producers will suffer. Depending on livestock production to sustain current inhabitants is likely to lead to big changes in ownership and control, unless there are continuing subsidies of capital. Many ranchers already have to find part-time wage or service work. Ownership is shifting to people or organizations that have accumulated wealth from distant sources.

Urban population in the region is increasing dramatically, which will accelerate the alteration of regional landscapes to meet urban expectations (Cronon 1991). Rural landowners are a shrinking minority (Orr 1994, p. 185). They could offset their declining numerical power with additional wealth, but the productivity of drought-prone rangeland makes accumulation of surplus wealth from the land very unlikely. Furthermore, in this region much of the range is controlled by the federal government, hence management policy is subject to urban political influences from outside the region (Sheridan 1995).

It is very unlikely that rural ranchers will eliminate urbanized democracy and install a social order in which power is based on land ownership. If their interests are to be secured, they must explore other options to consolidate power. Ranchers' cooperatives offer possibilities to spread risk and provide insurance against catastrophes. Rural people may be able to cultivate urban constituencies for political and economic clout. What could be of concern to urban dwellers? Quality meat, quality recreation (hunting, horse training, etc.), and quality of ecological stewardship are all legitimate concerns for at least some urban Americans. Note the repeated emphasis on quality. Value is added by the perception of quality, which is driven by belief systems. To evaluate quality, the producer and client must agree upon how quality is to be measured.

The land and climate of Apacherian savannas create strong personal attachments for many people. This is a basis for shared values and a consensus about quality. How can ecological stewardship be measured in a way that a rancher and environmentalist can agree upon? Mutual participation in ecological monitoring could be the start of an evolving consensus about management goals and subsidies.

Environmentalists, field-oriented scientists, and ranchers share many concerns. These groups are beginning to foster productive discussions and dialogs, including those at this conference. Communication among various interest groups and ecological communities should become complex and networked in a manner analogous to the complexity and patchiness of the Apacherian

Savannas. To be effective, everyone should maintain a flexible approach that can include perspectives of ranchers, bird-watchers, urban consumers, and federal managers. The management skills needed to coordinate discussions, monitoring and consensus-building will be vital for the preservation of ecological communities. It is doubtful that any private or public group can sustain this effort over a long period. Hence the coordinators should nurture one or more successors to insure continuity of the dialogs and preserve traditions of integrity and trust among the people involved.

There has been considerable progress in our perception of Apacherian savannas, but we are far from assembling the coherent body of expertise needed for its effective inhabitation and management. Also, no centralized collection of knowledge can ever substitute for the accumulated experience of a resident ranch family with their land. The accelerating proliferation of communication technologies is creating an information storm that is tearing traditional cultures apart and perhaps even fragmenting personalities (Gergen 1991). We must not let the flood of new information destroy the slow knowledge accumulated by rural people living on their land and by passionate naturalists who have sustained a focus on some place or organism. Only through continued conversations, both among ourselves and with the land, will we keep a land base in our common culture. Through this continuing dialog we can discover ways that balance ecological health with human opportunity. This conference has provided a place to talk, and I am encouraged that, though the future may be uncertain, our dialog can endure.

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An Overview of Arid Grasslands in the Northern Chihuahuan Desert

K.M. Havstad[1]

ABSTRACT

The intent of this paper is to outline information on four topics regarding grasslands of the Chihuahuan desert: 1) general aspects of their ecological dimensions, 2) recent vegetation dynamics, 3) current threats, and 4) common ground with other desert grasslands. The Chihuahuan desert is a region of about 350,000 square kilometers. There are at least fifteen different definitions of the boundaries of this desert. Figure 1 is from Schmidt (1979) and its boundaries are based on an aridity index. Generally, this index reflects an area of <250 mm of average annual precipitation, an average mean annual temperature of 17 C, and an elevation of >1200 m. This paper will focus on the northern region of the Chihuahuan desert, an area called the Trans-Pecos which extends from Southeast Arizona across New Mexico into Texas. A small portion of the Trans-Pecos occurs in west Texas on the upper Pecos River below the Guadalupe Mountains. The western border of the Chihuahuan Desert in Arizona is defined by the amount of precipitation occurring during the summer monsoonal months. East of this line in the Sonoran desert >55% of the annual precipitation occurs during the summer. West of this line in the Chihuahuan desert <55% of the annual precipitation occurs during the summer months.

ECOLOGICAL DIMENSIONS

The Chihuahuan desert, like the Sonoran, can be referred to as a zone of ecological confusion. The Chihuahuan desert grasslands occur within a very dynamic mosaic of desert shrublands. Grasslands comprise about 10% of this region. The Chihuahuan region is the warm desert area of North America that exists east of the Continental Divide. The other warm deserts in North America are west of the Continental Divide (Figure 1). It is primarily a region of internally drained basins. Very little of this area serves as watershed other than the areas drained by the Rio Grande and the Pecos rivers. Vegetation dynamics are strongly affected by aspects of landform, topography and soils. The region does have a long history, over thousands of years, of herbivory. However, most of that history is associated with invertebrates and small mammals.

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Chihuahuan Desert as delineated by Schmidt (1979).
Marked area of about 350,000 km² is based on an aridity index of ≤ 10.
(where I = P mm / T °C + 10)
Region includes scattered mountain masses not classified as desert.

Figure 1. Map of the Chihuahuan Desert region as defined by Schmidt (1979).

Like most deserts these grasslands are water limited but also nutrient regulated. Biomass responses to water additions are based on the availability of soil nutrients, primarily nitrogen. The region supports about 120 mammalian species. Generally, these species are fairly common and are not threatened by any particular human activities. There are, however, some notable exceptions, and reintroductions, in particular the Mexican Wolf, have been proposed. Alien species are not a serious issue though there are local problems with both exotic flora and fauna. This is a significant area primarily because of its large dimensions. One particular concern for the conservation of the desert grasslands is that these grasslands serve as important wintering areas for many species, especially avian species. The region has a distinctive herptofauna and some species are threatened or endangered. Many of these species are linked to riparian habitats that exist throughout the region. Biological features of the Chihuahuan desert have been previously reviewed (see Wauer and Riskind 1977).

Like other deserts, one prominent ecological dimension is the variability inherent to the region. Both temporal (annual and seasonal) variability and spatial variability are common. An example of annual variability is illustrated in Table 1. The fluctuation in biomass productivity presented in this table is for a sandy upland ecological site on the Jornada Experimental Range in southern New Mexico. This variation in annual productivity is not unusual for this or other ecological sites in the Chihuahuan Desert (see Herbel and Gibbens 1996).

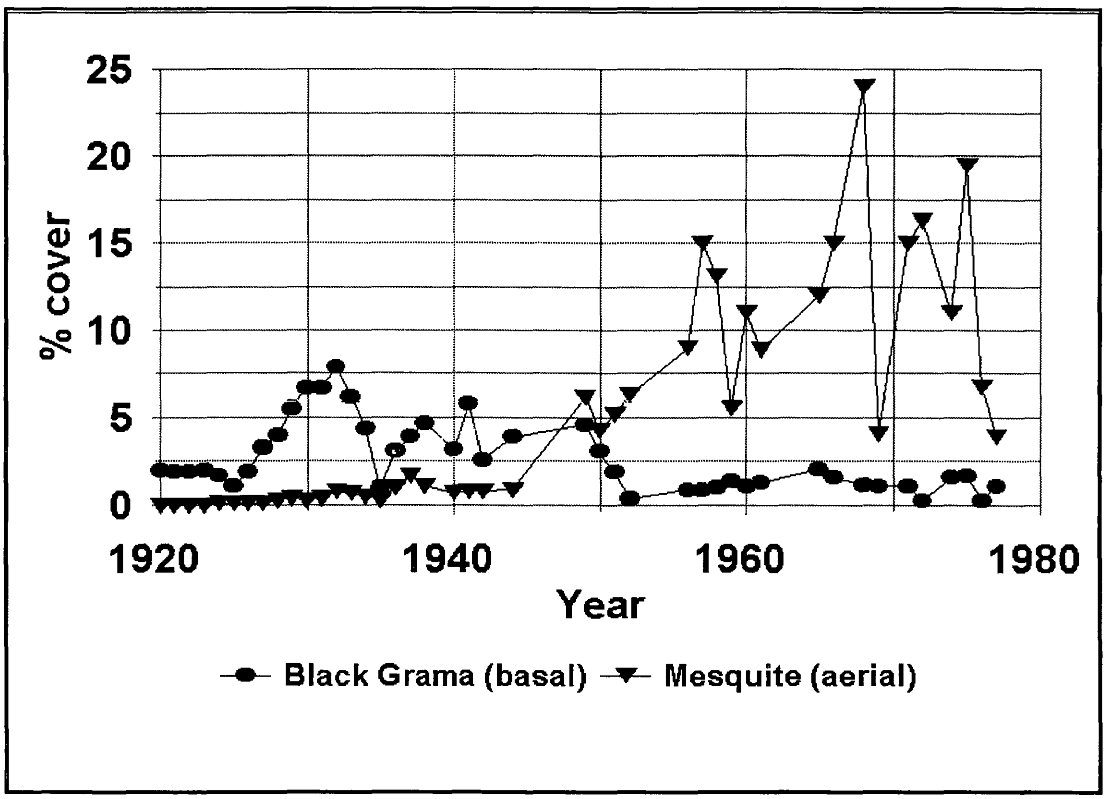

Figure 2. Changes in basal (for black grama) and aerial (for mesquite) cover between 1915 and 1977 on a lightly winter grazed sandy upland ecological site on the Jornada Experimental Range in south central New Mexico.

Year	Precipitation (mm) Crop-Year[2]	Seasonal[3]	Yield ± SE (ka/ha)
1960	105	52	177 ± 21
1961	352	263	644 ± 44
1962	298	212	797 ± 58
1963	199	124	336 ± 47
1964	156	118	302 ± 39
1965	138	85	182 ± 20
1966	199	135	477 ± 40
1967	203	154	145 ± 21
1968	226	122	181 ± 18
1969	164	110	372 ± 29
1970	168	97	174 ± 20
1971	148	93	249 ± 31
1972	284	136	473 ± 57
1973	289	81	195 ± 25
1974	212	187	190 ± 20
1975	297	147	344 ± 48
1976	239	127	354 ± 18
1977	320	219	800 ± 91
1978	157	75	659 ± 72
1979	290	89	156 ± 35
1980	189	91	179 ± 28
1981	229	156	300 ± 38
1982	162	99	99 ± 19
1983	182	41	38 ± 8
1984	194	76	480 ± 53
1985	284	91	526 ± 68
1986	276	122	550 ± 59
1987	349	139	382 ± 51
1988	305	172	500 ± 59
Average	234	131	354

Table 1. Variation in annual forage production from a black grama grassland site in southern New Mexico.[1]

[1] From Herbel and Gibbens (1996).
[2] Crop year = Oct. 1 of previous year through Sept. 30 of indicated year.
[3] Seasonal = July 1 through Sept. 30 of indicated year.

RECENT VEGETATION DYNAMICS

In addition to the dynamics of temporal and spatial variation are the dynamics of vegetation change that are characteristic of this region (see Gibbens and Beck 1988). There are many diverse agents of vegetation change (Grover and Musick 1990). One of the key agents of change has been unmanaged grazing in this region, especially during the post Civil War period. Livestock grazing in the Trans-Pecos region has occurred for over 400 years. However, for the first 300 years that history of grazing was fairly localized (Hastings and Turner 1965). This pattern changed with a number of events after 1865, especially new technologies for pumping water and the availability in the west of transportation systems for shipping livestock to urban markets. Livestock numbers increased dramatically following the Civil War and widespread overgrazing resulted in deteriorated range conditions throughout the region by the early 1900's (Wooten 1908).

The roots of the rangeland management profession actually are in these dynamics and agents of change. A prime motivation for the development of range science and eventually the establishment of principles of range management were the deteriorated conditions of southwestern rangelands around 1900 (Smith 1899). Recognition of the need for scientifically based management practices and improvement techniques was the primary motivation for the establishment of the first rangeland research stations in Texas, Arizona and New Mexico. The first publications from these research stations detailed the influences of grazing management, drought and competition among plant species as principle factors affecting vegetation change throughout the Southwest (see Jardine and Hurtt 1917, and Jardine and Forsling 1922).

We have a few well documented examples of vegetation dynamics during the 20th century as a result of these research stations. For example, Figure 2 presents basal cover dynamics of an important dominant, native perennial grass species, black grama (*Bouteloua eriopida*), that characterizes desert grasslands in the trans-Pecos region. From 1915 through the early 1930's scientists recorded considerable fluctuation in black grama basal cover, primarily due to periodic drought. However, following the intensive drought of the 1950's the cover of black grama drastically declined and has not recovered. Many of these former grasslands are now dominated by native shrubs, such as honey mesquite (*Prosopis glandulosa*). It is currently hypothesized that once mesquite aerial cover exceeds 8% it becomes dominant and effectively initiates soil and surface alterations which restrict redevelopment of black grama cover. Thus, these shrub thresholds (see Archer et al. 1988) result in significant alteration of vegetation structures in these

Vegetation Type	**Biomass C aboveground**	**Biomass C total**	**Soil Organic Matter C**
Grassland	131	190	2112
Mesquite Shrubland	129	235	1804
Creosote Shrubland	102	159	1929
Tarbush Shrubland	82	119	4824

Table 2. Carbon Dynamics © units are g/m^2).
Adapted from Conin et al., 1997.

Time Period	Soil Movement Category	# of Points	Maximum (cm)	Minimum (cm)	Mean (cm)	Net Loss (-) or Gain (cm)
1935-1950	No Change	2				
	Deposition	4	3.2	0.6	5.1	
	Deflation	21	30.5	0.6	4.8	-2.9
1950-1955	No Change	2				
	Deposition	3	3	0.9	1.7	
	Deflation	22	10.5	0.6	3.6	-2.7
1955-1980	Deposition	18	25.1	1.2	7	
	Deflation	9	34.6	0.3	7.1	23

Table 3. Deposition and deflation of soil for an ungrazed area from 1935-1980
(values show change from one measurement to the next).
From Gibbens et al., 1983 (Note: textural changes associated with eolian processes).

deserts. We do not currently have effective remediation technologies to counteract this degradation.

These structural changes are accompanied by other ecologically significant changes. Pilmanis and Schlesinger (1996) have reported an increased spatial heterogeneity in N distribution with increased mesquite encroachment into desert grasslands (Figure 3). Connin et al. (1997) have reported a decrease in the amount of biomass C stored in mesquite dominated communities compared to grasslands (Table 2). The mesquite dominated sites studied by these investigators was a desert grassland until the 1930's. Gibbens et al. (1983) documented significant loss of soil and changes in residual texture for a mesquite duneland (Table 3). Soil losses were discontinuous, with large losses over the 50 year study occurring within a six year span. Finally, Fernandez (per communication, 1996) has reported preliminary results from controlled experiments on physiological differences among grass species, including relative growth rates (Table 4). Obviously, even replacement of perennial grass species by other grass species can create significant differences in biological processes within the desert. These examples illustrate an additional and extremely important dimension to these deserts. Ecological character of the desert is strongly reflected by the dominant species. Changing the dominant species, by whatever combination of causal agents, creates not only new structural features but significant alterations in biotic and abiotic features. These new conditions can be very resistant to regeneration of prior conditions (Schlesinger et al. 1990). In fact, it has been suggested that selecting a standard reference point for these grasslands as the conditions prior to the mid 19th century may be naive. It is probably more appropriate to think of these landscapes, and the rangeland vegetation they support, as highly dynamic (and episodic in their change) and adaptive to evolving environmental conditions. These systems not only have naturally changed, but have been altered through introduction of new biological agents (plants and animals), loss of some agents (predator species reductions), increases in atmospheric concentrations of some gasses (CO_2 and CH_4), and restriction of some habitat factors (control of wildfires). With all of these alterations it is difficult to assume that even removal of all livestock from these deserts will result in regeneration of prior states that existed in the mid 19th century.

Grass Species	Relative Growth Rate (g/d)	Leaf Area Ratio (cm^2/d)
Bush Muhly	0.12	39.7
Mesa Dropseed	0.11	48
Vine Mesquite	0.09	50.5
Black Grama	0.07	13
Tobosa	0.06	11.5
Burrograss	0.03	3.6

Table 4. Physiological aspects of some desert grasses, species not functionally redundant.

From Fernandez, R., pers. comm., 1996.

THREATS

There are many issues that are relevant to current management of these desert rangelands. Several of these issues frequently are energetically debated by opposing parties and are common newspaper and television news stories. These issues include property rights, private equity in public lands and biodiversity. These issues, though, are normal debates about the mechanics of managing these lands. Though there can be strong disagreement on solutions for these issues and though they are very important issues, they should not be viewed as threats to the Chihuahuan Desert grasslands. Rather, they are obstacles to management. There are three basic threats confronting this ecosystem. One threat is desertification. Though this is a global phenomenon, and the definition of desertification has occasionally changed, the issue of degradation of these resources is still very relevant to North America and the Southwest. In many fashions we are still contending with degradation of 100 years ago. Much of our arid rangelands are slow to respond, or the natural recovery mechanisms are no longer functioning. In addition, we lack affordable technologies to remediate landscapes that have degraded. Coupled with this real threat is the need to develop sustainable and affordable technologies for remediating these landscapes (Fredrickson et al. 1996).

Another prominent threat in this region is development. Cities throughout the Southwest, on both sides of the border, are some of the fastest growing population areas in North America. This threat is not so much the need to stop development, but to understand the carrying capacities of the deserts for supporting these concommittent escalations upon resource demands. A basic tenet of rangeland management has historically been the identification of the grazing capacity of the forage resources for an ecological site, and adjusting grazing use to this capacity. This is a difficult limit to quantify, and managers typically rely on historical knowledge of resource use. This historic approach will be difficult to use as increasing population pressures cause exponential increases in resource use. We do not have many reference points for estimating these carrying capacities. Contending with this threat is the very real need to identify carrying capacities for habitation in our deserts. Capacities need to be identified not only for available water resources, but for the full array of resources found within the desert.

The last general threat is one of diatribe. The rhetoric regarding resource use issues has become excessively abusive. All perspectives on these issues seem to have been, at one time or another, engaged in diatribe. If this is not accurate, it is at least a common perception.

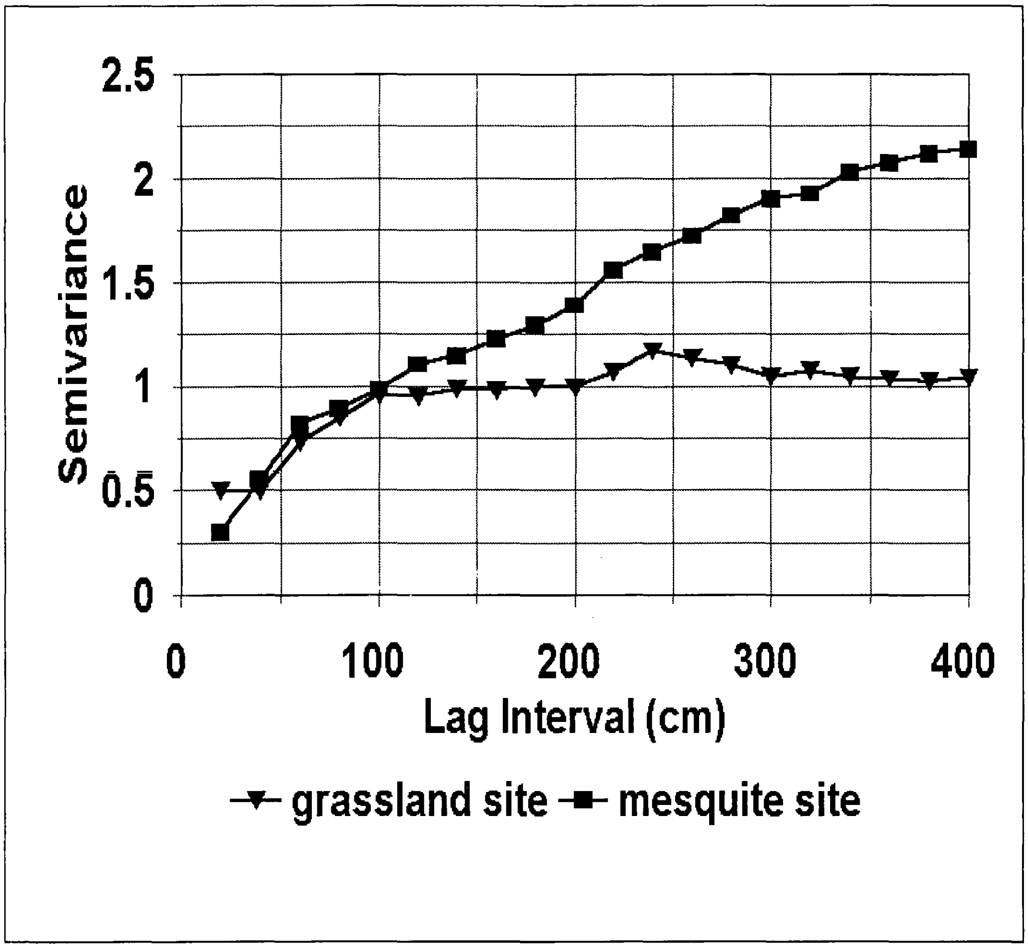

Figure 3. Semivariograph for nitrogen spatial distributions within grass and mesquite dominated sites. The relatively even semivariance for the grass site over 400 cm distances indicates a relatively homogenous distribution of N. The increasing semivariance for the mesquite with increasing distance indicates a more heterogeneous spatial distribution of N. These two sites are adjacent to each other, and the mesquite dominated site has developed on a former grassland. These data are adapted from Pilmanis and Schlesinger (1996).

Unfortunately, there are relatively few people involved in debates about stewardship of our deserts. Realistically, more people will probably attend a sports convention in Tucson some weekend to trade baseball cards than will ever read articles within these proceedings. Thus, diatribe becomes even a larger threat when few people are even engaged in a discussion. We must get past this threat. It is important to argue convictions, but it must be recognized that there are numerous valid and different convictions regarding conservation of our deserts. Individuals that contribute to diatribe are a major threat to effective management of these landscapes.

COMMON GROUND

Other people have recently articulated some very well thought out perspectives on common ground. In particular, Brown and McDonald (1995) have argued for staking out a position at a radical center. Pivotal to this perspective is the philosophy that maintaining and improving the health of these deserts requires keeping rural people on the land. But this use must be balanced with a thorough knowledge of the ecological needs of the desert grasslands. Management is an active, participatory process. Our scientifically based perspectives on deserts have matured today to the point that we understand that abandoning the land will not restore prior conditions. In addition, prior conditions are not ecologically realistic benchmarks for future sustainable landscapes.

Our understanding of the volatile ecological dimensions of our deserts and the real threats they face should reinforce the need for common ground. Our deserts in the Southwest can be managed effectively. We have scientific institutions in place to provide objective information. We have forums for exchanging information and developing reasoned strategies for management. We need to understand what the real threats are and recognize that these problems are solvable. Our deserts, including the grasslands of the Chihuahuan Desert, provide crucial resources for our future and we are in position to find consensus strategies for their management.

One final perception on common ground that surfaces from a review of the dimensions and threats to these desert grasslands is the complexity of these ecosystems. This complexity cannot be easily communicated. Yet, these deserts will continue to provide crucial resources to a significant portion of this region's 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 problems are generally not simple, and we should not create false expectations.

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Mexican Grasslands and the Changing Aridlands of Mexico: An Overview and a Case Study in Northwestern Mexico

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ABSTRACT

Grasslands cover about 14% of Mexico. They comprise alpine and subalpine grasslands, tropical savannas, arid and semi-arid grasslands, and induced grasslands. Arid and semi-arid grasslands comprise most of the grass-dominated communities in Mexico. There is great concern about the transformation of these into thornscrub through the action of several interrelated factors, mainly: overgrazing and diminishing fire frequency. At the same time, the introduction and naturalization of African grasses is changing the structural and functional properties of native grasslands and are creating new grass-dominated communities at the expense of other types of vegetation. In some cases the conversion has been so successful that consequences are irreversible in the short-term. A case study in the Sonoran Desert is presented where African buffelgrass (*Pennisetum ciliare*) is being planted for the deliberate conversion of the desertscrub. It is now actively invading large tracts of central Sonora, Mexico. Its presence in desert communities introduce a grass/fire cycle in assemblages of species with little evolution with fire. The presence of buffelgrass is creating a new, highly xerophytic grassland in Sonora at the expense of the desertscrub. The conversion changes the structure and functioning of the community, lowering the standing crop biomass and overall diversity.

INTRODUCTION

Grasslands in Mexico are a diffuse, ecologically diverse, and poorly known biome. In his work on the *Vegetation of Mexico,* Rzedowski (1978) grouped as grasslands all communities that had grasses as major structural and floristic components. These included zacatonales, pastizales , high

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elevation grasslands (páramo), and savannas (sabana). Also he included segments of communities with shrubs and trees at various elevations, including transitional communities with a major component of grasses associated with pine forests, oak woodlands, mesquite forests (mezquitales), tropical deciduous forests, and thornscrub. However, given the botanical scope of his work, he dealt only superficially with the processes of land use. The processes of land conversion, modification, and disturbance are of paramount importance to arid grasslands and desertscrub not only ecologically, but also in economical terms because of the use of grasses as forage by livestock.

Grasses are well known for their resistance to harsh environmental conditions. In Mexico, as happens in many other regions, grasslands are usually found on marginal habitats where extreme heat, cold, aridity, flooding, or special soil structure and composition are limiting to most plants (Rzedowski 1978, Van Devender 1995). These features coupled with the presence of fire and grazing have created and maintained grass-dominated communities that follow poorly understood rules of persistence. Mexican grasslands encompass communities governed by climatic factors, recurrent fires, particular soil properties, presence of specific herbivores and granivores, disturbance by man and cattle, or a combination of these. Such factors create a mosaic of grassland associations that are present over most of the country (Rzedowski 1975, 1978, Brown 1982a, McClaran 1995). According to COTECOCA (National Commission for the Determination of Cattle Stocking Rates), grass-dominated communities cover almost 14% of Mexico (Jaramillo 1994a, b, c). These grasslands have been divided into three major categories by Rzedowski (1978): 1) Grasslands (pastizal), equivalent to short-grass prairie that include all grasslands growing on steppe climates, 2) Savanna (sabana , or pastizal de clima caliente), that are mainly tropical or subtropical grass-shrub associations usually growing on heavy, poorly drained soils that experience seasonal cycles of flooding and dryness, and 3) Alpine and subalpine grasslands and montane meadows (zacatonal y praderas alpinas) that occur in the tropical high mountains, mainly in central Mexico. Another major type of grassland present in Mexico is the induced grassland created by the transformation and conversion of other plant communities. These are usually established through the introduction of exotic grass species, and special cultural practices.

Other, less extensive grasslands have high habitat specificity caused mainly by special edaphic conditions, or disturbance of forests. Some extreme examples of these, are the tidal grasslands of *Distichlis palmeri* in the Colorado delta (Glenn *et al*. 1992), halophilous grasslands in some closed basins (bolsones), gypsophilous grasslands on karstic and sedimentary substrates, and high elevation grasslands derived from the destruction of the oak and pine forests, mainly along the Eje Neovolcanico in Central Mexico.

In this paper, we will briefly describe the major types of grassland found in Mexico, and outline their distribution. Later, we will try to picture the two most extensive type of Mexican grasslands: desert grasslands, and induced desert grasslands. We will focus on their use, historical trends, threats and conflicts between pastoralists and conservationists. Finally, we will explore the development of a new type of grassland whose future as a permanent attribute of the aridlands is still uncertain, but likely to persist.

ECOLOGICAL DIMENSIONS

Alpine and Subalpine Grasslands

Alpine and subalpine grasslands cover about 3% of the country (*ca*. 18,250 ha, Jaramillo 1994a). Except for the alpine meadows and areas above the timberline, they are derived mainly from disturbances of coniferous forests. These grasslands occur on top of the major mountains of Mexico near the timberline (between 3500-4500 m; Rzedowski 1978). Only a few mountains in central Mexico have sufficient vertical development to provide this habitat, and thus are highly restricted in area. The climate is alpine (type ET), isothermal with average annual temperatures between 3-5°C, and annual rainfall between 600-800 mm. Beaman (1965) and Cruz (1969, in Rzedowski 1978) are among the few authors that have dealt with these communities, which according to Rzedowski (1978) are distinctly Mexican in term of species endemisms (70%). The maritime grasslands are more related at the specific level to South America than North America (18 vs 0% of total species), but at the generic level, holartic affinities predominate over neotropical (17 vs 12%). Typical grasses in these grasslands are: *Muhlenbergia quadridentata, Calamagrostis tolucencis, Festuca tolucencis, and F. livida* growing along with many Asteraceae and prostrate representatives of many other families.

On lower, but still high elevation sites in central Mexico, and along the major ranges some grasslands develop after the destruction of oak and pine forests and are kept in this seral stage by burning, cattle grazing, and use of their roots for broom manufacturing. These are similar to the alpine grasslands with the same tussock grasses plus many representatives of other genera with affinities to more arid communities, including *Andropogon, Aristida, Bouteloa, Hilaria, Stipa, and Trachypogon.* Such grasslands are much more extensive than their alpine counterparts, but still have small areal extent (*ca*. 515,000 ha, Jaramillo 1994a).

Tropical Savannas

Natural grasslands in tropical Mexico cover a rather small area (less than 1% of the country, Jaramillo 1994b). Most of the tropical grasslands have been classified as savanna (*ca*. 1,234,520 ha, Jaramillo 1994b). However, some very small patches can also be described as halophyte grass associations. Mexican savannas are tropical climate grass-shrubland associations that occur in periodically flooded lowlands. Proper savanna occur only in type A climates on heavy, argillaceous soils along the coast of the Gulf of Mexico, and in the Pacific basin from Sinaloa to Chiapas (Rzedowski 1978). The precipitation exceeds 1000 mm distributed in a well defined wet season during summer. In winter, most savannas experience a well defined seasonal drought.

There has been great debate over the origin and original distribution of tropical savannas. Some authors favor the idea that savannas are the final stages of evolution of tropical soils coupled with the periodic effects of fire (Miranda 1958, Rzedowski 1978), while others suggest that savannas are the product of disturbance by man, mainly by clearings for agriculture that have changed irreversibly the structure and drainage of the soil (Sarukhn 1968, Pennington and Sarukhn 1968).

Disregarding their origin and precolumbian distribution, tropical savannas owe their existence to the very same mechanisms proposed for the persistence of desert grasslands by McAuliffe (1995): the presence of an impermeable layer on the soil that permits little infiltration to deeper layers. In humid-seasonal climates, that layer causes flooding during the wet season, and xeric conditions during the dry months, limiting the development of trees and shrubs to isolated pockets of better drained terrain. Common woody species are: *Byrsonima crassifolia, Curatella americana, Crescentia alata, C. cujete, Quercus oleoides, Coccoloba* spp, and species of Melastomateaceae (Pennington and Sarukhn 1968, Rzedowski 1978). Grasses are mainly species of *Paspalum, Andropogon, Aristida, Imperata, Digitaria, Leptocoryphium,* and *Axonopus*, growing along with many Cyperaceae.

Arid Grasslands

Arid grasslands, desert grasslands, semi-desert grasslands (including the Apacherian mixed shrub savanna of Burgess [1995]) form extensive areas with dominance or co-dominance by grasses. These have been described from northeastern Sonora, a long strip running on the eastern flank of the Sierra Madre Occidental from northwestern Chihuahua, to northeastern Jalisco on the Mexican Northern Plateau (Mesa del Norte), and a sizable area within the Mexican Central Plateau (Altiplano Central). These can be viewed as an extension of the large grasslands of the North

American mid-west (Shreve 1942, Rzedowski 1978, McClaran 1995). Such a broad distribution area include a multiplicity of climatic, soil and disturbance variants, producing grasslands with different structural, functional, and floristic features. The discussion by Burgess, and other authors in McClaran and Van Devender (see McClaran 1995) on the features of the desert grasslands is crucial in highlighting their inherent structural and functional instability, and their close relationships with other types of vegetation, mainly desertscrub, thornscrub and oak woodlands.

About 90% of the Mexican grasslands are concentrated in the arid and semi-arid regions (24,334,273 ha, Jaramillo 1994c). More than half of these (13,643,423 ha) can be grouped as short grass prairies, while the rest comprise different associations of tussock, bunch and halophyte grasses (Jaramillo 1994c). These extensive arid and semi-arid grasslands form a nearly continuous belt bordered by desertscrub and thornscrub at the lower elevations and woodlands and forests in the mountains and higher elevations. Most of these form a climatic climax according to Rzedowski (1978). However, more recent studies indicate that the role of soils and soil history play a major role in determining the presence of grasslands or other types of vegetation in a given area (McAuliffe 1995). This feature is particularly applicable to some of the western USA and Mexican grasslands that are present on bajadas and extensive alluvial fans along the flanks of the Sierra Madre Occidental, foothills of Basin and Range mountains, and the slopes and plains north of the Eje Neovolcanico.

Typically, Mexican grasslands develop on areas with steppe climate (type Bs). This feature is reflected on the close correlation between Bs climate and the distribution of grasslands (Gentry 1957, Rzedowski 1978, Schmutz *et al*. 1991, McClaran 1995). However, the most xeric grasslands can be found at the lower elevations in desert climates (type Bw), as happens near Moctezuma, Sonora; Delicias, Chihuahua, and Gomez-Palacio, Durango. Also, some grasslands in Mexico occur on exposed, southern slopes with shallow, argillaceous soils overlying a rocky impermeable layer. The latter occur in temperate mesothermal climates (Cw), as those encountered in intermediate elevations on both sides of the Sierra Madre Occidental. Even in Bs climates, where grasslands are more prevalent, other types of vegetation can be found. These are the extensive and highly structured thornscrub communities found on the western side of the Sierra Madre Occidental, and large tracts in the Bajío region that have a close affinity to tropical deciduous forests. These seem to replace grasslands in areas with warmer, more dependable weather (Rzedowski 1978, Burquez, Martinez and Felger in press).

Floristically, endemism at the species level is very important in Mexican grasslands. Two thirds of the grassland species in Durango, Mexico are endemic, and their phytogeographic affinities at the generic level are mainly tropical (Gentry 1957, Rzedowski 1975). This interpretation can be extended to most Mexican arid grasslands (Rzedowski 1978). Dominant grass species include many representatives of *Bouteloa, Aristida, Andropogon, Muhlenbergia, Setaria, Stipa* among others. Members of the Asteraceae are exceedingly common, along with herbs and shrubs prevalent on desertscrub and oak woodlands.

The New Desert Grasslands

Grasslands derived from other types of vegetation are common. Some have been already mentioned, as those derived from the destruction of pine and pine-oak forests in high elevation ecosystems. Others are the result of intentional conversion of one type of vegetation into grasslands. In most cases, once the pressure of the disturbance factor is released, the communities follow a trajectory that returns to conditions resembling those prior the disturbance. However, in some cases irreversible changes occur, leading to a new vegetation equilibrium. These sorts of phenomena are most evident in arid ecosystems where succession does not, even grossly, conform with the Clementsian paradigm. We will illustrate this issue with a case study: the conversion of large tracts of the Sonoran Desert into induced grasslands, and the seeming evolution of the community from desertscrub to a new grassland equilibrium.

Modification and Conversion

Land used for human activities alter the land cover or vegetation. This alteration takes two major forms: modification and conversion. Modifications include the alteration of the quantity and quality of the land cover by subtle changes in use, while conversion is the replacement of one community type by another. Grazing is a common land modifier. The environment we see today in southwestern USA and northwestern Mexico is, in part, the consequence of land modified by the recent introduction of cattle. Historical documentation shows, for some areas like the San Pedro and San Rafael Valleys on the border between Arizona and Sonora, a lush, green valley laden with thick sacaton grasslands, and walnuts, ashes and willows in the canyons and wetlands. These have changed toward a more xeric condition (Bahre 1991). Now the vegetation cover and diversity have decreased, and many riparian habitats are impoverished. The process of land modification has been taken to its extreme, modifying, and in some cases, converting the former grasslands to thornscrub because of several interrelated factors that include changes in the periodicity of fire, and overgrazing by cattle as major elements (Fleishner 1994).

Although land cover modification effects are seldom considered in models of global change, their importance is beginning to permeate the current modeling of global biogeochemical cycles, by considering how they increase the greenhouse gases concentration, and lower the carbon storage, and biodiversity in natural communities. We will not elaborate more on this phenomenon, which has been treated exhaustively in the literature, but will only remark again that it is prevalent and widespread in the arid lands of Mexico and southwestern USA.

Conversion can occur by deliberate clearings and subsequent changes in the soils or by the natural invasion of new organisms into the land. The ecology of invasion has well documented examples. The prickly pears in Australia and the Klamath weed in America are examples of unexpectedly successful land conversion and later rehabilitation by appropriate biological control. Arid land conversion -the replacement of desertscrub by another vegetation- occurs by deliberate transformation of the land mainly by extirpating the desertscrub to transform it into agricultural land, and by the replacement of the desertscrub by induced grasslands to increase the stocking rate for cattle. This section deals with the present irnpact of the desert conversion and subsequent invasion by buffelgrass (*Pennisetum ciliare*) in Sonora and with how diversity is affected, and how, even the low desert carbon productivity, is being released into the atmosphere in ever increasing amounts.

Buffelgrass Ecology and the Sonoran Drylands

African buffelgrass has altered the landscape of large tracts of land in Australia and America. In central Australia and western North America it has established a strong foothold (Cox *et al*. 1988a, Cox 1991). It is the dominant herbaceous plant in large tracts of the southwestern USA and northern Mexico (8-10 million ha according to Cox 1991). In the Sonoran Desert it is actively invading natural desertscrub and thornscrub communities. Buffelgrass, 30 years after its introduction to NW Mexico, is altering the landscape at a fast pace(as happened to sizable areas of NW Australia, see Cox *et al*. 1988a, Ibarra *et al*. 1995). It is fully naturalized in Central Sonora and is establishing itself northwards with no recognition of national boundaries (Burgess *et al*. 1991, Yetman and Búrquez 1994).

Buffelgrass is native to the arid lands of eastern Africa. It has been successfully used as a forage in South Africa, where it has been encouraged by cultural practices and the introduction of more productive strains. In the 1940s the Soil Conservation Unit of USDA imported it to the Americas as an alien plant suitable for erosion control. By the sixties major efforts to release it into Mexican aridlands were made, resulting in its massive introduction to northern Mexico. There is an official estimate of 1.5 million ha already cleared purposely for buffel, and Sonora has now more than 600,000 ha officially planted with buffelgrass (Cox *et al.* 1988a. Johnson and Navarro 1992, Yetman and Burquez 1994). The government provides subsidies for desertscrub clearings for buffel, and permits are issued annually to increase their extent. Clearings are usually larger than officially granted, and many areas are converted illegally without government permits. These factors give a conservative estimate of about 1.2 million ha deliberately cleared in the state of Sonora. The prime habitat for conversion, as recommended by range managers of COTECOCA is central Sonora (Navarro 1988). These technicians have determined that about one third of the state (*ca.* 6,000,000 ha) was suitable for conversion into buffelgrass. Buffelgrass thrives in sites with precipitation between 150-600 mm, concentrated mainly during summertime. It prefers warm, frost-free weather, and flourishes in most soil types (Ibarra *et al.* 1995). The area proposed by government agencies cover most of the Sonoran Desert subdivision Plains of Sonora, and portions of the Foothills of Sonora, and tropical deciduous forests (Navarro 1988, Johnson and Navarro 1992).

Originally, buffelgrass was established by clearing the natural desertscrub by chain, and blade bulldozing, a process called desmonte (Hanselka and Johnson 1981). These started in the neighborhood of Carb in central Sonora in the 1970s. At the same time the CIPES (Centro de Investigaciones Pecuarias del Estado de Sonora) was created in Carb with the mission of developing new forms of exploitation of the range (CIPES 1989). Special emphasis was given to the conversion of the desert into managed induced grasslands. As a result, large areas can now be seen mostly devoid of arborescent desert, grossly on a circle 200 km in diameter centered around Hermosillo. Today, new desmontes are carried out under new government directives that encourage leaving about 20% of the original tree cover in the plains, and 100% along watercourses. However, given the invasive nature of buffelgrass, soon these ratios change towards a greater grass dominance.

Conversion has been beneficial to cattle growers because trials have shown that buffelgrass can increase the stocking rate of the land up to 3 times (CIPES 1989, Hanselka and Johnson 1991, Johnson and Navarro 1992). However, at the time of its introduction, several ecological considerations were not taken into account, mainly its ability to naturally spread into the desertscrub (See Cox *et al.* 1988a, Ibarra *et al.* 1995), particularly into heavily overgrazed desertscrub (Sonora averages 60% overstocking and in some areas up to 400%; Aguirre 1980, Johnson 1990). This capability created unexpected sequels difficult to assess at the time of introduction, but with far reaching consequences. Among these are the effect of supplanting key desert species, the weedy behavior creating problems mainly with the agriculture of perennials, and the overwhelming increase in the uncommon desert fires.

In addition to the clearings of desertscrub for buffel grasslands, large areas have been invaded by buffelgrass, mainly urban and suburban plots, and highway shoulders. A conservative estimate indicates that between 1,000-10,000 ha of pure stands of prime buffelgrass are distributed along the major Sonoran highways (Highways: 15, 16, 20, and 21). These highly disturbed communities are well watered by runoff from the tarmac, allowing almost a continuous production of seed throughout the year. Indeed, these are the main sources for commercial seed collection. However, only a small fraction of their seed output is gathered, and undoubtedly most of the seed crop disseminates along an ever increasing, vast, linear (more than 600 km along major roads), dispersal source to colonize the desertscrub. The response of buffelgrass to disturbance of the cryptobiotic crust of the desert is almost immediate germinating in the small depressions formed after breaking it. The process of natural colonization usually starts near roads or near deliberately induced grasslands. The grass progresses along watercourses - which are naturally disturbed during the rainy season, and which provide ample moisture- and finally radiates to the more fertile, slightly disturbed areas beneath tree crowns (MM and AB unpubl. data).

The presence of buffelgrass produces an increase of the fine-fuel, easily flammable fractions that start a fire cycle in a community with species with no adaptations to fire (D'Antonio and Vitousek 1992, McPherson 1995). Indeed, suburban fires in the Hermosillo area, virtually unknown before buffelgrass, increased in frequency to almost one every two days during the dry summer months prior to the rains (unpublished data assembled from recent reports at local newspapers, but see Bahre 1985, Humphrey 1987).

Some common desert species, mainly brittlebush (*Encelia farinosa*) and cholla (*Opuntia fulgida*) recolonize buffel grasslands, but these are not palatable to cattle (Ibarra *et al*. 1985). The usual recommendation by range managers to maintain the grasslands has been prescribed burning (Cox *et al*. 1988b). However, cattlemen use it only as a last resort because burning is a sacrifice of valuable forage. Induced buffel grasslands are subjected to heavy grazing and ordinarily remain relatively open with a moderate accumulation of fine litter. Only after a good year of rains, or in stands not severely used, enough fuel accumulates increasing the chances of fire. No statistics are available, but most buffel grasslands in central Sonora have suffered at least one fire in the last 20 years, and many have been subjected to fires every few years. In more inaccessible areas, such as hillsides near highways or near buffel grasslands, the naturalized stands of buffelgrass are becoming dominant. As these are not so heavily grazed, there is enough litter accumulation as to start a natural fire cycle after a few years following colonization, and thus enlarging the affected area, and providing new seed sources.

Structure and Functioning of Buffel grasslands

It is well known that the fertility of the soil and the diversity of plant and animal life is much higher under the canopy of trees that outside their shade (Garca-Moya and McKell 1970, Burquez and Quintana 1994). Once trees are removed, a large guild of associated animals and plants disappear from the area. Paired sampling of neighboring plots with induced buffelgrass and desertscrub (with naturalized buffel) have shown that plant species richness decreases up to 4 times, and diversity goes down up to 10 times. Also, vertical heterogeneity of the vegetation changes from highly complex 2-3 strata to a single stratum (AB unpubl. data), suggesting corresponding effects on the fauna. Soils in converted desertscrub change dramatically. Buffelgrass exposes the soil to higher insolation, and changes soil features by increasing the organic matter content (Ibarra *et al*. 1995). Also, buffelgrass quickly deplete the soil nutrients, both by the net export of nutrients taken by cattle, and by the volatilization of nitrogen and secondarily of phosphorous and potassium after the recurrent fires.

Conversion from desertscrub to buffel grasslands changes the aboveground standing crop biomass by about 3-4 times (1-4 Mg/ha buffel vs 5-20 Mg/ha natural vegetation, AM and AB unpubl. data). That produces a release between 4-16 Mg/ha of carbon, mostly as carbon dioxide since nearly all the removed vegetation is burned after the clearings. Gross estimates indicate that about 5 million Mg have been already released into the atmosphere and, if the government goal is effected about 50 million Mg will be released. These figures are highly conservative because they only consider the land officially designated as buffel grasslands, and do not include the transformation that is occurring naturally, the numerous illegal clearings, and the contribution of below-ground biomass. For arid lands, these figures are staggering.

The Sonoran Savanna Revisited

Since Shreve (1951) described the vegetation of the Sonoran Desert, some changes have been made to the original boundaries. These include the segregation of the subdivision Foothills of Sonora into thornscrub (Brown and Lowe 1974, Felger and Lowe 1976, Brown 1982b, Turner and Brown 1982), the mention of the subtle boundary between some sections of the Arizona Upland, arid grasslands and thornscrub (Turner and Brown 1982), and the recognition that large sections of the Plains of Sonora subdivision were, and some still are, distinctly savannoid in appearance, dominance and composition (Shreve 1951, Brown 1982c, Van Devender *et al.* 1990). The successful introduction of buffelgrass into the Plains of Sonora seems to prove that a marginal advantage in water use, coupled with increased incidence of fire and disturbance by cattle, can shift dramatically the dominance from desert arborescent forms to desert grasslands in the deep alluvial soils of central Sonora..

HISTORICAL TRENDS AND CURRENT THREATS

Although a sizable portion of the land designated as Mexican arid grasslands might represent a climatic climax, most of their present area can be ascribed to cultural or biological factors (Rzedowski 1978). The instability of arid grasslands is best exemplified by the major changes that occur once recurrent disturbance agents come into play. Slight changes in the frequency and intensity of herbivory, granivory, and fire produce large changes in the structural and functional properties of the grassland, to the extreme of irreversibly (in the ecological sense) shifting the community into a new equilibrium state (Rzedowski 1978, Fleishner 1994, Burgess 1995, McPherson 1995, Jeltsch *et al.* 1996). There is a persistent idea that woody xerophytes have recently invaded the arid grasslands. However, the evidence comes mainly from anecdotal accounts gathered by ranchers and broad surveys by range managers that perceived the decreasing ratio of grasses to woody perennials as detrimental (as is to cattle, indeed, see Bahre 1991). The visually dramatic change from a community dominated by grasses to one with more vertical complexity might not represent an invasion of previously absent woody species, but the alteration of the dominance hierarchy of species already present in the area (Hastings and Turner 1965, Humphrey 1987). Several entangled factors are involved, perhaps fire suppression and overgrazing being the most relevant players (Bahre 1991).

Livestock was bred in Mexico before its introduction in the present USA. Major herbivores were brought to central Mexico right from the start of the conquest of Mexico by the Spaniards, and horses represented a major technological advantage over the native Mexicans (Daz del Castillo 1984). Cattle was reared during the colonial times providing meat and animal traction mainly for the mining industries (Ezcurra and Montana 1988). The pristine American landscape seen by the conquistadores regained some of the megafauna lost during the Holocene (see Martin and Klein 1984), and some localized areas near major population centers and mines were impacted by increasing deforestation and overgrazing. Twenty years after the arrival of Spaniards into central Mexico, a large herd of livestock was carried along with the Coronado expedition marking the start of the cattle industry in the aridlands of northern Mexico (Wagoner 1952). Our perception of pristine is rather romantic, as large tracts of land were already altered by agriculture, urban and engineering developments, and large-scale use of forests and drylands to provide fuel (see for example Ezcurra [1992] for an account of the deforestation caused by the construction of the Teotihuacan pyramids). However, it was not until the development of the haciendas , during the nineteen century, that large-scale cattle production started, leading to extensive overgrazing. A respite from the large-scale overgrazing occurred during the Mexican revolution in 1910, when herds were heavily culled (Wagoner 1952). This episode caused a marked, but short-lived, reduction of the cattle herds, allowing some recovery of the arid grasslands. By the 1930s the Mexican government started a process of land distribution that lasted almost sixty years and allocated most of the federal land in Mexico, either to private individual holders, or to communal holders, mainly in the form of ejidos . The process of redistribution to private land holders allowed a maximum property size based on an estimate of the sustainable stocking rate (enough land to sustain 500 head of cattle). As in any legislation, many legal loopholes were and are exploited to increase the land controlled by investors, increasing their share of the land at the expense of ejidatarios who did not have, until the very recent modifications to the constitution, access to credit. Grassland resilience has been abused by overstocking, creating a less productive system. In the near future little can be done to ameliorate the pressure imposed upon these tenuously-balanced communities. The search for new forms of use of the range has now focused on the desertscrub and one avenue has been its conversion into a new form of grassland disregarding the ecological and economical imbalances that are produced by the introduction of highly aggressive alien species.

COMMON GROUND BETWEEN ECOLOGISTS AND PASTORALISTS

Grasslands are extremely important to mankind because of their use by domestic livestock, mainly cattle. At least one third of the Mexican cattle industry take advantage of the forage present in drylands, of these, a large proportion are localized in arid grasslands (Ezcurra and Montaa 1988). Most grasslands in Mexico have been used intensively and extensively for cattle, both by private and communal exploitation (Wagoner 1952, Ruiz 1988). Factors such as land tenure, better roads, increasing local population pressures, shifts from subsistence to market economy, and new cultural practices are likely to result in ecological change of grasslands than does climate (see Humphrey 1987, Fleishner 1994). The former are all interrelated. The opening of new and better roads, coupled with better transportation facilities has opened tracts of grassland previously unavailable for intensive local and export exploitation. The development of new techniques to provide water to cattle, the transference of large tracts of land from small-scale farmers to cattle barons, have all shifted the balance from a subsistence economy into a market economy (see contributions in Camou 1991, Prez 1992, 1993). The owners of most of the large cattle herds live in large cities mostly detached from the rural environment, and the small holders and ejidatarios are constrained by economic pressures with the need to share their range with many comrades. Both strategies overexploit the scant drylands resources because the land management has been aimed to a single resource: cattle raising. From a previous state of local ranching, subsistence farming and gathering, pastoralists have shifted to a single commodity. This scheme points to an ever increasing impoverishment of the drylands at the expense of a rich ecological heritage of multiple use of resources.

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Factors Controlling the Structure and Function of Desert Grasslands: a Case Study from Southeastern Arizona

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ABSTRACT

Twenty-eight years' field work at and adjacent to the Appleton-Whittell Research Ranch in Santa Cruz County, Arizona, have focused on the effects of livestock grazing, fire, drought, and establishment of non-native glasses on the vegetation and wildlife of this desert grassland site. Grazing reduces grass cover and fire frequency, while encouraging shorter-stature grasses and wildlife typical of lower elevation desert sites. Fires cause temporary declines in grass cover and some shrubs, and temporary increases in herbs and seeds, while favoring birds, rodents, and insects dependent on seeds and preferring more open habitats. Droughts cause temporary declines in shrubs, certain herbs and grasses, and associated wildlife. One key grass species, plains lovegrass, appears to survive drought better if it has recently burned. The independent and interactive impacts of drought, fire, and grazing have created temporal and spatial mosaics of native plant and animal assemblages. However, the establishment of non-native African lovegrasses threatens to permanently diminish many native populations of both plants and animals. Future integrity of the site depends upon reversing the spread of these exotics.

INTRODUCTION

Precipitation, fire, and ungulate grazing are major factors determining the structure and function of most of the world's grasslands, including those of western North America (Anderson 1982, Sims 1988, McClaran and Van Devender 1995). However, grazing by large hooved mammals has been a relatively unimportant force pre-historically in the American Southwest, due to scarcity or absence of North America's only abundant native grazer, the bison (McDonald 1981, Truett 1996). Historically, two powerful anthropogenic forces have been added purposefully to the repertoire of factors influencing arid grasslands of the Southwest: livestock grazing and exotic grasses, particularly African love grasses of the genus *Eragrostis* (Anable et al. 1992, Bahre 1991, 1995, Roundy and Biedenbender 1995).[2]

Understanding the independent and interactive effects of fire, drought, grazing, and colonizing species depends upon long-term comparisons among areas variously affected or immune from these environmental forces. The Appleton-Whittell Research Ranch is a 3,160-ha sanctuary of the National Audubon Society on the Sonoita Plain - a high desert grassland in Santa Cruz County,

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[2] See Appendix for scientific names of all species.

southeastern Arizona. A former operating cattle ranch, the site has been ungrazed by livestock and generally undisturbed since 1968, and so has had the potential to serve as a site for monitoring post-grazing ecological changes, including fuel accumulations resulting in the return of wildfire to something perhaps resembling prehistoric frequency and intensity. In addition, the Research Ranch continues to support stands of exotic African love grasses planted prior to its establishment as a sanctuary.

Our objective in this paper is to review studies conducted on and adjacent to the sanctuary since 1968, and to summarize what they suggest about the ways the precipittion, fire, livestock grazing, and alien grasses may generallly affect the assemblages of native plants and animals comprising desert grassland communities.

STUDY AREA AND METHODS

The Research Ranch includes rolling semiarid grasslands, oak savannas, and riparian bottom lands along largely seasonal watercourses, between the Santa Rita and Huachuca Mountains, in Santa Cruz County, Arizona. Elevations range from 1400 to 1560 m. Predominant soils are gravely loams (Richardson et al. 1979). Between 1968 and 1995, mean daily low January temperature was -2.1°C, mean daily high June temperature was 32.1°C, and mean annual precipitation was 44 cm (range 27 to 73). About 60% of annual precipitation falls during the summer monsoon season, between July and early September, which is the period of peak plant productivity.

Grassland habitats dominate the northern two-thirds of the sanctuary, where most of our studies have been conducted (J. Bock and C. Bock 1986). Broad floodplains are dominated by big sacaton, a tall grass frequently growing in nearly pure stands, interspersed with patches of blue grama, vine mesquite, and native dicots. Slopes adjacent to floodplains support diverse mixtures of mid- and short stature grasses, including side oats grama, blue grama, plains love grass, purple three awn, Texas bluestem, tangle head, spruce top grama, and curly mesquite. Level to rolling uplands are dominated by stands of blue grama, plains love grass, wolf tail, purple three awn, hairy grama, spruce top grama, and curly mesquite. Uplands also support scattered mesquite trees and various shrubs, including burro weed, yerbe de pasmo, and cat claw mimosa.

Research on the sanctuary has been carried out using standard field and analytical methods for quantifying and comparing abundances of vegetation and animal populations among areas with known differences in land-use history.

Vegetation line-point intercept transects and quadrants, bird transects and point counts, rodent live-trapping, and grasshopper hoop counts are among the field methods that have been employed (Onsager and Henry 1978, Verner 1985, Krebs 1989). Readers are referred to the REFERENCES below for details of these procedures, but in each case an attempt was made to compare areas differing only in terms of the variable of interest. These have included comparable mesa tops transected by boundary fences separating the sanctuary from adjacent grazed lands, grassland communities sampled before and after wildfire, stands dominated by exotic love grasses vs. adjacent topographically similar areas without the exotics, etc.

LIVESTOCK GRAZING

Understanding the effects of livestock grazing in arid grasslands depends upon the existence of ungrazed control areas for comparison. No such exclosures were established at the time livestock were introduced into the Southwest, although the impacts of grazing during the drought years of the 1890's doubtless were extreme (Bahre 1995). Ecological changes on exclosures established since 1900 cannot tell us with certainty what desert grasslands looked like prior to the time of Coronado, but they can help us to rank species in terms of their sensitivity to livestock grazing.

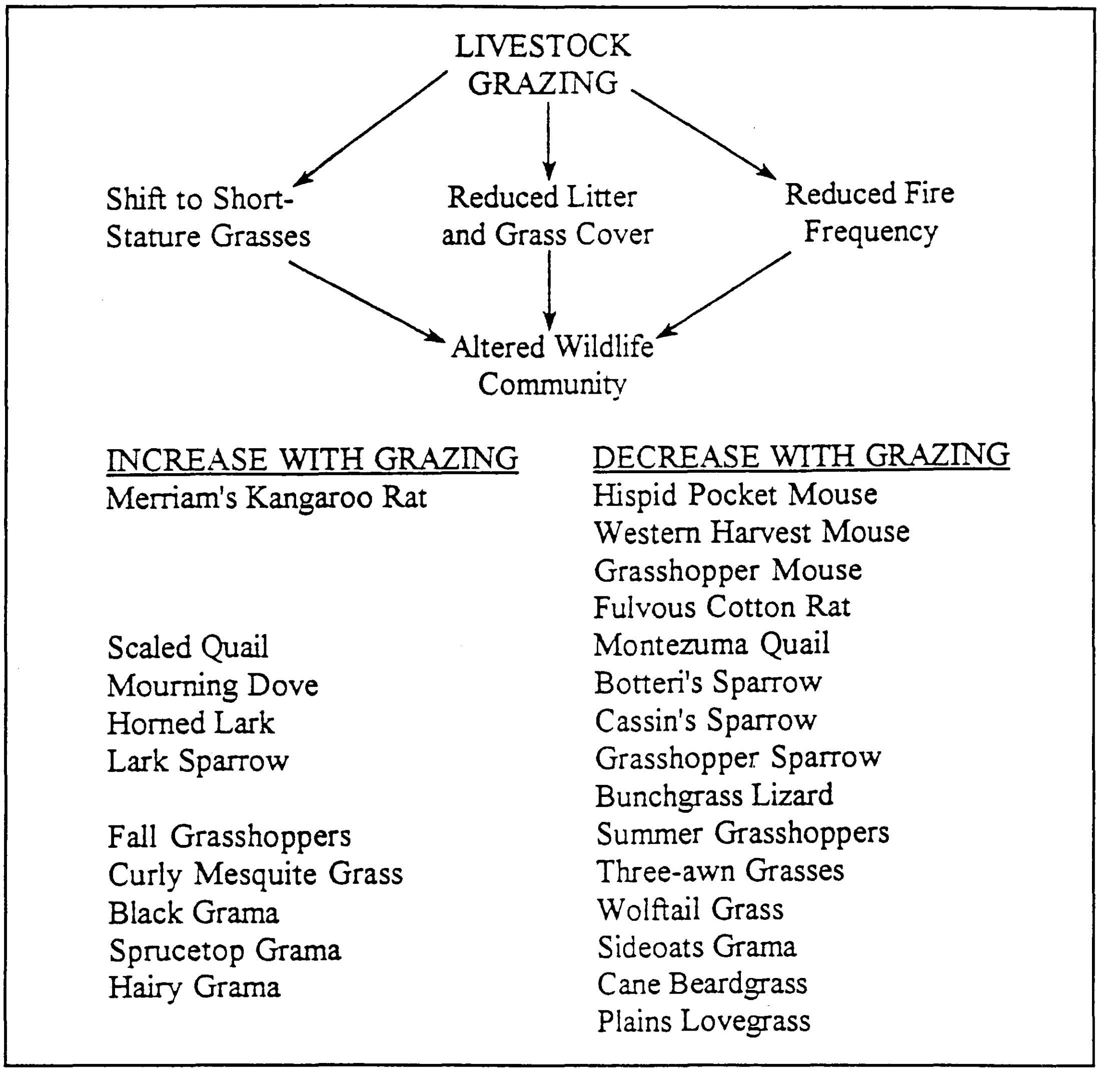

Figure 1. Effects of livestock grazing on native flora and fauna of the Appleton-Whittell Research Ranch Sanctuary in southeastern Arizona.

Cross-fence comparisons were not conducted on the Research Ranch when livestock were first removed in 1968, although a vegetation analysis of the sanctuary did occur in 1969-1971 (Bonham 1972). Because the land-use history of the sanctuary was similar to that of the Sonoita Plain as a whole prior to 1968 (Bahre 1977), it is reasonable to assume that subsequent cross-fence differences between the sanctuary and adjacent operating cattle ranches have been the result of livestock exclusion.

Brady et al. (1989) sampled vegetation canopy cover in 1984 on some parts of the sanctuary originally inventoried by Bonham (1972), and coupled this with cross fence comparisons. Their results showed approximate fivefold increases in the canopy cover of mid-height grasses, both cross-fence and over time within the sanctuary, while other components of vegetation were not significantly different. We compared grass canopy cover across fence lines on eight sites around the perimeter of the sanctuary in 1990, 22 years after livestock removal (C. E. Bock and J. H. Bock 1993). Total grass canopy cover was significantly higher on the ungrazed portion of each site, due largely to relative increases in abundances of taller bunch grasses. There was a strong positive correlation between flowering height and amount of positive response to release from grazing among the ten most common grass species. Taller species such as plains love grass, cane beard grass, and side oats grarna were much more abundant inside the exclosure, while shorter-stature grasses such as blue grama, spruce top grama, black grama, and curly mesquite did not differ across fence lines, or were more common in grazed areas (Figure 1).

Woody plants have responded variously to livestock removal. Kenney et al. (1986) found that one of the two most abundant shrubs in the region, yerbe de pasmo, was more abundant on than off the sanctuary, apparently because livestock will browse it in winter. However, mesquite and burro weed did not differ across fence lines (C. Bock et al. 1984).

Animals responding positively to livestock exclusion have been species generally characteristic of taller and denser grasslands, while those we have found to be more common outside the sanctuary are species associated with relatively open and/or desert-like habitats (C. Bock et al. 1984, 1990, Jepson-Innes and Bock 1989, Stromberg 1990, C. Bock and J. Bock 1991). For example, songbirds counted more often on grazed lands included such open-ground species as scaled quail, horned larks, and lark sparrows, while common grassland species were common on the sanctuary. In fall, common grasshoppers were species that fed primarily on forbs, and most were relatively common in grazed habitat.

In conclusion, comparative studies indicate that livestock directly and dramatically influence the composition and structure of grass communities, favoring shorter grass species, while reducing grass canopy and litter (Figure 1). These changes in turn affect the relative abundances of birds, rodents, reptiles, and insects. When stocked at economically meaningful rates, livestock have controlling influences on ecosystem structure and function that qualify them as keystone herbivores in the desert grasslands of the Sonoita Plain. They do not preclude native flora and fauna, but they determine which species will increase and which will decrease. An additional effect of livestock grazing is reduction in the intensity and frequency of fire, which we shall consider in the next section of this paper.

Fires once were common natural events in desert grasslands. They doubtless had a major impact on ecosystem structure and function, including keeping grasslands in a relatively shrub-free state (McPherson 1995). However, livestock grazing, beginning especially in the 1880's, reduced fine fuels and therefore fire frequencies (Bahre 1991). Lightning and human-caused wildfires have occurred with some regularity on the Research Ranch since the early 1970's, probably related to increased fuel accumulations after livestock removal. Therefore, the sanctuary has afforded an opportunity to study the ecological effects of fire in a desert grassland under circumstances perhaps more closely resembling prehistoric conditions than is usually the case.

We studied the effects two upland wildfires that occurred in 1974 (J. Bock et al. 1976), two sacaton bottom land fires in 1975 (C. Bock and J. Bock 1978), and the results of small upland prescribed burns in 1984 (J. Bock and C. Bock 1992b). Particularly important were studies of a large and unusually intense lightning-caused wildfire that burned nearly one-third of the sanctuary in July, 1987 (C. Bock and J. Bock 1991, 1992, J. Bock and C. Bock 1992a). Related to other studies, we had sampled a variety of areas affected by the 1987 burn prior to its occurrence, and so we were in a position to measure pre-and post burn plant and wildlife populations, and to compare these results with data from a similar array of unburned control plots. Several consistent patterns emerged from these various studies (Figure 2).

Fires caused little if any grass mortality, but temporarily reduced the canopy cover of most species, including sacaton, for two or sometimes three growing seasons. Herbs usually increased in abundance and variety for about the same period, probably as a consequence of the reduced grass canopy. We found no long-term fire effects on woody plants, except for burro weed, which suffered virtual 100% mortality, as has been found elsewhere (Martin 1975). Scattered mesquite on the sanctuary rarely died in fires, although they suffered considerable loss of outer limbs and frequently re-sprouted from their lower trunks.

Wildlife responses to fire on the Research Ranch have been complex, but consistent with fire effects on their preferred habitats. Increased seed production by grasses and by short-lived perennial dicots during first post-fire growing seasons dramatically increased abundances of wintering sparrows on recently burned areas. Animals dependent on heavy grass cover, such as fulvous cotton rats and various nesting sparrows, declined on burned plots until grass canopy had recovered to pre-burn levels. Others preferring relatively open habitats, such as kangaroo rats and horned larks, temporarily increased on burned areas. We found no evidence of direct fire-caused mortality of any animal species, except a few reptiles and certain grasshoppers.

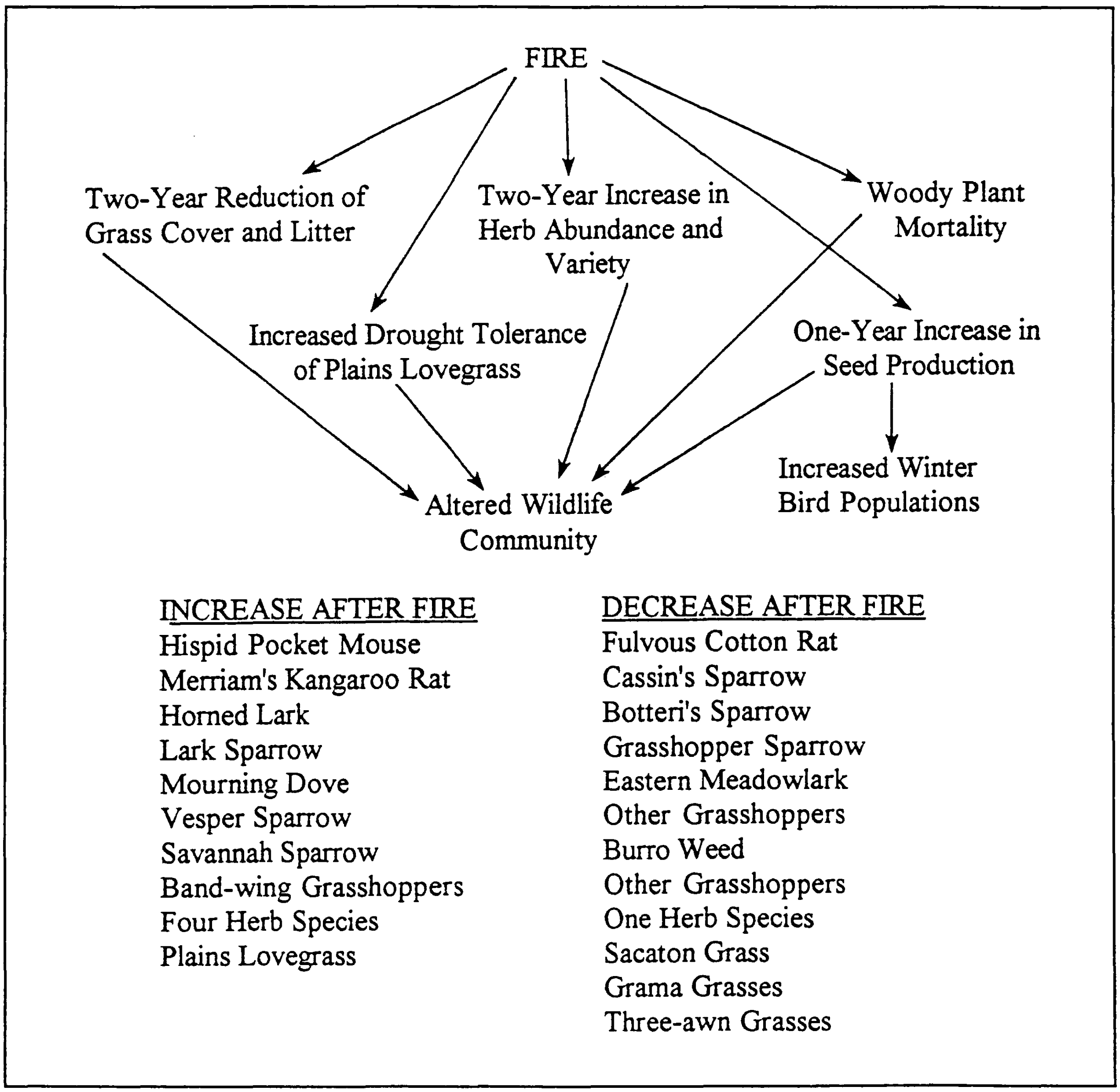

Figure 2. Effects of fire on the native flora and fauna of the Appleton-Whittell Research Ranch Sanctuary in southeastern Arizona.

In conclusion, most plants and animals of the Research Ranch appear to tolerate fire, and sometimes to benefit from it, but not to be fire-dependent. A conspicuous exception is plains love grass, one of the characteristic upland bunch grasses on the sanctuary. This species has suffered heavy mortality apparently due to drought, except in areas that have burned within the previous three years (C. Bock et al. 1995). It is not clear why fire might increase plains love grass' survivorship during drought, but long-term dominance of this species may depend on relatively frequent burning.

PRECIPITATION

Changes in amounts and seasonal distribution of precipitation doubtless affect the composition of desert grasslands, but the relative influence of climate versus fire and grazing in shaping the structure and function of these ecosystems remains unclear (Hastings and Turner 1965, Neilson 1986, Schlesinger et al. 1990, Bahre and Shelton 1993, McPherson 1995). Livestock exclosures such as the Research Ranch have value in this regard, because the effects of precipitation can be studied in the absence of exotic grazers and in the presence of more natural fire regimes.

Studies at the sanctuary began only in 1968, and so their results cannot yet reveal the consequences of any possible long-term changes in climate. Furthermore, because precipitation is uncontrolled, studies of drought and its consequences are correlational only and cannot be planned in advance. Nevertheless, projects designed for other purposes have yielded data on population trends of vegetation and wildlife, which we could then correlate with precipitation data collected on the site. In particular, data from control plots that were parts of studies evaluating the impacts of grazing, fire, and exotic vegetation revealed short-term changes in grassland community composition that could be compared with trends in amounts and seasonal distribution of rainfall on the sanctuary .Declines in vegetation cover and in some animal populations have correlated with decreases in annual precipitation, but most of these changes have been short term and have reversed themselves as soon as precipitation increased (Figure 3; C. Bock et al. 1986, C. Bock and J. Bock 1992, J. Bock and C. Bock 1992a,b). One of the most important ecological changes related to drought is reduced seed production, which in particular has affected the abundance of migratory songbirds wintering on the sanctuary (Pulliam and Brand 1975, Pulliam and Dunning 1987).

Three plant species have shown relatively dramatic and longer-term changes that appear to be related to precipitation. Plains love grass is a mid-height perennial bunch grass that is particularly sensitive to grazing, and that has become locally very common on the sanctuary since livestock removal (C. Bock and J. Bock 1993). However, this otherwise dominant species experienced widespread mortality during a relatively dry period between 1989 and 1990, and had only recovered to pre-drought levels by 1993 (C. Bock et al. 1995). As noted above, plains love grass that had been burned within three years prior to the drought did not suffer comparable mortality. This observation deserves further study.

Two shrubs on the Research Ranch, burro weed and yerbe de pasmo, have fluctuated in ways suggesting their positive association with winter rains (C. Bock and J. Bock, in press). Both species increased between 1982 and 1985, a period of relatively wet winters, declined during the dry winters of 1986-1990, and then increased through 1995, coincident with a second wet period. Burro weed in particular showed dramatic population fluctuations, increasing from a low of 20 plants/200m2 in 1982 to a high of 80 plants/200m2 in 1985. Similar fluctuations in burro weed have been observed in other desert grasslands, also related to winter precipitation (Martin 1975).

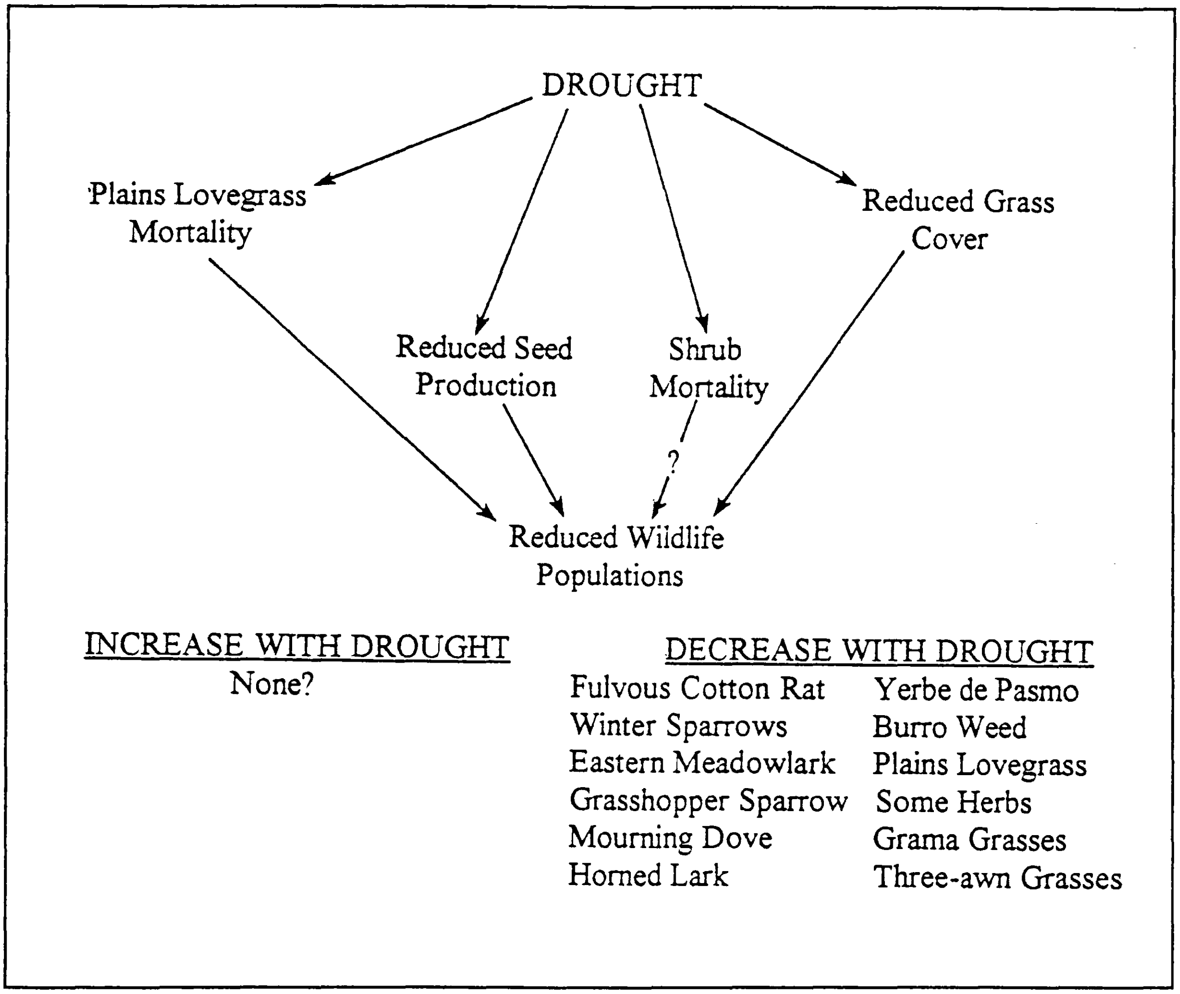

Figure 3. Major effects of short-term reductions in precipitation on native flora and fauna of the Appleton-Whittell Research Ranch Sanctuary in southeastern Arizona.

EXOTIC GRASSES

Certain love grasses *(Eragrostis* spp.) native to Africa were purposefully introduced into southwestern grasslands as a range restorative tool, beginning in the 1930's (An able et al. 1992, Bahre 1995). Lehmann's love grass in particular has spread subsequently into thousands of hectares in the region, because of its prolific seed production, positive response to fire, and wide range of environmental tolerance (Ruyle et al. 1988, Cox et al. 1988). Because exotic love grasses continue to be seeded in the Southwest, it is important to understand the consequences to native flora and fauna.

In the 1940's and 1950's, both Lehmann's and Boer's love grass were planted on certain mesas in the Sonoita Plain that subsequently became part of the Research Ranch. In 1984-1985, we compared three sites on the sanctuary dominated by African love grasses with comparable areas lacking these exotics (C. Bock et al. 1986). Results of that study suggest that introduction and spread of the alien grasses significantly reduced native biodiversity of the areas affected. The exotic grasses have formed near-monocultures on the sanctuary, at the expense of most native vegetation. Furthermore, the love grass plantations supported a greatly reduced variety and

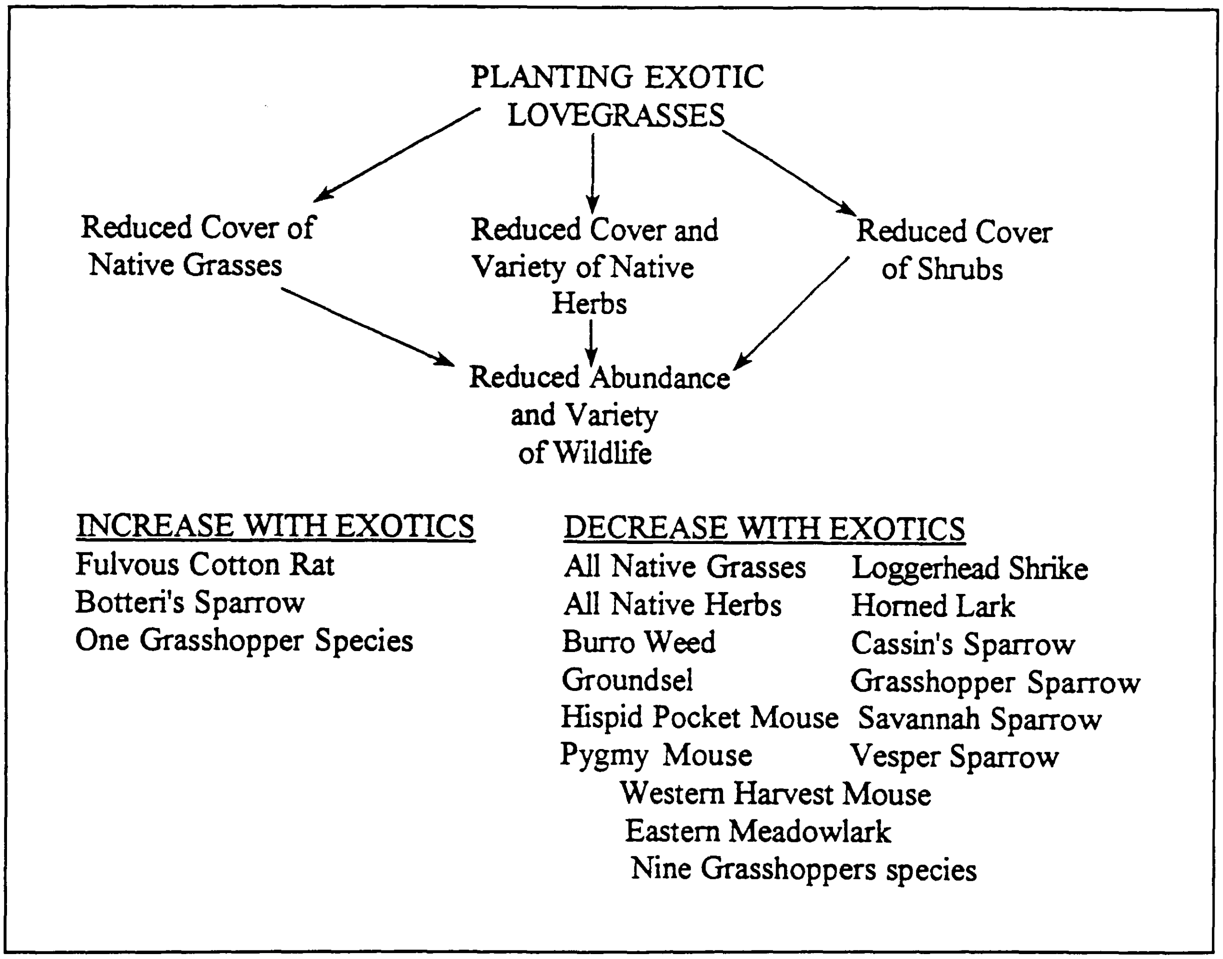

Figure 4. Major effects of African lovegrasses on native flora and fauna of the Appleton-Whittell Research Ranch Sanctuary in southeastern Arizona.

abundance of native wildlife, including grasshoppers, rodents, and birds (Figure 4). Among vertebrates, the only exceptions were the fulvous cotton rat and Botteri's sparrow, species characteristic of very heavy grass cover, such as provided by the exotic grasses.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Episodes of fire and drought once maintained a natural mosaic of grass and grass/shrub habitats in lowlands of the American Southwest. Livestock grazing historically reduced fire frequency and exacerbated the effects of drought, generally increasing woody species at the expense of grasslands (Humphrey 1987, Bahre 1991, 1995, Bahre and Shelton 1993, McPherson 1995). At the lowest elevations, alterations in soil nutrient distribution may have rendered these grazing-induced changes essentially permanent (Schlesinger et al. 1990). However, our work at the Appleton-Whittell Research Ranch suggests that, at somewhat higher elevations such as on the Sonoita Plain, grasslands released from the controlling influence of livestock can move fairly quickly toward a new dynamic equilibrium, dominated by different species of plants and animals that may be more indicative of conditions as they existed prior to the eighteenth century. The grazed lands themselves continue to support diverse communities of vegetation and wildlife, so that a mosaic of landscapes in various stages of post-grazing ecological succession is likely to support the full complement of native plants and animals.

As long as management plans include significant numbers of large and permanent livestock exclosures, as refuges for those species especially sensitive to the activities of large herbivores, we do not perceive responsible grazing as a threat to regional biodiversity of southwestern grasslands in relatively mesic sites, if stocking rates are adjusted to variations in precipitation. Planting alien grasses is quite another matter. While the African exotics may help to stabilize soils in degraded sites, and provide some forage, they apparently do so at the expense of much of the native flora and fauna. There is no sign on the Research Ranch that native grasslands are replacing the exotics, even after 28 years without livestock or other anthropogenic disturbances. In fact, both Boer's and Lehmann's love grasses appear to be spreading on the sanctuary (W. Branan, pers. comm.), as they are in other grasslands of the Southwest both with and without livestock (An able et al. 1992). The African exotics therefore resemble other successful alien species, in their apparent abilities to invade undisturbed as well as disturbed sites, and to significantly change resulting ecosystem structure and function (Crawley 1986, Vitousek 1986, Rice and Mack 1991).

Future integrity of many arid southwestern ecosystems, including those on the Sonoita Plain, depends upon finding ways to reverse or at least halt the spread of alien grasses. This should be a top research and management priority for all individuals and organizations committed to the stewardship and conservation of these extraordinary grasslands.

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APPENDIX
Common and Scientific Names of Species

Grasses

cane beard grass *(Bothriochloa barbinodis)*
Texas bluestem *(Schizachyrium cirracus)*
blue grama *(Bouteloua gracilis)*
sideoats grama *(B. curtipendula)*
hairy grama *(B. hirsuta)*
spruce top grama *(B. Chondrosioides)*
black grama *(B. eriopoda)*
plains love grass *(Eragrostis inter media)*
Boer's love grass *(E. curvula* var. *conferta)*
Lehmann's love grass *(E. Lehmanniana)*
curly mesquite *(Hilaria belangeri)*
vine mesquite *(Panicum obtusum)*
big sacaton *(Sporobolus wrightii)*
tangle head *(Heteropogon contort us)*
purple three awn *(Aristida purpurea)*
wolf tail *(Lycurus phleoides)*

Woody Plants

burro weed *(Haplopappus tenuisectus)*
yerbe de pasmo *(Baccharis pteronioides)*
mesquite *(Prosopis velutina)*
cat claw mimosa *(Mimosa dysocarpa* and *M. biuncifera)*
groundsel (*Senecio douglasii*)

Vertebrates

bunch grass lizard *(Sceloporus scalaris)*
scaled quail *(Callipepla squamata)*
Montezuma quail *(Cyrtonyx montezumae)*
mourning dove *(Zenaida macroura)*
homed lark *(Eremophila alpestris)*
loggerhead shrike *(Lanius ludovicianus)*
Cassin's sparrow *(Aimophila cassinii)*
Botteri's sparrow *(A. botterii)*
vesper sparrow *(Pooecetes gramineus)*
lark sparrow *(Chondestes grammacus)*
savannah sparrow *(Passerculus sandwichensis)*
grasshopper sparrow *(Ammodramus savanna rum)*
eastern meadow lark *(Sturnella magna)*
hispid pocket mouse *(Chaemerops hispictus)*
Merriam's kangaroo rat *(Dipodomys Merriam I)*
western harvest mouse *(Reithrodontomys megalotis)*
northern pygmy mouse *(Baiomys Taylori)*
southern grasshopper mouse *(Onychomys torridus)*
fulvous cotton rat *(Sigmodon fulviventer)*
bison *(Bison bison)*

Chapter II
Identifying Grassland Issues

This chapter presents a series of sessions that examined a range of issues related to grasslands and human use of them. David Brown presented the results of his study of changes in bird and mammal distribution changes in the southwest. Rod Mondt chaired a panel on wildlife issues which included changes in bird and mammal distribution, migrating birds, and wildlife corridor issues. A paper by Phil Rosen and others that was not actually presented at the conference on reptiles and amphibians was added here to broaden the coverage. George Ruyle chaired a session on grazing and fire management and the connection between grazing and fire including a look at historical patterns of fire, experimental fire research, burning policy and ranching. John Brock led a session on the role of exotic plants with papers by two authors who look at ecological characteristics of invasive alien plants, means of exotic plant introduction (a poster), and Lehmann lovegrass. Finally, Roy Jemison and Barbara Tellman led sessions on water quality, erosion, and water supply issues that are addressed with papers about hydrology and watershed management, water supply and sustainability, and a case study of water supply determination in southeast Arizona.

Wildlife Issues Session

Grazing Management and Fire Issues Session

Terrestrial Bird and Mammal Distribution Changes in the American Southwest, 1890 - 1990

David E. Brown[1] and Russell Davis[2]

ABSTRACT

Distribution changes over the past one hundred years are summarized for a number of terrestrial mammals and birds in Arizona and New Mexico. At least 39 species appear to have been extirpated or suffered range restrictions, while 55 others have experienced range expansions. Even when exotics are excluded, the biodiversity of endotherms is now greater than in 1890. As expected, the ranks of the "losers" contain a disproportionate number of large predators and grassland-associated animals. By way of contrast, the majority of the "winners" were forest and/or scrubland-adapted species. More germane to this study was the fact that more than 70 percent of the "winners" were species that have their primary biotic affinity south of the U.S.-Mexico border. Few Rocky Mountain, Great Basin, or Great Plains species increased in distribution. Possible reasons for these phenomena are discussed including the potential effect of increasing winter temperature minima on plant distributions and the availability of invertebrates.

Much well-deserved concern has recently been expressed regarding an increase in the number of endangered species and a loss in biodiversity. Each year sees additional animals proposed for state or federal listing as "threatened" or "endangered" species. But, although much effort is expended to determine the actual status of these animals, the stated reasons for their decline are often vague and subjective. Rarely, and only recently, have overall changes in the status of an animal's habitat and its associated biota been properly evaluated and appreciated. To achieve a better perspective of the possible influence of an overall environmental change, we examined the distributional status of terrestrial mammals and birds in the states of Arizona and New Mexico during the past 100 years.

THE STUDY AREA

The states of New Mexico and Arizona in the American Southwest provide an ideal study area for a long term analysis of the effects of climatic change on endothermic animals. The region's southern position astride the Continental Divide, and its great range in elevations from less than 30

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m where the Colorado River enters Mexico to more than 4,000 m atop Wheeler Peak in the Sangre de Cristo Mountains, provide climates ranging from subtropical to arctic-boreal. Also, depending on location, mean annual precipitation can be as low as 75 mm to greater than 780 mm. The result is that almost every biome found in North America -- alpine tundra, boreal conifer forest, temperate deciduous forest, evergreen woodland, chaparral, grassland and desert -- can be found somewhere in these two states. Moreover, the Southwest's othography provides both mountain and valley corridors extending northward into the Rocky Mountains and Great Basin as well as southward into Mexico. Thus, birds, and many mammals, can, in a single day, travel from an environment in which freezing temperatures may occur at any time of the year to those which rarely experience a 24-hour freeze.

The American Southwest's biotic diversity is also due to its special evolutionary history. Most of the region was not covered by ice sheets during the Pleistocene Epoch. Although the alternating drying and cooling that accompanied glacial advances and retreats had an immense effect on Southwest environments, the region's great topographic relief, manifested in such features as the Grand Canyon and Mogollon Rim, coupled with it southern latitudes, served to provide warm-temperate refugia for a number of endemic Pleistocene plants and animals. These features, coupled with the erratic but overall drying and warming trend that accompanied the onset of Holocene times about 11,500 years ago, have resulted in the Southwest being the location of isolated Pleistocene forests on mountain-tops, relict mild-winter conifers and water-dependent deciduous forests beneath the Mogollon Rim, and a tension zone of diminishing areas of grasslands and evergreen woodlands between 1000 and 2000 m elevation. The most recent phenomenon has been the development and advance of the four North American deserts, parts of all of which occur in the Southwest (see e.g., Van Devender et al. 1987). The result today is a great mixing of old and new plant and animal species that have segregated out into a mosaic of Tertiary, Nearctic and Neotropical habitats (Lowe and Brown 1982).

This biodiversity, coupled with the region's general aridity, has made the Southwest a focal point of study for a variety of environmental disciplines. During the last 100 years the Southwest has provided a unique field laboratory for zoologists, botanists, ecologists, archeologists and paleontologists. Not only has the region's abundant fossil record been much investigated (see e.g., Harris 1985), much of the pioneering and ongoing work on fossil pollen analysis, tree-ring chronology and other techniques to measure climatic change have been focused in or near the Southwest. Especially germane to this effort is the work of Hastings and Turner (1965) and their successors who have demonstrated important landscape changes over the past 100 years through the use of repeat-photography. The result is that few if any regions of North America have a more complete fossil and recent history of faunal and vegetative changes. That these changes have been dramatic and have been shown to have continued into modern times, both facilitates and lends impetus to the work at hand.

Another factor contributing to our understanding of the Southwest's biota was its relatively late settlement by Western Man. Acquired by the United Stated from Mexico in the mid-19th Century, New Mexico Territory had remained virtually uninhabited by either Spaniards or Mexicans. This circumstance enabled American scientists to report on the region's landscapes and biota <u>prior</u> to large scale ranching and agricultural development (see e.g., Davis 1982). Moreover, this late settlement, combined with the region's rugged topography and general aridity, prolonged the settlement process. Even as late as 1880, few settlements existed outside of the river valleys and the environs of mining camps. The late entry of Arizona and New Mexico into the Union in 1912 also allowed for the inclusion of sizable tracts of land within National forests and parks before they were irreversibly impacted by a long history of unregulated grazing, land clearing and other ecologically disruptive influences.

Last, but not least, the American Southwest was visited by a number of competent naturalists around the turn of the century. People like Elliot Coues, E.A. Mearns, Herbert Brown, H.S. Swarth, Vernon Bailey and Florence Merriam Bailey made systematic attempts to inventory the birds and mammals of Arizona and New Mexico and reported on their habitat affinities and status (e.g., Swarth 1914). Other investigators conducted studies on the distributions of particular species of birds and mammals as well as the natural history of specific locales (e.g., Merriam 1890). These studies have continued to the present day, allowing for a progression of comprehensive treatments on the region's mammals and bird (e.g., Coues 1867, Mearns 1907, Ligon 1927, Bailey 1928, Bailey 1931, Hall 1946, Ligon 1961, Phillips et al. 1964, Findley et al. 1975, Hubbard 1978, Monson and Phillips 1981, Hofmeister 1986). Also relevant to this study is the fact that 100 years of climatological data are now available for a number of New Mexico and Arizona stations (see e.g., Karl et al. 1989, Sellers et al. 1985).

STUDY METHODS AND LIMITATIONS

Using as base references the basic works on avian and mammalian distribution noted above, state endangered animal summaries (Arizona Game and Fish Department 1988, New Mexico Department of Game and Fish 1992), specific journal articles (e.g. Hock 1952, Hubbard 1977, Lomolino et al. 1989) and our own work (e.g. Brown 1973 and 1989, Davis and Dunford 1987, Davis and Brown 1989, Davis and Callahan 1992), we listed those species of terrestrial mammals and birds, that appear to have increased or decreased their Southwest distributions during historic times. For comparative purposes we have also listed terrestrial species of exotics which are deemed to have established self-sustaining populations. To determine if the distribution of animals in certain habitats had changed more than in other habitats, each species was assigned the biotic community or communities with which it is primarily associated. These lists were then commented on and added to by John Hubbard, Gale Monson and Barry Spicer. Dr. Hubbard and Mr. Monson are recognized authorities on the status of birds in New Mexico and Arizona, and Dr. Hubbard and Mr. Spicer have been involved in the preparation of status reports on rare and endangered species for their respective state agencies. Their enthusiastic assistance was a major contribution to this study.

Bird names follow Hubbard (1978) and Monson and Phillips (1981). Mammal names follow Jones et. al. (1992). The biotic community affiliations are those discussed in Brown (1982, 1994) and mapped by Brown and Lowe (1980, 1990).

Our lists only include those species of terrestrial birds and mammals known to have bred in the Southwestern states of Arizona and New Mexico since 1890. Subspecies are not included. This limited geographical perspective is due both to a lack of comparable historical data for the Mexican states of Baja California, Sonora and Chihuahua and to the fact that we have less experience with conditions in these states as well as those in California, Nevada and Texas. Regrettably, comparable historical data and experience are also lacking for the Southwest's herptile and invertebrate faunas. Such information could have contributed greatly to the breadth of our analysis.

The massive changes that have occurred in the Southwest's riparian and other wetland habitats also precludes a comparable analysis of the region's aquatic and wetland faunas. However, it is important to point out that the dire status of the Southwest's native fishes and their extensive displacement and replacement by "exotics" has been well documented (see e.g. Minckley and Deacon 1991). It goes without saying that endothermic animals such as the River Otter *(Lutra* *canadensis)* and Beaver *(Castor canadensis)* have experienced similar displacements. Nonetheless, it should also be noted that a number of wetland birds including the Bald Eagle *(Halieatus leucocephalus),* Clapper Rail *(Rallus longirostris),* Mexican duck *(Anas diazi),* Black-bellied Whistling Duck *(Dendrocygna autumnalis)* and Cattle Egret *(Bubulcus ibis)* now enjoy a greater distribution in these two states than they did in 1900.

There are, of course, a number of problems inherent in any comparative analysis of patterns of past and present animal distributions. Perhaps the foremost of these is that any knowledge of the actual previous (and present) distribution of a species is imperfect and open to interpretation. The age-old question of whether a new locale for a species represents a range extension or merely a lack or failure of previous sampling efforts will never be answered in every case to everyone's satisfaction. The distributions of some species, especially those at the edge of their range, are especially dynamic and the occurrence of these species in Arizona or New Mexico is inherently sporadic (e.g. the Ghost-faced Bat *(Mormoops megalophylla)* and Rosethroated Becard *(Pachyramphus aglaiae)* in Arizona. These species are either omitted from our analysis or indicated with a question mark. Moreover, the status and distribution of some species such as the Long-nosed Bat *(Leptonycteris curasoae = sanborni) is* a matter of some debate (see e.g., Howell and Roth 1981, Cockrum 1991). For purposes of this analysis, we have excluded those species which are known to irregularly occur in the American Southwest or whose past and present distributional status is considered questionable by biologists involved in their study. Since this is a study of the dynamics of distribution, we have considered only changes in the distribution of species, not an increase or decrease in population sizes.

RESULTS

Nine species have been extirpated in Arizona and New Mexico (Table 1). Not surprisingly, three of these are large carnivores that were systematically hunted as livestock predators. One other, the black-footed ferret, may have been lost as a result of prairie dog control efforts, although the animal's demise due to one or more introduced pathogens is a distinct possibility. Two large game animals, the elk and bison, formerly present and subsequently extirpated, have since been reintroduced, the former with marked success. The remaining three extirpated species are grassland-associated birds.

Thirty-four species are still present but appear to have experienced range reductions since 1890 while 55 species now seem to enjoy an expanded distribution (Tables 2 and 3). Although human-assisted introductions and the occurrence of artificial feeding and watering sites can explain some of the increases in distribution, the reasons for most are unclear and cannot be explained by direct human intervention. Conversely, introduced diseases, competition with exotic animals and grazing by livestock have been implicated as reasons for many of the species now having decreased distributions.

Only 19 exotics (13 mammals and six birds) appear to have become established in Arizona and New Mexico by 1890. The two camels have since been eliminated and the status of several other species (e.g., Swine, Chukar Partridge and Black Rat) may be tenuous. A surprising result of the analysis was that even when exotic animals are excluded and extirpated species included, more animals appear to have experienced range expansions (55) than declines (43). As far as terrestrial birds and mammals are concerned, biodiversity is now greater in the American Southwest than it was in 1890.

Tables 5 and 6 summarize the formation-types, biotic community affinities and centers of biogeographic distributions of 39 mammals and birds which appear to now have reduced distributions in the American Southwest. The majority (59%) of these are grassland-affiliated species. Nearly all of the biogeographic provinces are represented, with nearly as many species having their centers of distribution to the north or northeast (49%) as to the south or southeast (51%).

Formation-class affinities and biogeographic centers for the 55 species of mammals and birds breeding in the American Southwest and which have experienced range expansions are presented in Tables 7 and 8. Twenty-nine, or more than half (53%), of these "winners" are forest and woodland species. Another seven (13%) are associated with chaparral or other scrublands, only seven are grassland-associated species and, oddly enough, only three (5%) are desert species. The most surprising statistic, however, is the number of species having their biogeographic center of distribution to the south of the American Southwest (Table 8). More than half of the "winners" have their nearest ecological center in either Mexico's Sierra Madre (27%) or the forests and scrublands of Sonora and Sinaloa (29%). None of the "winners" are headquartered in the Great Basin and only two mammals and two birds can be considered as Rocky Mountain species.

The above distributional changes strongly suggest recent changes in both landscape character and climate. Indeed, a change in vegetation from open grasslands and woodlands to more closed communities of forest and scrubland has been well documented for Arizona by Hastings and Turner (1965) and in New Mexico by Dick-Peddie (1993). While climatic change has been going on in the Southwest since the advent of the Holocene (see e.g., Houghton et al. 1990, Davis and Shafer 1992), the amount of this occurring within a time frame of only 100 years is difficult to assess. Climatic data since 1890 show no appreciable trends in either summer or winter precipitation amounts in Arizona (Sellers et al. 1987) and changes in minimum temperatures are often masked by the effects of urban warming (Kirby and Sellers 1987, Sellers 1990). Nonetheless, regional climatic data which has been corrected for the effects of urban warming shows a significant increase in winter, summer and annual temperature minima since ca. 1960 for the "Southern Deserts" which encompass southern New Mexico and Arizona (Karl et al. 1989). No such trend is apparent for the "Great Basin" and "Southern Rockies" regions. Clearly, further investigation into the possible effects of short-term climatic change are warranted. It may be instructive to monitor and evaluate short-term (50 to 100 year) changes in the distributions of selected species of terrestrial ectotherrns (invertebrates and herptiles) to determine what role, if any, climate change might also be playing on their distributions in the American Southwest.

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Species	Primary Biotic Affinities in the Southwest
MAMMALS	
Ursus arctos, Grizzly Bear [1]	Rocky Mountain Subalpine Forests and Grasslands downward to Madrean Evergreen Woodland and Interior chaparral
Canis lupus, Gray Wolf [1]	Rocky Mountain Montane Forests downward through Plains Grassland and Madrean Evergreen Woodland to Chihuahuan Semidesert Grassland
Mustela nigripes, Black-footed Ferret [2, 3]	Great Basin Grassland
Panthera onca, Jaguar [1]	Madrean Evergreen Woodland and Riparian communities upward to Rocky Mountain Conifer Forest
Cervus elaphus, Elk [4]	Rocky Mountain Conifer Forest and Meadow Grassland
Bos bison, American Bison [4]	Plains Grasslands in West Texas and New Mexico
BIRDS	
Falco femoralis, Aplomado Falcon	Chihuahuan Semidesert Grassland
Centrocercus urrophasianus, Sage Grouse [5]	Great Basin Desertscrub with Wet Meadows
Pediocetes phasioanellus, Sharp-tailed Grouse [5]	Intermountain Grassland interspersed with Scrub

Table 1. Nine species of terrestrial mammals and birds breeding in the American Southwest in 1890 and that were extirpated prior to 1990.

1. Purposefully extirpated through direct human intervention.
2. Inadvertently extirpated through direct human intervention.
3. Shown to be susceptible to diseases transmitted by introduced animals.
4. Successfully reintroduced after 1912.
5. Populations shown to be susceptible to livestock grazing and changes in land use.

Species	Primary Biotic Affinities in the Southwest
MAMMALS	
Lepus alleni, Antelope Jackrabbit	Sonoran Savanna Grassland, Sonoran Desertscrub, Chihuahuan Semidesert Grassland
?Spermophilus tridecemliniatus, Thirteen-lined Ground Squirrel	Plains and Great Basin Grasslands
Cynomys ludovicianus, Black-tailed Prairie Dog [1]	Plains and Chihuahuan Semidesert Grasslands
Cynomys gunnisoni, Gunnison's Prairie Dog [1]	Great Basin Grassland
?Tamius minimus, Least Chipmunk	Rocky Mountain Subalpine and Montane Conifer Forests and Montane Meadows
?Crategeomys castanops, Yellow-faced Pocket Gopher	Plains Grassland
Microtus pennsylvanicus, Meadow Vole [2]	Rocky Mountain and Great Basin Meadows and Marshlands
Sigmodon arizonae, Arizona Cotton Rat	Grassy areas within Sonoran Desertscrub and various Riparian Biomes
Zapus hudsonius, Meadow Jumping Mouse [2]	Rocky Mountain Subalpine and Montane Meadows; Marshlands
Vulpes velox, Kit Fox, Swift Fox [1, 3]	Sonoran, Mohave and Chihuahuan Desertscrubs; Plains Grassland
Ursus americanus, Black Bear [1]	Rocky Mountain Subalpine and Montane Conifer Forests
Odocoileus virginianus, White-tailed Deer	Madrean Evergreen Woodland, Chihuahuan Semidesert Grassland and Riparian Forest within Interior Chaparral and other Biomes
Antilocapra americana, Pronghorn	Plains and Chihuahuan Semidesert Grasslands; Sonoran Desertscrub (Lower Colorado River Valley subdivision)
Ovis canadensis, Bighorn Sheep[3]	Sonoran and Mohave Desertscrub; Chihuahuan Semidesert Grassland; various Great Basin and Rocky Mountain Biomes

Table 2. Thirty-four species of terrestrial mammals and birds breeding in the American Southwest and experiencing range reductions since 1890.

1. Some isolated populations extirpated through direct human intervention.
2. Largely a wetland species in the Southwest.
3. Shown to be susceptible to diseases transmitted by introduced animals.
4. Also successfully introduced to non-native habitats.
5. Populations shown to be susceptible to livestock grazing and/or browsing.

Species	Primary Biotic Affinities in the Southwest
	BIRDS
Buteo regalis, Ferruginous Hawk	Great Basin Grassland
Buteo nitidus, Gray Hawk	Sonoran and adjacent warm-temperate Riparian Woodlands of Mesquite and Cottonwood trees
Caracara cheriway, Caracara	Sonoran Desertscrub
Meleagris gallopavo, Wild Turkey [3, 4]	Madrean and Rocky Mountain Conifer Forests, Riparian Deciduous Forest
Tympanuchus pallidicinctus, Lesser Prairie-chicken [5]	Plains Grassland
Lagopus leucurus, White-tailed Ptarmigan [5]	Rocky Mountain Alpine Tundra and Shrubland
Callipepla squamata, Scaled Quail	Chihuahuan Semidesert Grassland
Colinus virginianus, Bobwhite [5]	Plains Grassland; Sonora Savanna Grassland
Cyrtonyx montezumae, Montezuma Quail [5]	Madrean Evergreen Woodland Savanna
Columbina passerina, Ground Dove	Weedy fields within Chihuahuan Semidesert Grassland and Sonoran Desertscrub
Melanerpes erythrocephalus, Red-headed Woodpecker	Riparian Deciduous Forest and telephone poles and trees within Plains Grassland
Glaucidium brasilianum, Ferruginous Pygmy Owl	Sonoran Desertscrub (Arizona upland subdivision)
Tyrannus tyrannus, Eastern Kingbird	Riparian Deciduous Forest and other Wooded Habitats within Plains Grassland
Epidonax fulvifrons, Buff-breasted Flycatcher	Madrean Evergreen Woodland and Chaparral
?*Vireo vicinior,* Gray Vireo	Great Basin Conifer Woodland, Interior Chaparral
?*Passerina ciris,* Painted Bunting	Riparian Deciduous Woodlands
Ammodramus savannarum, Grasshopper Sparrow	Plains Grassland, Chihuahuan Semidesert Grassland
Aimophila carpalis, Rufous-winged Sparrow	Sonoran Savanna Grassland
Aimophila botterii, Botteri's Sparrow	Chihuahuan Semidesert Grassland
Coccothraustes vespertinlls, Evening Grosbeak	Rocky Mountain Subalpine Conifer Forest

Table 2 (continued). Thirty-four species of terrestrial mammals and birds breeding in the American Southwest and experiencing range reductions since 1890.

1. Some isolated populations extirpated through direct human intervention.
2. Largely a wetland species in the Southwest.
3. Shown to be susceptible to diseases transmitted by introduced animals.
4. Also successfully introduced to non-native habitats.
5. Populations shown to be susceptible to livestock grazing and/or browsing.

Species	Primary Biotic Affinities in the Southwest
MAMMALS	
Didelphis virginiana, Virginia Opossum	Various warm temperate Biomes in Southwestern Arizona
?Mormoops megalophylla, Ghost-faced Bat	Riparian communities within Madrean Evergreen in Southwest Texas
Idionycteris phyllotis, Allen's Big-eared Bat	Various warm and cold temperate Biomes
Nyctinomops femorosaccus, Pocketed Free-tailed Bat	Sonoran Desertscrub and adjacent warm temperate Biomes
Dasypus novemcinctus, Nine-banded Armadillo	Warm temperate Riparian communities along the Pecos River in West Texas
Sciurus aberti, Abert's Squirrel	Madrean and Rocky Mountain Montane Conifer Forests
Baiomys taylori, Northern Pygmy Mouse	Plains and Chihuahuan Semidesert Grasslands
Sigmodon hispidus, Hispid Cotton Rat	Chihuahuan Semidesert Grassland and various Riparian communities
?Sigmodon sulviventer, Tawny-bellied Cotton Rat	Madrean Evergreen Woodland and Chihuahuan Semidesert Grassland
Sigmodon ochrognathus, Yellow-nosed Cotton Rat	Madrean Evergreen Woodland Savanna and Montane Meadow Grassland
Microtus mexicanus, Mexican Vole	Meadow and Grassland areas within Madrean, Rocky Mountain and Great Basin Montane Biomes
Canis latrans, Coyote	All, or nearly all, biomes
? Vulpes vulpes, Red Fox	Rocky Mountain Alpine Tundra and Subalpine Conifer Forest; may now be extending its range into Plains and Great Basin Grasslands and other Biomes
Nasua narica, White-nosed Coati	Madrean Evergreen Woodland
Conepatus mesoleucus, Common Hog-nosed Skunk	Various warm temperate Biomes
Tayassu tajacu, Collared Peccary	Sonoran Desertscrub and adjacent warm temperate Biomes
Cervus elaphus, Elk	Rocky Mountain Montane Forest and adjacent Meadows
Bos bison, Bison	Plains and Great Basin Grasslands within and outside of historical range
Odocoileus hemionus, Mule Deer	Nearly all Biomes having sufficient cover and not occupied by *O. virginianus*

Table 3. Fifty-five species of terrestrial mammals and birds that appear to have increased their breeding distributions in the American Southwest since 1890.

1. Range expansion possibly influenced by the provision of feeding stations.
2. Some, but not all, range expansions are due to introductions.
3. Despite what appears to be a general increase in distribution, at least one race (S. *f. goldmani)* of this species is believed to have been extirpated in the Southwest.
4. Populations of this species have continued to increase in distribution since being reintroduced (and in some cases introduced) after 1912.

Species	Primary Biotic Affinities in the Southwest
BIRDS	
Coragyps atratus, Black Vulture	Sonoran Desertscrub
Ictinia mississippiensis, Mississippi Kite	Riparian Deciduous Forest within Sonoran Desertscrub
Elanus leucurus, White-tailed Kite	Riparian Deciduous Forest within Chihuahuan Semidesert Grassland
Parabuteo unicinctus, Harris Hawk	Sonoran Desertscrub (Arizona upland division); Mohave Desertscrub; Mesquite and other dense vegetation within Chihuahuan Desertscrub
Scardasella inca, Inca Dove	Urban areas within Sonoran Desertscrub
Zenaida asiatica, White-winged Dove	Sonoran Desertscrub and adjacent warm-temperate Biomes including residential areas
?Chaetura pelagica, Chimney Swift	Urban and residential areas
?Calothorax lucifer, Lucifer Hummingbird	Riparian communities within Madrean Evergreen Woodland Savanna
Calypte anna, Anna's Hummingbird	Urban areas within Sonoran Desertscrub
?Amazilia beryllina, Berylline Hummingbird	Riparian communities within Madrean Evergreen Woodland
Amazilia violiceps, Violet-crowned Hummingbird	Riparian communities within Madrean Evergreen Woodland
Trogon elegans, Elegant Trogon	Riparian communities within Madrean Evergreen Woodland
Euplilotus neoxenus, Eared Trogon	Riparian communities within Madrean Evergreen Woodland
Dendrocopos pubescens, Downy Woodpecker	Deciduous trees within Rocky Mountain Subalpine and Montane Forests; Riparian Deciduous Forest
Tyrannus crassirostris, Thick-billed Kingbird	Riparian Deciduous Forests within Chihuahuan Semidesert Grassland and Sonoran Desertscrub
Tyrannus melancholicus, Tropical Kingbird	Riparian deciduous woodlands within Chihuahuan Semidesert Grassland and Sonoran Desertscrub
Cyanocitta cristata, Blue Jay	Riparian deciduous trees and residential areas

Table 3 (Continued). Fifty-five species of terrestrial mammals and birds that appear to have increased their breeding distributions in the American Southwest since 1890.

1. Range expansion possibly influenced by the provision of feeding stations.
2. Some, but not all, range expansions are due to introductions.
3. Despite what appears to be a general increase in distribution, at least one race (S. *f. goldmani)* of this species is believed to have been extirpated in the Southwest.
4. Populations of this species have continued to increase in distribution since being reintroduced (and in some cases introduced) after 1912.

Species	Primary Biotic Affinities in the Southwest
Parus atricapillus, Black-capped Chickadee	Rocky Mountain Subalpine and Montane Conifer Forests; cold temperate Riparian Deciduous Forest
Toxostoma bendirei, Bendire Thrasher	Sonoran Desertscrub, Chihuahuan Desertscrub, Chihuahuan Semidesert Grassland
Sialia sialis, Eastern Bluebird	Riparian Deciduous Woodland, Madrean Evergreen Woodland
Heliminthophila luciae, Lucy Warbler	Mesquite communities within Sonoran Desertscrub and various warm temperate Riparian Biomes
Cardellina rubrifrons, Red-faced Warbler	Madrean Evergreen Forest and Woodland
Cardinalis cardinalis, Cardinal	Riparian communities within Sonoran Desertscrub (Arizona upland subdivision)
Cardinalis sinuatus, Pyrrhuloxia	Denser communities within Sonoran and Chihuahuan Desertscrub
Piranga bidentata, Flame-colored Tanager	Riparian communities within Madrean Evergreen Woodland
Icterus spurius, Orchard Oriole	Riparian Deciduous Woodlands and residential areas in Southeast New Mexico
Icterus cucullatus, Hooded Oriole	Tropical and warm temperate Riparian Deciduous Forests within Sonoran, Chihuahuan and Mohave Biomes
Quiscalus mexicana, Great-tailed Grackle	Urban and cultivated lands within Sonoran Desertscrub and various warm temperate and cold temperate Biomes
Quiscalus quiscula, Common Grackle	Urban and cultivated lands within various cold temperate Biomes
Molothrus ater, Brown-headed Cowbird	Ranch yards, irrigated areas and Riparian areas from tropical to cold temperate Biomes
Molothrus aeneus, Bronzed Cowbird	Ranch yards, irrigated areas and Riparian communities within Chihuahuan semidesert

Table 3 (Continued). Fifty-five species of terrestrial mammals and birds that appear to have increased their breeding distributions in the American Southwest since 1890.

1. Range expansion possibly influenced by the provision of feeding stations.
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4. Populations of this species have continued to increase in distribution since being reintroduced (and in

Species	Primary Biotic Affinities in the Southwest
MAMMALS	
Scirus niger, Eastern Fox Squirrel	Riparian Deciduous Forests, Orchards and residential Parks within Chihuahuan and Sonoran Biomes
Rattus rattus, Black Rat [1]	In and around human habitations within Chihuahuan Semidesert Grassland, Chihuahuan Desertscrub and Sonoran Desertscrub
Rattus norvegicus, Norway Rat	In and around human habitations within a variety of Biomes
Mus musculus, House Mouse	In and around human habitations; Chihuahuan Semidesert Grassland, Plains Grassland and Riparian communities within several biomes
Camelops spp., Dromedary and Bactrian Camels	Mohave and Sonoran Desertscrubs
Equus asinus, Feral Ass	Sonoran and Mohave Desertscrubs; Chihuahuan Semidesert Grassland, Great Basin Desertscrub and Great Basin Conifer Woodland
Equus caballus, Feral Horse	Chihuahuan Semidesert Grassland, Sonoran Desertscrub, Interior Chaparral, Great Basin Conifer Woodland and possible other Biomes
Ammotragus lervia, Barbary Sheep [1]	Rugged areas within Plains, Chihuahuan and Great Basin
Oryx gazella, Gemsbok	Chihuahuan Semidesert Grassland and Chihuahuan Desertscrub
Capra hircus, Goat [1]	Sonoran Desertscrub, Chihuahuan Semidesert Grassland, Interior Chaparral
Capra ibex, Ibex	Interior chaparral, Chihuahuan Semidesert Grassland, Great Basin Scrubland and possibly other Biomes
Sus scrofa, Feral Pig	Madrean Evergreen Woodland
BIRDS	
Alectoris chukar, Chukar	Great Basin Desertscrub and Grassland
Phasianus colchicus, Pheasant	Agricultural areas within various warm temperate and cold temperate biomes
Lophortyx californicus, California Quail	Riparian scrubland within Plains Grassland
Columba livia, Rock Dove	In and around human habitations in various biomes.
Sturnus, vulgaris, Starling	In and around human habitations in various biomes.
Passer domesticus, House Sparrow	In and around human habitations in various biomes.

Table 4. Exotic species of terrestrial mammals and birds which became established in the American Southwest between 1890 and 1990.

1. Present status unknown; may now be absent from the Southwest

Alpine Tundra	Forests and Woodlands	Scrublands
Lagopus leucurus	*Tamius minimus* *Odocoileus virginianus* *Buteo nitidus* *Meleagris gallopavo* [2, 3] *Melanerpes erythrocephalus* *Tyrannus tyrannus* *?Vireo vicinior* *?Passerina ciris* *Coccthraustes vespertinus*	*Epidonax fulvifrons* *Glaucidium brasileanum*
Grasslands (includes Meadows and Savanna)	**Desertlands**	**Residential Areas and Farmlands**
Lepus alleni *Spermophilus tridecemliniatus* *Cynomys ludovicianus* [2] *Cynomys gunnisoni* [2] *Crategeomys castanops* *Microtus pennsylvanicus* *Sigmodon arizonae* *Zapus hudsonius* *Mustela nigripes* [2] *Antilocapra americana* *Cervus elaphus* [3] *Bos bison* [3] *Buteo regalis* *Falco femoralis* *Tympanuchus pallidicinctus* *Centrocercus urophasianus* *Pediocetes phasianellus* *Callipepla squamata* *Colinus virginianus* *Cyrtonyx montezumae* *Ammodramus savannarum* *Aimophila carpalis* *Aimophila botterii*	*Vulpes velox* [2] *Ovis canadensis* [2] *Caracara cherwayi*	*Columbina passerina*

Table 5. Formation-type affinities of 39 terrestrial mammals and birds that have been extirpated or experienced range reduction in the American Southwest since 1890 [1]

1. *Large predators excepted.*
2. *Shown to be susceptible to diseases transmitted by introduced animals.*
3. *Now successfully introduced to both former and non-native habitats.*

Great Basin (N NW)	**Rocky Mountain (N. NE)**	**Plains (NE E)**
Cynomys gunnisoni	*Tamlas mlnlmus*	*Spermophilus tridecemliniatus*
Mustela nigripes [2]	*Microtus pennsylvanicus*	*Cynomys ludovicianus* [2]
Centrocercus urophasianus	*Zapus hudsonius*	*Crategeomys castanops*
Pediocetes phasianellus	*Lagopus leucurus*	*Bos bison* [4]
Buteo regalis	*Coccothraustes vespertinus*	*Tympanuchus pallidicinctus*
		Colinus virginianus [3]
		Vireo vicinior
		Ammodramus savannarum
Southeastern (E)	**Tamaulipan (E. SE)**	**Chihuahuan (SE. S)**
Odocoileus virginanus	*Falco femoralis*	*Callipepla squamata*
Meleagris gallopavo		*Aimophila botterii*
Melanerpes erythrocephalus		
Tyrannus tyrannus		
Passerina ciris		
Madrean (S)	**Sonoran/Sinaloan (S. SW)**	**Widely Distributed Within Southwest**
Odocoileus virginianus [3]	*Lepus alleni*	*Vulpes velox*
Meleagris gallopavo [2,3,4]	*Sigmodon arizonae*	*Ovis canadensis*
Cyrtonyx montezumae	*Buteo nitidus*	
Epidonax fulvifrons	*Caracara cheriway*	
	Colinus virginianus	
	Columbina passerina	
	Glaucidium brasilianum	
	Aimophila carpalis	

Table 6. Principal biotic affinities and direction of biogeographic center for 39 species of terrestrial mammals and birds that have been extirpated or experienced range reductions in the American Southwest since 1890. [1]

1. Large predators excepted.
2. Shown to be susceptible to diseases transmitted by introduced animals.
3. Southwest populations having more than one primary biotic affinity.
4. Successfully introduced to former and non-native habitats after 1890.

Alpine Tundra	**Forests and Woodlands**	**Scrublands**
None	*Didelphis virginianus*	*Tayassu tajacu*
	?Mormoops megalophylla	*Odocoileus hemionus*
	Idionycteris phyllotis	*Parabuteo unicinctus*
	Dasypus novemcinctus	*Zenaida asiatica*
	Sciurus aberti [2]	*Heliminthophilia luciae*
	Sigmodon fulviventer [3]	*Cardinialis cardinalis*
	Sigmodon ochrognathus	*Cardinalis sinuatus*
	Nasua narica	
	Conepatus mesoleucus	
	Cervis elaphus [4]	
	Ictinia mississippiensis	
	Caprilmulgus ridgwayi	
	?Calothorax lucifer [1]	
	?Amazilia beryllina [1]	
	Amazilia violiceps	
	Trogon elegans	
	Euptilotus neoxenus	
	Dendrocopos pubescens	
	Tyrannus crassirostris	
	Tyrannus melancholicus	
	Cyanocitta cristata	
	Parus atricappillus	
	Sialia sialis	
	Cardellina rubrifrons	
	Piranga bidentata	
	Icterus spurius	
	Icterus culcullatus	
	Passerina cyanea	
	Passerina versicolor	
Grasslands	**Desertlands**	**Residential Areas & Farmlands**
Baiomys taylori	*Nyctinomops femorosaccus*	*Scardafella inca*
Sigmodon hispidus	*Coragyps atratus*	*Chaetura pelagica*
Microtus mexicanus	*Toxostoma bendirei*	**Two or More Formation-Types**
Aimophila quinquestriata	*Calypte anna* [1]	*Canis latrans*
Bos bison [4]	*Quiscalus quiscula*	*Vulpes vulpes*
Elanus leucurus	*Molothrus ater*	
	Molothrus aeneus	

Table 7. Primary Formation-type affinity of 55 terrestrial mammals and birds breeding in the American Southwest and that have experienced range expansions since 1890.

1. Range expansion possibly influenced by the provision of feeding stations.
2. Some, but not all range expansions are due to introductions.
3. Despite what appears to be a general increase in distribution, one race of this species, *S. f. goldmani*, is believed to have become extinct.
4. Populations of this species have continued to increase in distribution since being reintroduced or transplanted after 1912.

Great Basin	**Rocky Mountain**	**Plains**
(N NW)	**(N. NE)**	**(NE. E)**
None	*Vulpes vulpes*	*Bos bison*
	Cervus elaphus	
	Dendrocopos pubescens [1]	
	Parus atricapillus [1]	
Southeastern	**Tamaulipan**	**Chihuahuan**
(E)	**(E. SE)**	**(SE. S)**
Didelphis virginiana [1]	*Dasypus novemcinctus*	*Baiomys taylori*
Ictinia mississippiensis	*?Sigmodon hispidus*	
?Chaetura pelagica	*Sigmodon fulviventer*	
Cyanocitta cristata	*Aimophila cassinii*	
Sialia sialis		
Icterus spurius		
Quiscalus quiscula		
Passerina cyanea		
Madrean	**Sonoran/Sinaloan**	**Californian**
(S)	**(S, SW)**	**(W)**
?Mormoops megalophylla	*Didelphis virginiana* [1]	*Elanus leucurus*
Idionycteris phyllotis	*Nyctinomops femorosaccus*	*Calypte anna*
Sciurus aberti	*Tayassu rajacu*	
Sigmodon ochrognathus	*Coragyps atratus*	
Microtus mexicanus	*Parabuteo unicinctus*	
Nasua narica	*Scardafella inca*	
Conepatus mesoleucus	*Zenaida asiatica*	
Calothorax lucifer	*Caprilmulgus ridgwayi*	
?Amazilia beryllina	*Tyrannus crassirostris*	
Amazilia violiceps	*Tyrannus melancholicus*	
Trogon elegans	*Toxostoma bendirei*	
Euptilotus neoxenus	*Heliminthophila luciae*	
Cardellina rubifrons	*Cardinalis cardinalis*	
Piranga bidentata	*Quiscalus mexicana*	
Aimophila quinquestriata	*Molothrus aeneus*	
	Passerina versicolor	
Centered or Widely Distributed Within the Southwest		
Canis latrans		
Odocoileus hemionus		
Cardinalis sinuatus		
Icterus cucullatus		
Molothrus ater		

Table 8. Principal biotic affinities and direction of biogeographic center for 55 species of terrestrial mammals and birds that have expanded their range in the American Southwest since 1890.

1. Advancing in more than one direction

Herpetology of the Sulphur Springs Valley, Cochise County, Arizona

Philip C. Rosen[1], Shawn S. Sartorius[1], Cecil R. Schwalbe[2], Peter A. Holm[1], and Charles H. Lowe[2]

ABSTRACT

The valleys of southeastern Arizona exemplify the biological diversity of the desert grassland. Among them, the Sulphur Springs Valley has especially significant amphibian and turtle populations, at least two of which (plains leopard frog and yellow mud turtle) are presently in danger of extirpation. It has one remaining key Chiricahua leopard frog population, but has already lost other populations of this threatened species.

Based on our work 1993-6 and earlier, and on museum records, we present an annotated checklist of the 61 species (11 frogs and toads, 1 salamander, 3 turtles, 21 lizards, and 25 snakes) confirmed from the valley. Based on habitat use and geographic distribution, this fauna has a core of (Chihuahuan) Desert Grassland taxa (many of which also occupy plains grassland and Chihuahuan desertscrub), and a smaller number of widespread North American Desert species. Sonoran Desert species are either rare or restricted to low arid slopes, and Madrean Woodland species enter the valley only peripherally.

Long utilized for farming and ranching, the Sulphur Springs Valley now faces suburbanization and increasing traffic. This could rapidly close its open spaces and eliminate the potential for native ecosystem restoration. This is so even though the herpetofauna is still robust--except for aquatic species and the massasauga. We recommend a conservation program that includes land acquisition, cooperative work with landholders, state protection, and additional survey and research as needed.

INTRODUCTION

The Sulphur Springs Valley (SSV) presents the herpetofauna of the desert grassland, including many characteristic species and subspecies, ranging widely over a large valley area. We focus on this valley for two reasons. First, it has heavy and increasing human impact, and second, it supports a diversity of wetland reptiles and has extensive amphibian populations, including declining species. We summarize our field observations, a national search of museum records, and discuss eco- and

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biogeography of the herpetofauna. We conclude with a summary of key aspects of herpetological conservation biology.

It has been suggested that the desert grassland in SE Arizona and nearby areas may have a characteristic herpetofauna (Parmenter and Van Devender, 1995), or that it is a filter barrier between biomes (Morafka, 1977). The desert grassland may also be envisioned as co-extensive with the Chihuahuan Desert (Schmutz *et al.*, 1992), although Morafka (1977) treats it as an ecotone with strongest ties to Chihuahuan (desert) and Kansan (plains grassland) biogeographic provinces. Parmenter and Van Devender (1995) noted taxonomic differentiation to only the subspecific level (except for the recently derived parthenogenetic species, the desert grassland whiptail), as expected for a recently derived biome (Van Devender, 1995). Perhaps there is a more unique component of this system, one involving arid-adapted species of the southern and western plains and of grassy aspects of the Chihuahuan Desert. If so, and after our limited geographic study we think so, then the desert grassland herpetofauna is indeed unique and diverse, and moreover, this area is an important evolutionary arena for herpetofauna.

The grassland biome, compared to woodland or forest, is relatively recent in origin (although older than desert), perhaps of mid-Cenozoic vintage (Van Devender, 1995). In SE Arizona, desert grassland has been continuously present for perhaps 8,000 or 9,000 years, since the last pluvial (Martin, 1963), at which time woodland and forest flora descended at least to Willcox Playa. Over glacial-interglacial cycles in the Pleistocene, these biotas have presumably waxed and waned repeatedly at any given locale.

Environment of the Chiricahua region desert grasslands.

The grasslands in Cochise County are a mosaic of desert grassland proper (with dominance of arid-adapted grasses in their ecological metropolis), scrub-invaded grasslands with much mesquite and burroweed (*Isocoma tenuisectus*), Chihuahuan desertscrub, and sites with mixed thornscrub and perennial grass. Many of the grasslands, especially the scrub-invaded ones, are co-dominated by the introduced Lehmann's lovegrass (*Eragrostis lehmanniana*).

The SSV is the area from Douglas to Fort Grant, and encircled by the Galiuro, Santa Teresa, Pinaleño, Chiricahua, Dos Cabezas, Dragoon, Mule, Pedrogosa, and Perilla Mountains (Fig. 1). It continues slightly farther south in Mexico, to the Sierras Anibacichi and Ceniza and Cerro Cabullona, but we did not work there. It is a large valley, about 190 long x 25-40 km wide. Elevations range from 4,000-4,300 ft (1,219-1,311 m) in the flats to 4,500-5,200 ft (1,372-1,585 m) at the base of the rock slopes.

The SSV has a well developed slope gradient. There are rock slopes supporting juniper or mesquite savannah, grassland, grassland-shrub, thornscrub, or desertscrub. Immediately below the rock slopes, uppermost bajadas (less rocky and steep) may support similar vegetation, before giving way to middle bajadas that support either Chihuahuan desertscrub, plains grassland, or mesquite-burroweed scrub. Lower bajadas are still slightly sloping but have finer and denser soils, and typically have more mesquite and burroweed, and often much grass and soaptree yucca (*Yucca elata*). We include all of these environments in this treatment of the SSV.

Most characteristic of the SSV is the broad level floor extending at a distance from Whitewater Draw in the south and from Willcox Playa in the north. The southern area supports a distinctive tobosa (*Hilaria mutica*)-dominated desert grassland flora, extending from McNeal to about 3 mi north of Douglas. East of this is a classic swath of Chihuahuan desertscrub on the bajada, grading eastward into thornscrub-grassland around the Leslie Canyon riparian gallery forest. The valley floor near Douglas, below the tobosa patch, supports a diverse, medium-tall scrub of mesquite and other dry tropic shrub-trees, yucca, agave, and mixed cactus, with Chihuahuan desertscrub in places.

To the north, the saline flats around Willcox Playa support a grassland, dominated by alkali sacaton (*S. wrightii*) and saltgrass (*Distichlis stricta*), which is thoroughly invaded by mesquite-dominated scrub except in the NE quadrant. Mesquite scrub extends up the Dragoon bajada to the west, while a bajada grassland extends east from the playa to mixed thornscrub, or to Madrean woodland, at the Dos Cabezas or Chiricahua Mountain bases respectively. The valley north of Willcox is primarily agricultural, and was little surveyed by us.

The Sulphur and Squaretop Hills dominate the center of the SSV, which is occupied by scrub and introduced grasses in most areas. South of this central area, the valley floor is extensively agricultural to Elfrida and even southwest of McNeal near Whitewater Draw. Martin (1963) presents an excellent description of vegetation and landform in the southern part of the valley.

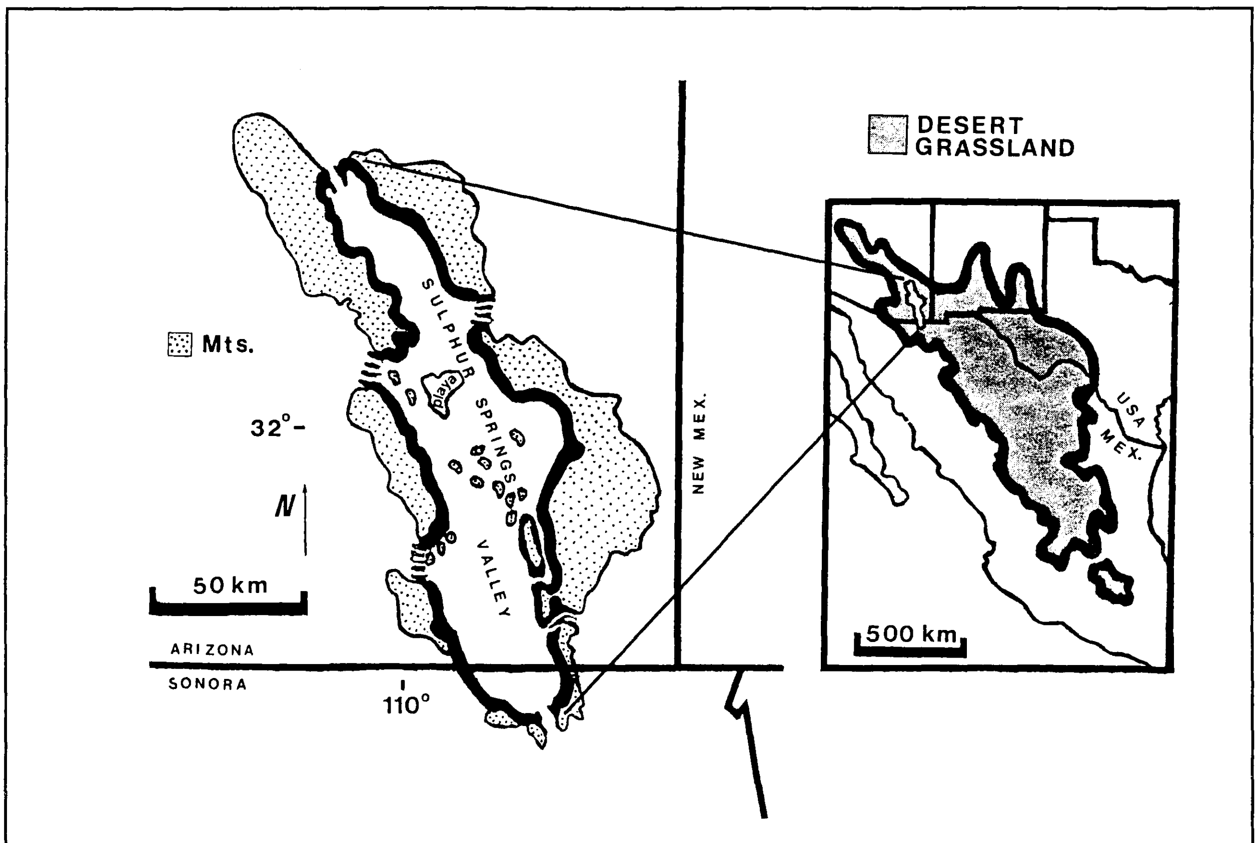

Figure 1 Map of the study area, Sulphur Springs Valley (left) with surrounding mountains shown, and of the desert grassland (right, following Schmutz et al., 1992), showing the location of the study area. Additional descriptions are given in the text.

Natural perennial waters in SE Arizona grasslands are primarily valley bottom springs; mountain streams submerge before entering the valleys, except during floods. The San Bernardino, San Pedro, Santa Cruz, and Babacomari Rivers, and Cienega and Arivaca Creeks (and formerly the San Simon River) rise on grassland floors. Whitewater Draw rose in grassland as a partly permanent stream (Hendrickson and Minckley, 1985), perhaps largely drying during less rainy eras. The Sulphur Springs probably had the least perennial water of any SE Arizona valley, save the Avra-Altar on the Sonoran Desert edge. Today, major valley spring systems are modified by impoundment and by down-cutting of streams into formerly marshy cienegas. Man-made stock ponds dot the landscape, and many sites are supplied with wind-powered wells, maintaining unnaturally constant water levels. Water is more widespread on the landscape than originally, but there is far less natural wetland habitat.

Checklist of the Amphibians and Reptiles of the Sulphur Springs Valley, Cochise County, Arizona

The primary focus of this checklist is to (1) present an overview of a desert grassland fauna, (2) outline community structure and biogeography in relationship to habitat, and (3) identify key issues for conservation or management. We worked extensively in the valley for three years, 1993-1996. In addition, we include data from previous work in the valley, principally during the 1980's and mid-1970's. The 1990's field work produced 701 observations (195 for anurans, 8 for salamanders, 45 for turtles, 114 for lizards, 338 for snakes), with each observation being an independent locality record, sometimes of numerous individuals per species. Finally, we made inquiries of many museums, and incorporated the resultant information for 2640 specimen records (681 anurans, 2 salamanders, 60 turtles, 1315 lizards, 582 snakes) into this report. The work reported here is not exhaustive--much remains to be learned, even at the survey level, and even in areas we worked intensively.

The currently known species total for SSV includes 61 species (11 frogs and toads, 1 salamander, 3 turtles, 21 lizards, and 25 snakes; see Table 1): we observed 53 during the 1990's. There will undoubtedly be additions as more data become available. In evaluating occurrence and abundance of species, we have relied on the data at hand, and information in Lowe and Johnson (1976), Lowe and Zweifel (1992), and Nickerson and Mays (1969). The common names used are those for the species as a whole; trinomials (subspecific designations) are given only for regionally endemic forms.

Amphibians.

Sonoran Desert Toad--*Bufo alvarius*. Abundant in Chihuahuan desertscrub-alkali sacaton in Malpai lands of the lower San Bernardino Valley, in Guadalupe Canyon, and as far north as Mormon Tank along Black Draw, but rare in SSV.

GREAT PLAINS TOAD--*Bufo cognatus*. Abundant throughout the SSV, especially on the bajada east and north of Sunizona. Along with *Scaphiopus couchii* and *S. multiplicatus*, it is the most widely and abundantly observed amphibian in the valley.

GREEN TOAD--*Bufo debilis*. Seen breeding in large numbers in 1989 and 1993 in shallow grassland temporary ponds in the south-central SSV, and in lower abundance in surrounding desert at slightly higher elevations.

RED-SPOTTED TOAD--*Bufo punctatus*. In desert grassland on lower slopes; not seen on the valley floor or bajadas.

WOODHOUSE TOAD--*Bufo woodhousii australis* (Southwestern Woodhouse Toad). Widespread but nowhere seen in numbers in the valley.

PLAINS SPADEFOOT--*Scaphiopus bombifrons*. Seen in some abundance in northern sections of the valley, south to Elfrida, but not to McNeal. Major breeding sites found in 1993 were identical to those vouchered in the 1950's and 1960's.

COUCH'S SPADEFOOT--*Scaphiopus couchii*. Abundant in lowland areas throughout much of the SSV and elsewhere in Cochise Co.. In syntopy with other spadefoots it was the least abundant one. In the desertified vegetation north of Douglas on Leslie Canyon Road, it was the dominant, and was increasingly abundant southward on Central Highway.

SOUTHERN SPADEFOOT--*Scaphiopus multiplicatus*. Abundant over a wide area of the SSV, across a spectrum of habitats, including lower madrean woodland in Pinery Canyon.

PLAINS LEOPARD FROG--*Rana blairi*. Occurs in the SSV more than 300 km west of the nearest species population. In 1974 Frost and Bagnara (1977) found it, as today, on the flats, but also in association with lower montane streams. The period of abundance of aquatic amphibians in the early-mid 1970's may represent a short-term climatic maximum, during wetter years, at a time of great success of native ranid frogs in man-made waters. There were subsequent extirpations caused by introduced species, as seen also in Colorado (Hammerson, 1982). Today the plains leopard frog is only at four localities, all on the valley floor, and all with high spatial and temporal heterogeneity that allows co-existence with introduced, permanent-water vertebrate species. For example, The Lakes on lower Whitewater Draw may cover an area of over 1 km^2 during summer high water; they may also go nearly dry, apparently constraining the population sizes of introduced yellow bullheads (*Ameiurus natalis*) and bullfrogs. The plains leopard frog survives by breeding during early July rains and transforming prior to pond contraction or drying.

CHIRICAHUA LEOPARD FROG--*Rana chiricahuensis*. Formerly at many localities in the valley (Frost and Bagnara, 1977; Clarkson and Rorabaugh, 1989), but now extirpated except at Leslie Canyon National Wildlife Refuge. It is also in remnant populations in the Chiricahua, Dragoon, and Galiuro Mountains (M. Sredl, pers. comm.). Localities formerly occupied on the valley floor either went dry after the mid-1980's, or were occupied by exotic species that usually exclude the Chiricahua leopard frog.

BULLFROG--*Rana catesbeiana*. An introduced species, seen by us in the Whitewater Draw drainage, and at Sunsites. It appeared at West Turkey Creek in the early 1980's and rapidly eliminated the native leopard frogs throughout the system there (J. Austin, pers. comm.). We also have museum records near Kansas Settlement in the 1970's and late 1980's, and presume it is still there. This species will probably continue to spread in the Chiricahua region, unless a concerted management effort is taken.

TIGER SALAMANDER--*Ambystoma tigrinum mavortium* (Barred Tiger Salamander). Another exotic expanding its distribution in the valley area. Greatest abundances were at Willcox sewage

Figure 2 Plains leopard frog from the Sulphur Springs Valley. The SSV population is more than 300 km from the nearest species population, and is currently restricted to four localities. Photo by Cecil Schwalbe.

lagoons, power plant ponds southwest of Willcox Playa, and below Chiricahua National Monument. However, we saw it on roads further south. Such an obvious abundance could not have been overlooked prior to the 1960's and 1970's, tending to confirm the exotic origin of the Cochise County population.

Reptiles.

WESTERN BOX TURTLE--*Terrapene ornata luteola* (Desert Box Turtle). Seen in numbers in several areas of the SSV, which, together with the San Bernardino Valley, is the species core in Arizona. During routine summer field work we often saw 2-3 per day. They were found in far greater numbers, especially at the hills east of Pearce, prior to severe highway mortality in the 1960's-1980's. Box turtles are not common north of Sunsites. Although we didn't record them in Chihuahuan desertscrub in the SSV, they occur in and near sacaton bottoms in desertscrub at the lowest elevations of the San Bernardino Valley.

YELLOW MUD TURTLE--*Kinosternon f. flavescens* (Yellow Mud Turtle). Rare, and only seen in the flats of the lower valley (from Elfrida south). This attractive mud turtle is in danger of disappearing from the SSV. We also discovered this taxon in Graham Co., in thriving populations in the San Simon and Whitlock valleys, also on the valley floor. Appropriate wetland management may be required to prevent the extirpation of this subspecies from Arizona.

SONORAN MUD TURTLE--*Kinosternon sonoriense*. Rare in the valley, and known only from just south of McNeal to near Douglas. The presence of this turtle is consistent with historical reports of perennial flow in lower Whitewater Draw. In contrast, the yellow mud turtle thrives in ephemeral and fluctuating summer waters further up-drainage, just as observed for the plains leopard frog.

MADREAN ALLIGATOR LIZARD--*Elgaria kingii (=Gerrhonotus kingii)*. Only on the valley periphery. The Whitewater Draw riparian habitat may be too weakly developed to support this species in an arid valley. It is possible that microhabitat trampling by cattle, or the historical broad floods across the valley floor, contribute to its absence.

WESTERN BANDED GECKO--*Coleonyx variegatus*. Rare or uncommon in high Chihuahuan desertscrub, and possibly mesquite flats.

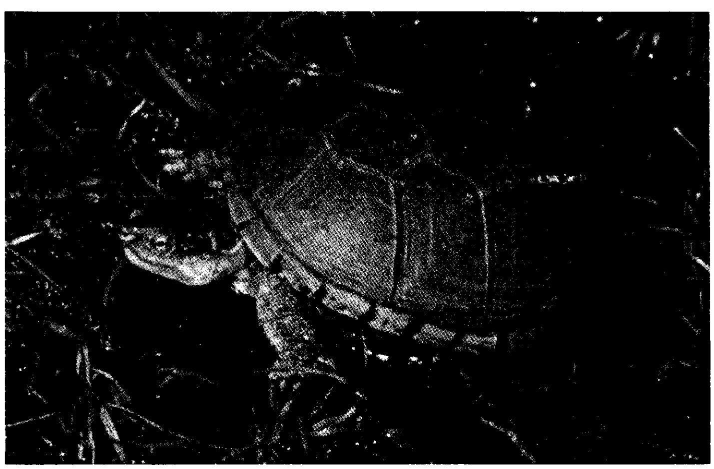

Figure 3 Yellow mud turtle from the Sulphur Springs Valley. The population is apparently declining, and the species is rare in the valley. This subspecies occurs as a western isolate in the Sulphur Springs Valley and adjoining San Simon-Whitlock Valleys, at the arid edge of its range. Photo by Cecil Schwalbe.

GILA MONSTER--*Heloderma suspectum*. Seen uncommonly on high desert bajadas and hills.

LESSER EARLESS LIZARD--*Holbrookia maculata*. Primarily a grassland lizard, this is one of four prominent lizards in the valley. It was seen on open patches of ground.

GREATER EARLESS LIZARD--*Cophosaurus texanus*. In a restricted band of habitat in southern Arizona--on the upper, desert bajadas (often on rocks in arroyos) and up into the lower mountain slopes in Madrean oak woodland. We have not verified it for the lowlands.

COMMON COLLARED LIZARD--*Crotaphytus collaris*. Probably on all of the rocky hills that are widely scattered in and around the valley, but infrequently seen by us in any locality during the past decade on the west side of the Chiricahuas.

LONG-NOSED LEOPARD LIZARD--*Gambelia wislizenii*. Well-known from tobosa and alkali sacaton habitats on the valley floor, but not seen often during our surveys.

TEXAS HORNED LIZARD--*Phrynosoma cornutum*. On the broad flats of the Sulphur Spring Valley floor, this species and the Mojave rattlesnake are the only members of their respective diverse genera; and both are quite frequently seen. The Texas horned lizard, however, is also in high Chihuahuan desertscrub, unlike the Mojave (which is replaced there by the western diamondback); but like the Mojave (again replaced, in low Chihuahuan desertscrub, by the diamondback), the Texas horned lizard tends to be replaced by the regal horned lizard at the lower grassland-desertscrub transition. The SSV is a showcase for such habitat partitioning, which is less striking in many other areas of SE Arizona.

SHORT-HORNED LIZARD--*Phrynosoma douglasii*. We saw this species locally in the margins of the valley.

ROUND-TAILED HORNED LIZARD--*Phrynosoma modestum*. Known in the region primarily from stony or rocky desert bajadas (Wade Sherbrooke, pers. comm.).

REGAL HORNED LIZARD--*Phrynosoma solare*. Only seen by us in the lower valley near Douglas. In the dense desertscrub (thornscrub) or semidesert grassland along Geronimo Trail, it is nearly as abundant as the Texas horned lizard, although neither is seen there frequently.

CLARK'S SPINY LIZARD--*Sceloporus clarkii*. An abundant riparian species, consistently present on rocky sites within and around the valley, and also abundant in montane oak environments. We have not found it in close sympatry with the desert spiny lizard in the Chiricahua region, and only rarely so elsewhere in Arizona.

DESERT SPINY LIZARD--*Sceloporus magister*. Uncommon in eastern Cochise Co.. We saw it only at three sites on the west and northwest fringes of Willcox Playa in mesquite-burroweed scrub-grassland, and at Hot Well Dunes.

EASTERN FENCE LIZARD--*Sceloporus undulatus consobrinus* (Southern Prairie Lizard). Perhaps the second most frequently seen lizard in the valley, where it lives on the ground near dense grass or scrub, on shrubs, and on and around, or under, human-made debris. Especially conspicuous at corrals and ruins. Also seen occasionally on rocks.

TREE LIZARD--*Urosaurus ornatus*. Widespread and abundant, arboreal and saxicolous, this is among the four most frequently observed lizards in the valley. It is on fence posts, corrals, and walls and buildings, especially ruins, on small trees, and on rocks and boulders at hilly sites.

SIDE-BLOTCHED LIZARD--*Uta stansburiana*. Not on the valley floor, but at least occasionally in the surrounding high Chihuahuan desertscrub. We only saw it southwest of Castle Dome (Pedrogosa Mountains), and at Hot Well Dunes.

GREAT PLAINS SKINK--*Eumeces obsoletus*. Abundant in some other grassland valleys in SE Arizona, its rarity in the Sulphur Springs is apparently real. It is usually seen on thornscrub-grassland slopes, and in less arid bajada grassland in the San Bernardino Valley; it is on low rocky slopes, and in lower montane canyons, including Leslie Canyon.

LITTLE STRIPED WHIPTAIL--*Cnemidophorus inornatus arizonae* (Arizona Whiptail). Described as *Cnemidophorus arizonae* based on an 1894 specimen from "Fairbank" (a generalized locality statement in those days [pers. obs.]), it was rediscovered by Wright and Lowe (1965), and still occurs, in a local population near Willcox, on the low ground surrounding the dry lake. It is a grassland species, here primarily in alkali sacaton and saltgrass. Like the massasauga, it probably underwent a range reduction after the terrific 19th-century overgrazing. Sites where Mitchell (1979) studied this species now support only the desert grassland whiptail. We found it within about 3 miles of Willcox in the 1990's, numerically predominant (5 to 1) over the desert grassland whiptail. Its range apparently continues to contract in response to invasion and growth of mesquite, with competition from the desert grassland whiptail.

"SONORAN SPOTTED" WHIPTAIL--*Cnemidophorus sonorae* sensu lato. This is an undescribed parthenospecies (John Wright, pers. comm.) that is widespread in SE Arizona on rolling grassland, encinal, and desert grassland. Mitchell (1979) collected it from the upper bajada of the Dos Cabezas, and we found it to be the only whiptail at Leslie Creek.

WESTERN WHIPTAIL--*Cnemidophorus tigris*. Our nearest record for this desert species is at Hot Well Dunes in sandy desertscrub. Mitchell (1979) reported it on the Dos Cabezas bajada southeast of Willcox.

DESERT GRASSLAND WHIPTAIL--*Cnemidophorus uniparens*. This unisexual (all-female, parthenogenetic) lizard is ubiquitous in the valley, and is the most conspicuous reptile in most areas of the valley floor and on most of the bajadas. It is the only whiptail over virtually the entire area, including in most tobosa and other grasslands.

GLOSSY SNAKE--*Arizona elegans*. Uncommon in the valley and elsewhere in Cochise Co.; probably has declined significantly over the past 3 decades. Most observations are from the mesquite region west of Willcox Playa that yielded other widespread desert forms.

RINGNECK SNAKE--*Diadophis punctatus*. Apparently absent except in the rocky periphery of the valley. Discussion under Madrean alligator lizard applies verbatim here.

GREEN RAT SNAKE--*Elaphe triaspis (= Senticolis triaspis)*. Rare in low canyons with riparian development. It is known to enter grassland environments at distance from such canyons (D. Parizek, pers. comm.), so we expect its occasional presence in the valley.

CHIHUAHUAN HOOK-NOSED SNAKE--*Gyalopion canum*. Rarely seen in SE Arizona, almost always on bajadas (in both grassland and desertscrub) or lower mountain slopes (in canyons and well up into oak woodland). Recorded in the valley from high bajada grassland near Chiricahua National Monument, and in the tobosa grassland area south of McNeal.

WESTERN HOGNOSE SNAKE--*Heterodon nasicus kennerlyi* (Mexican Hognose Snake). We found only road-killed hognose snakes, suggesting that their diurnal activity and love of warmth are costly under increasing automotive traffic in the valley. The SSV may be the ecological metropolis for this species in Arizona, as might be expected for a toad- and frog-eating snake. We saw them primarily in the vicinity of major anuran choruses, and most often during the brief temporary pond anuran breeding season.

NIGHT SNAKE--*Hypsiglena torquata*. Has the broadest ecological range of any Arizona reptile except the gopher snake; but not seen by us on grassland flats in the SSV.

COMMON KINGSNAKE--*Lampropeltis getula splendida*. At its ecological metropolis for Arizona in grasslands around the Chiricahuas, it vies with the Mojave rattler for most frequently seen snake in the SSV grasslands. It is present as the speckled-saddled subspecies, inaptly named "desert kingsnake"; we suggest "desert grassland kingsnake". West of Willcox Playa, the kingsnakes are intermediate between this and the western form, *L. g. californiae*.

SONORAN WHIPSNAKE--*Masticophis bilineatus*. A Madrean and riparian species that is in the valley periphery, often in abundance in lower canyons.

COACHWHIP--*Masticophis flagellum*. As for the gopher snake, not as common as expected in grassland flats. The valley population may be a blend of three subspecies.

GOPHER SNAKE (BULLSNAKE)--*Pituophis melanoleucus*. Our observations suggest (surprisingly, considering its broad niche, distribution, and frequent association with grasslands) that it is not very common in native grassland habitats on the valley floor.

LONG-NOSED SNAKE--*Rhinocheilus lecontei*. A desert-oriented species that is moderately abundant in the SSV. Those we observed were a bright red morph similar to *R. l. tesselatus*.

GRAHAM PATCH-NOSED SNAKE--*Salvadora grahamiae*. Primarily a montane species, abundant in the region, that may appear in bajada habitats with *Salvadora hexalepis*.

WESTERN PATCH-NOSED SNAKE--*Salvadora hexalepis*. Normally a habitat generalist in the desert, valley records are restricted to high on the bajada. We recorded it rarely in the SSV, possibly as a sampling artifact: it is abundant in low Chihuahuan desertscrub in the San Bernardino Valley, and elsewhere on grassy bajadas in SE Arizona.

GROUND SNAKE--*Sonora semiannulata*. This species, usually regarded as a habitat generalist, in southern Arizona is primarily in grassland, degraded desert grassland, and encinal (oak) grassland habitats. It is found, sometimes in abundance, only at a few grassland or encinal localities. Local demes in Arizona (except near Phoenix) of this polymorphic species tend to be monomorphic, and many demes present unique coloration details. Thus, this species shows strong local differentiation, and may be locally adapted. On southern Arizona uplands, snakes have red with black cross-banding. The three specimens we have examined from the SSV floor are brown or tan with a single reddish-purple mid-dorsal stripe, generally like those from other southern Arizona valley floors. Despite its poor showing during the relatively dry years of our work (as also for other small secretive snakes), it appears to be a strongly grassland-associated component of the regional herpetofauna.

SOUTHWESTERN BLACK-HEADED SNAKE--*Tantilla hobartsmithi*. The records are from west and northwest of Willcox, in an area with records for other widespread desert forms not seen elsewhere in the SSV.

PLAINS BLACK-HEADED SNAKE--*Tantilla nigriceps*. Thus far, no records for the southern portion of the valley.

BLACK-NECKED GARTER SNAKE--*Thamnophis cyrtopsis*. A canyon-dweller in Arizona that is also occasionally seen on valley floors. Surprisingly abundant around the Chiricahuas on bajadas at distance from rocky slopes. There is a large metapopulation in the Chiricahua Mountains that extends into Chihuahuan desertscrub and high grassland where we might otherwise expect the checkered garter snake.

CHECKERED GARTER SNAKE--*Thamnophis marcianus*. The only garter snake seen on the SSV floor, where it is abundant at most (probably all) sites with breeding populations of anurans, especially in the flats around Whitewater Draw.

LYRE SNAKE--*Trimorphodon biscutatus*. Usually rock-associated, in Cochise County it may be seen in Chihuahuan desertscrub many miles from rocky slopes. We found it in the Leslie Canyon riparian.

TEXAS BLIND SNAKE--*Leptotyphlops dulcis*. The most frequently-collected blind snake in SE Arizona.

WESTERN CORAL SNAKE--*Micruroides euryxanthus*. Mainly peripheral in the valley, though locally common at least in the high arid scrub near Dos Cabezas.

WESTERN DIAMONDBACK RATTLESNAKE--*Crotalus atrox*. Remarkably, not seen on the floor of the valley at all during 1993-1996, although museum records place it west and northwest of Willcox Playa on the valley floor, as for *B. alvarius*, *S. magister*, *T. hobartsmithi*, *A. elegans*, and *L. getula splendida X californiae*. Despite its absence from the valley floor, the diamondback was abundant in all regional Chihuahuan desertscrub environments we studied, as well as on the Dragoon bajada. It occurs on or near rocky hills within the valley. Despite the burgeoning abundance of the diamondback in recent decades (Mendelson and Jennings, 1992; Rosen *et al.*, 1996a), it has not invaded Mojave rattlesnake habitat in the SSV, and may even have contracted in habitat distribution. There may be a constriction of desert species populations in SE Arizona as the environment recovers from historic overgrazing. Species successful in highly xeric environments (the Mojave rattler, glossy snake, and possibly others) may decline (in relative or absolute terms) due to niche space contraction simultaneous with expansion of competitor populations.

BLACK-TAILED RATTLESNAKE--*Crotalus molossus*. An abundant montane and rock-dwelling species in SE Arizona that is at Leslie Canyon and may be on rocky hills in the valley.

MOJAVE RATTLESNAKE--*Crotalus scutulatus*. The most frequently seen snake in the valley. In the Sonoran Desert, this species broadly overlaps the western diamondback in macro- and micro-habitat, but in the SSV and much of the rest of SE Arizona there is sharp habitat partitioning. Perhaps co-existence in the Sonoran Desert reflects the marked xeroriparian-upland desertscrub differentiation within Sonoran Desert environments. Some SE Arizona grassland Mojaves look like prairie rattlers (*C. v. viridis)*, but all that we examined had key characters unmistakably identifying them as Mojaves.

MASSASAUGA--*Sistrurus catenatus edwardsi* (Desert Massasauga). This species was as far west as the Huachuca Mountains bajada in historic times, but now is virtually restricted to a few miles of habitat in the San Bernardino Valley (Andy Holycross, pers. comm.) above 5000' (1525m) elevation. Conversion of desert grassland from grassland to scrub under historic overgrazing is probably the cause of decline, and may be ongoing. The SSV population, known only from the tobosa area in the southern valley, seems to be vanishing. There is a voucher from as late as 1989, although we located none despite some directed searching. There is a possible sight record for the old Willcox dump (Clay May, pers. comm.). This is a species of great conservation concern in the valley.

Potential Species.

We regard the following taxa to be of possible (?) or probable (*) occurrence in the Sulphur Springs Valley. In the following cases listed taxa would enter the valley only peripherally: canyon treefrog (*Hyla arenicolor*,*), lowland leopard frog (*Rana yavapaiensis**), desert tortoise (*Gopherus agassizii*?), mountain skink (*Eumeces callicephalus*?), zebra-tailed lizard (*Callisaurus draconoides*?; seen at Hot Well Dunes), bunch-grass lizard (*Sceloporus scalaris*?), canyon spotted whiptail (*Cnemidophorus burti*?), Chihuahuan spotted whiptail (*C. exsanguis*?), additional undescribed "Sonoran spotted" whiptails (*C. sonorae* sensu lato*, including *flagellicaudus*), Sonoran mountain kingsnake (*Lampropeltis pyromelana**), milk snake (*Lampropeltis triangulum*?), striped whipsnake (*Masticophis taeniatus*?), Yaqui black-headed snake (*Tantilla yaquia**), Mexican garter snake (*Thamnophis eques*?), rock rattlesnake (*Crotalus lepidus*?), tiger rattlesnake (*C. tigris*?), and western rattlesnake (*C. viridis*?). The western blind snake (*Leptotyphlops humilis**) is highly secretive and hence poorly sampled, and may thus occur over some significant portion of the valley.

STRUCTURE AND BIOGEOGRAPHY OF THE HERPETOFAUNA

Species characteristically in Sonoran thornscrub, riparian gallery forest, or Madrean woodland are present only peripherally in the Sulphur Springs Valley: Sonoran whipsnake, black-tailed rattlesnake, Clark's spiny lizard, Sonoran spotted whiptail, green rat snake, Mexican garter snake, Chiricahua leopard frog, ringneck snake, Graham patch-nosed snake, Madrean alligator lizard, and short-horned lizard. The first 4 listed, however, are important in many Sonoran Desert rockpile assemblages, and are also abundant on low rocky sites at SSV. Further, the black-necked garter snake, which is important in the SSV, is prominent at Sonoran Desert springs (as well as in Madrean woodland). Similarly, Sonoran-Mojave Desert endemics in the SSV are rare or mostly restricted to upper bajadas and low, arid rock slopes: western coral snake, Gila monster, western banded gecko, regal horned lizard, and Sonoran Desert toad. Chihuahuan Desert endemics, primarily rock-dwelling reptiles, are absent from the SSV. In summary, on the SSV periphery, the herpetofauna of arid rocky habitats has a Sonoran cast.

Desert species within the SSV are wide-ranging across the North American warm deserts and associated semi-arid scrublands: western diamondback and Mojave rattlesnakes, coachwhip, western patch-nosed snake (sensu lato), gopher snake, glossy snake, long-nosed snake, common kingsnake, night snake, lyre snake, southwestern black-headed snake, western whiptail (sensu lato), leopard, collared, desert spiny, tree, and side-blotched lizards, red-spotted toad, and Couch's and southern spadefoots. Of this list, only the first 9 of the 11 snakes listed, the 2 spadefoot toads, and the leopard lizard and tree lizard, play significant roles in the SSV desert grassland assemblage.

The only arguably Chihuahuan desertscrub contribution to the SSV herpetofauna are the round-tailed horned lizard, greater earless lizard, and Chihuahuan hook-nosed snake. However, these 3 are not true desert species: they are also widespread and prominent in grassland habitats, and we interpret them as Chihuahuan desert grassland species that are relatively successful in the desert aspect of the desert grassland.

Few forms are endemic to the northern desert grassland that Morafka (1977) described as a filter barrier. These are the recently-derived parthenoforms, desert grassland whiptail and New Mexico whiptail (occurring east of the study region). There are endemic subspecies of little striped whiptail (*C. i. arizonae*), the western box turtle (*T. o. luteola*) and the massasauga (*S. c. edwardsi*). We suggest a broader concept of the desert grassland, as outlined in McClaran and Van Devender (1995) and Schmutz *et al.* (1992), is especially appropriate for the herpetofauna.

The core of the SSV herpetofauna, which includes the 4 endemics and 3 "Chihuahuan Desert" forms, listed above, is a large group of desert grassland species that centers on the Chihuahuan Desert region and the southern plains (especially from north central Texas, to east-central Mexico, and to SE Arizona--range maps in Conant and Collins, 1991; Morafka, 1977; and Stebbins, 1985). The key forms are: the green toad, Texas toad (*Bufo speciosus*, which occurs east of our region), checkered garter snake, plains black-headed snake, Texas blind snake, little striped whiptail, Texas horned lizard, and Great Plains skink; and characteristic subspecies of wide-ranging forms, desert grassland kingsnake (*L. g. splendida*), and southern prairie lizard (*S. undulatus consobrinus*). We associate the ground snake with this group, although it also ranges into the western deserts.

Species typically viewed as "Kansan" may be observed to be part of the Chihuahuan-centered, arid lands herpetofauna: yellow mud turtle, western hognose snake, lesser earless lizard, Great Plains toad, and plains spadefoot. By virtue of its adaptation to ephemeral water, the plains leopard frog may be adaptationally similar to this group, but it appears to be of eastern, rather than Chihuahuan origin. Others in this category may be the massasauga, western box turtle, and Woodhouse toad, although they are all subspecifically differentiated in the desert grassland region.

The desert grassland herpetofauna in the SSV has 4 apparently eastern species, 13 wide-ranging North American Desert generalists, and about 18 species of Chihuahuan affinity (all listed in the preceding five paragraphs). This herpetofauna bears marked structural similarity to that found with the bolson tortoise (*Gopherus flavomarginatus*) in the Bolson de Mapimi, 650 km to the southwest in the heart of the Chihuahuan Desert: Morafka and McCoy (1982) report 26 species there, of which 21 are in the SSV, and 3 of the 5 differing species have ecologically and phylogenetically similar species in the SSV. The herpetofauna of the Sulphur Springs Valley is that of a Chihuahuan bolson, with an arid rocky fringe occupied by primarily Sonoran, rather than Chihuahuan species.

CONSERVATION OF THE SULPHUR SPRINGS VALLEY HERPETOFAUNA

The most threatened parts of the SE Arizona herpetofauna are the aquatic and grassland assemblages. In the SSV, the aquatic species (see, e.g. Fig. 2) of greatest concern are also grassland associates, the plains leopard frog and yellow mud turtle. It is reasonable to focus on the grassland component as a whole, and explore ways that conservation in terrestrial, ephemeral water, and perennial water habitats may be combined.

The species of greatest concern, in order of priority for attention, with primary or potential threats or problems in parentheses, are (1) plains leopard frog (introduced species, habitat modification and destruction), (2) little striped whiptail (urban or suburban and agricultural encroachment, extremely localized distribution, grassland disappearance), (3) yellow mud turtle (habitat destruction, probable other unknown), (4) massasauga (unknown, possibly grassland degradation), (5) western box turtle (road mortality, possibly collecting), (6) green rat snake (possible over-collection), (7) western hognose snake (road mortality), (8) Chihuahuan hook-nosed snake (apparent rarity), (9) ground snake (potential damage to unique demes by collecting or trampling), (10) plains black-headed snake (current status unknown).

The following management recommendations may guide conservation work for the SSV (expanded discussion can be found in Rosen *et al.*, 1996b):

(I) PLAINS LEOPARD FROG. Develop easements and acquire habitat. List as endangered (i.e., "of special concern") for Arizona.

(II) LITTLE STRIPED WHIPTAIL. List the Arizona whiptail (*C. l. arizonae*) as threatened ("of special concern") for the state. More detailed study of distribution and ecology is required.

(III) YELLOW MUD TURTLE. State listing as threatened ("of special concern") for the subspecies *K. f. flavescens*. Distributional and ecological study is needed. Habitat conservation, through purchase and easements, at some sites with plains leopard frogs, is highly desirable.

(IV) MASSASAUGA. Further survey by road-driving, and research directed at identifying cause(s) of decline. Key grassland areas, especially extensive areas dominated by tobosa and other perennial desert grassland grasses, should be purchased or integrated into conservation plans. This aspect of habitat conservation could be physically connected in space with the recommended wetland conservation, in the southern half of the valley. These areas could be encompassed within a unified lower valley conservation area, or natural park.

(V) WESTERN BOX TURTLE, GREEN RAT SNAKE, WESTERN HOGNOSE SNAKE, CHIHUAHUAN HOOK-NOSED SNAKE, PLAINS BLACK-HEADED SNAKE. Encourage or support further study.

(VI) GROUND SNAKE. Southern Arizona populations should be evaluated for conservation (local distribution, genetic divergence); a statewide assessment should be made.

Generally, the herpetofauna of the Sulphur Springs Valley today remains strong, except for aquatic species and the massasauga. Quantitative road-driving at night yielded 1.4 live plus 1.5 dead snakes/100 km. The major threats are from human population pressure and traffic. Conservation of vulnerable species, and of this fine environment for us to enjoy, will require saving substantial areas as a viable ecosystem.

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Species			Habitat					Number of Records	
	rs	bd	bm	bg	gf	mf	ag	field	museum
Sonoran Desert Toad	-?	-?	-?	-?	-?	r	r	2	4
Great Plains Toad	u	c	c	c	c	c	c	33	86
Green Toad	u?	c	c?	-?	a	a	-?	20	187
Red-spotted Toad	u	-	-	-	-	-	-	0	1
Woodhouse Toad	-	-?	u	-?	r	u	u	9	15
Plains Spadefoot	-	-	-?	-?	a	a	c	10	208
Couch's Spadefoot	-	c	c	c	u	c	c	69	47
Southern Spadefoot	c	u?	c	a	a	a	c	36	63
Plains Leopard Frog	-	-	-	-	r	r	r	5	45
Chiricahua Leopard Frog	r	-	-	-	-	-	-	5	23
Bullfrog	-	-	u	-?	u	c	c	6	2
Tiger Salamander	c?	-?	u?	c?	c	c?	u?	8	2
Western Box Turtle	u	r	c	a	a	a	u	42	54
Yellow Mud Turtle	-	-	-	-	r	r	r	2	4
Sonoran Mud Turtle	-	-	-	-	r	-?	-?	1	2
Madrean Alligator Lizard	u	-	-	-	-	-	-	2	1
Western Banded Gecko	u	-?	-	-	-	-?	-	1	9
Gila Monster	c	-?	u	-	-	-	-	2	1
Lesser Earless Lizard	-?	r?	-?	c	a	c	-?	9	89
Greater Earless Lizard	u	-	-	u	-	-	-	2	74
Common Collared Lizard	u	-	-	-	-	-	-	2	7
Long-nosed Leopard Lizard	-	-?	u?	-?	u	u	-?	2	22
Texas Horned Lizard	r	u	c?	c	a	a	-?	13	60
Short-horned Lizard	u	-	-	c	-	r	-	1	9
Round-tailed Horned Lizard	c	-?	-	-?	-	-	-	0	21
Regal Horned Lizard	u	-	-	-	-	-2		8	13

Table 1. Habitat use and numbers of observations (for 1993-6, "field", and available museum records) for all amphibian and reptile species known from Sulphur Springs Valley, Arizona.

Habitat categories are: rock slope and rocky upper bajada (**rs**), bajada desertscrub (**bd**), mesquite-dominated bajada (**bm**), bajada grassland (**bg**), grassland flats (**gf**), mesquite-dominated flats (**mf**), and agricultural edge (**ag**); these are intended as mutually exclusive categories. The category **rs** amalgamates the following habitat types: lower rock slopes and hills with grassland, mesquite savanna, or grassy thornscrub; mixed upper bajada or pediment thornscrub-cactus; and riparian gallery forest. Further description is in text. Symbols for abundance in each habitat category are: **-** = no records; **r** = rare; **u** = low to moderate abundance; **c** = common; **a** = very common or abundant; **-?** = may possibly occur in habitat type in Sulphur Springs Valley, but not verified by us; **?** with **r,u,c, or a** = verified in the habitat type in the valley, but abundance estimate derived indirectly.

Species	Habitat							Number of Records	
	rs	bd	bm	bg	gf	mf	ag	field	museum
Desert Spiny Lizard	-	-?	-	-	-	u	-	3	1
Eastern Fence Lizard	-	-	u?	u?	a	a	c	25	70
Tree Lizard	u	u?	c	u	u	c	c	19	172
Side-blotched Lizard	r	u	r	-	-	-	-	1	3
Great Plains Skink	u	-	-	-?	-	-	-	2	4
Little Striped Whiptail	-	-	-	-	a	-	-	5	402
Sonoran Spotted Whiptail	c	-	-	-	-	-	-	2	27
Western Whiptail	r?	u	-?	-	-	-	-	0	13
Desert Grassland Whiptail	u	c?	a	a	c	a	a	17	309
Glossy Snake	-	-?	-?	-?	-?	r	-	1	6
Ringneck Snake	u	-	-	-	-	-	-	1	5
Green Rat Snake	r	-	-	-	-	-	-	1	0
Chihuahuan Hook-nosed Snake	-?	-?	-?	r	r	-	-	0	3
Western Hognose Snake	r	-	u	c	c	u	c	16	49
Night Snake	c?	u?	u	-?	-?	u	r	7	7
Common Kingsnake	u	-?	u	u?	a	a	c	32	51
Sonoran Whipsnake	a	-	r	-	-	-	-	6	19
Coachwhip	r?	u?	c	c	u	a	c	21	45
Gopher Snake (Bullsnake)	u	c	a	a	u	a	c	57	72
Long-nosed Snake	-?	c	c	r	u	c	-?	20	54
Mountain Patch-nosed Snake	r?	-	-	r?	-	-	-	1	1
Western Patch-nosed Snake	a	c	u?	c	r	u	-?	7	31
Ground Snake	c	-	-	-?	c	-?	-?	1	12
Southwestern Black-headed Snake	-?	-?	-?	-?	-	r	-	0	3
Plains Black-headed Snake	c?	-	u?	u?	u?	u?	-?	0	11
Checkered Garter Snake	-	-	-?	r	a	a	c	42	44
Black-necked Garter Snake	a	c	c	c	-	-	-	21	13
Lyre Snake	u	-?	-	-	-	-	-	1	11
Texas Blind Snake	c?	-?	-?	u?	-?	u?	-?	0	4
Western Coral Snake	c	-?	u?	-?	r	-?	-	2	6
Western Diamondback Rattlesnake	c	a	u	-	-	r	-	34	18
Black-tailed Rattlesnake	a	-	-	-	-	-	-	6	8
Mojave Rattlesnake	-	-	a	a	a	a	u	61	104
Massasauga	-	-	-	-	r	-?	-	0	5

Table 1 (continued)

Age-Related Population Trends of Landbirds Migrating Through Southwestern Semi-Arid Grassland

Wang Yong[1] and Deborah M. Finch[2]

ABSTRACT

Understanding the causal factors of population changes of North American migratory landbirds is essential for developing effective conservation plans. The factors affecting migratory populations in the western United States are poorly understood. We examined population trends of landbirds that migrate along the middle Rio Grande in central New Mexico by analyzing banding data collected during fall migrations between 1985 and 1995. To investigate the relationships between population trends and age structure, we tested for age-specific trends, changes of age-ratio, and correlations between capture numbers in consecutive years. We found that population changes were unequally distributed between hatching-year and adult populations. We suggest that age-related population variations are associated with events affecting reproductive success on the breeding grounds, and survivorship during wintering and migration seasons. A model that predicts the relationship between causal factors and age-related population changes of migratory landbirds is presented. Further studies evaluating age-related population trends detected during fall migration should clarify whether seasonal factors influence population dynamics of migratory landbirds in the western United States.

INTRODUCTION

The population status of migratory landbirds has been a topic of considerable debate, as short- and long-term evidence suggests that population trends vary by species, geography, habitat, and land use (Droege and Sauer 1989, Robbins et al. 1989a, Terborgh 1989, Askins et al. 1990, Finch 1991). Declines of some populations are attributed to low reproductive success associated with habitat fragmentation on the breeding grounds (Robbins 1980, Whitcomb et al. 1981, Ambuel and Temple 1983, Brittingham and Temple 1983, Blake and Karr 1984, Lynch and Whigham 1984, Wilcove 1985, Robbins et al., 1989b, Hutto 1988, Robinson 1992, Sherry and Holmes). Others have argued that declining populations of some species are related to lowered survival rates

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caused by deforestation on the wintering grounds; hence, recruitment of new breeders into migratory populations is correspondingly reduced (Rappole and Warner 1980, Lovejoy 1983, Morton et al. 1987, Terborgh 1989, Morton and Greenberg 1989, Morton 1992, Rappole and McDonald 1994). A few have speculated that conditions on both breeding and wintering grounds may limit neotropical migrant populations, or that problems along migratory routes might contribute to declines (Morse 1980, 1989, Moore and Simons 1992, Terborgh 1992, Sherry and Holmes 1993, Moore et al. 1995, Rappole 1996). These hypotheses are difficult to test because of 1) the global scales over which migrants travel; 2) species-specific responses to seasonal resources and habitats; 3) the diversity of factors inducing population changes; and 4) inherent difficulties in sampling migratory populations (Robbins et al. 1989a, Sherry and Holmes 1993, Rappole and McDonald 1994).

Long-term monitoring data are needed to determine whether survivorship and productivity of migratory landbird populations are associated with specific seasons (e.g., wintering, breeding, or migrating periods). Conservation plans should account for critical times during a bird's annual cycle. Population trends of migrating landbirds could be age-related if migratory species are affected most at certain times or locations. For example, some studies (Whitcomb et al. 1981, Robinson 1992, Sherry and Holmes 1992) have suggested that reductions in the quantity and quality of breeding habitats owing to habitat loss and fragmentation could lead to lowered reproductive success or reduced recruitment of hatching-year birds.

Constant-effort mist-netting is a commonly-used technique for monitoring avian populations and has been applied on the breeding grounds to assess the abundance, productivity, and adult survivorship of landbird populations (e.g. DeSante 1991), on wintering grounds to monitor wintering populations (e.g. Faaborg and Arendt 1992), and during migration to track changes in populations of landbird migrants (e.g. Hagan et al. 1992, Dunn and Hussell 1995). Banding data collected during fall migration are unique in that individuals of most North American migrant landbird species can be reliably aged by plumage and/or degree of skull ossification (USFWS and CWS 1984, Pyle et al. 1987). Detecting changes in reproductive success of migrant landbirds may be possible by examining long-term capture data at stopover sites during fall migration. However, long-term studies of age-related population changes based on migration captures are rare, and their value in identifying potential factors causing population changes is unclear.

In this study, we investigated population trends of landbirds that migrate along the middle Rio Grande in central New Mexico by analyzing banding data collected during fall migration. We examined relationships between population trends and variations in age structure of migrating populations. We evaluated whether analyses of age-related population changes detected from migration data were useful in discerning underlying reasons for population changes of migratory species.

METHODS

Banding data were collected between 1985 and 1995 at Rio Grande Nature Center (RGNC), Bernalillo County, New Mexico (N 35°07', W 106°41'). Rio Grande Bird Research, Inc. established a long-term banding station at RGNC and has mist-netted landbirds during fall migration since 1979. We used data collected from 1985 to 1995 because the netting effort was less constant during the first six years of the banding operation. The study area was established in a riparian habitat, and the sampling sites included woods, two manmade ponds, and agricultural fields. The banding location was excluded from public access, and habitat disturbance or modification during the study was not evident (Cox 1994). Although long-term changes in bird numbers can be influenced by natural habitat succession at study sites (Remsen and Good 1996), Yong and Finch (in press) suggest that such an effect was not important during this period at the RGNC site.

Twenty mist nests (12m x 2.6m with 30mm or 36mm mesh) were used to capture landbirds from early August through mid-November each year. Nets remained at the same locations through the study period and were operated by volunteers during weekends in fall. Nets were opened about 15 minutes before local sunrise, were checked every 20-30 min, and remained up for approximately six hours each banding day. Nets were closed during rain, snowfall, and other excessive weather conditions (i.e., temperature > 38°C or winds > 40 km/h). Species, age, and sex identification were based on the *North American Bird Banding Manual* (USFWS and CWS 1984), *Identification Guide to North American Passerines* (Pyle et al. 1987), and various field guides. Each bird was banded with a numbered aluminum leg band.

Ten species were examined in this study: Dusky Flycatcher (*Empidonax oberholseri*), Wilson's Warbler (*Wilsonia pusilla*), Warbling Vireo (*Vireo gilvus*), Western Tanager (*Piranga ludoviciana*), Black-headed Grosbeak (*Pheucticus melanocephalus*), Lazuli Bunting (*Passerina amoena*), Clay-colored Sparrow (*Spizella pallida),* Vesper Sparrow (*Pooecetes gramineus*), Dark-eyed Junco (*Junco hyemalis*), Lesser Goldfinch (*Carduelis psaltria*), and House Finch (*Carpodacus mexicanus*). We selected these species because: 1) they were common fall migrants along the Rio Grande of central New Mexico; all species had a total sample size >100, except Warbling Vireo (see Table 1), 2) age class of these species can be reliably identified during fall migration, and 3) species diversity was high enough to detect patterns among ecological groups, if there were differences.

We treated yearly weekend mist-netting efforts as temporally stratified repeated samples. We recognized that daily capture totals of each species could be affected by factors such as weather conditions and species-specific seasonal migration patterns but considered these factors to be of stochastic influence on the annual totals and population trends through the eleven-year period. Net-hour variation among years was adjusted by calculating yearly indices for each species and age group. To do this, we divided the numbers of total, hatching-year, and adult captures of a species by the total number of net-hours during a given year, and then multiplied the resulting values by 1,000. This produced a yearly estimate of birds/1,000 net-hours of banding operation.

To examine population trends, we followed the procedure used by Holmes and Sherry (1988). We applied a simple regression model for estimating changing captures of hatching-year birds and adults of each species over time: $\ln(_{capture} + 1) = {}_{year} (\ln[B]) + \ln(A)$, where $_{capture}$ is # captures/1,000 net hours in $_{year}$; 1 is an arbitrary constant added because the logarithm of zero is undefined; $_{year}$ is a number from 1-11 corresponding with the 11-year banding operation from 1985 to 1995; and ln(A) and ln(B) are fitted constants for the y-intercept and slope, respectively. The trend in original (non-log-transformed) units of captures was calculated by taking the antilog of the slope in the above regression: trend = $e^{(\ln[B] - 0.5[variance])}$, where variance is the square of the standard error (SE) of the estimated slope in the above regression. The variance term corrects for the asymmetry of the log-normal distribution. Finally, we transformed population changes to units of average % annual change: (t-1)(100), where t = trend.

Because hatching-year birds captured during fall migration of a given year become adults in the following spring, we performed correlation analyses between total captures of each species during a given year and adult captures of the following year, and between total captures during a given year and hatching-year captures of the following year. We calculated age ratios for each species by dividing the number of hatching-year captures by the number of adult captures (hatching-year/adult) of each year. We defined statistical tests as significant at $\underline{P} \leq 0.1$. We chose this alpha level because Type I error is less risky than Type II error in detecting population declines of

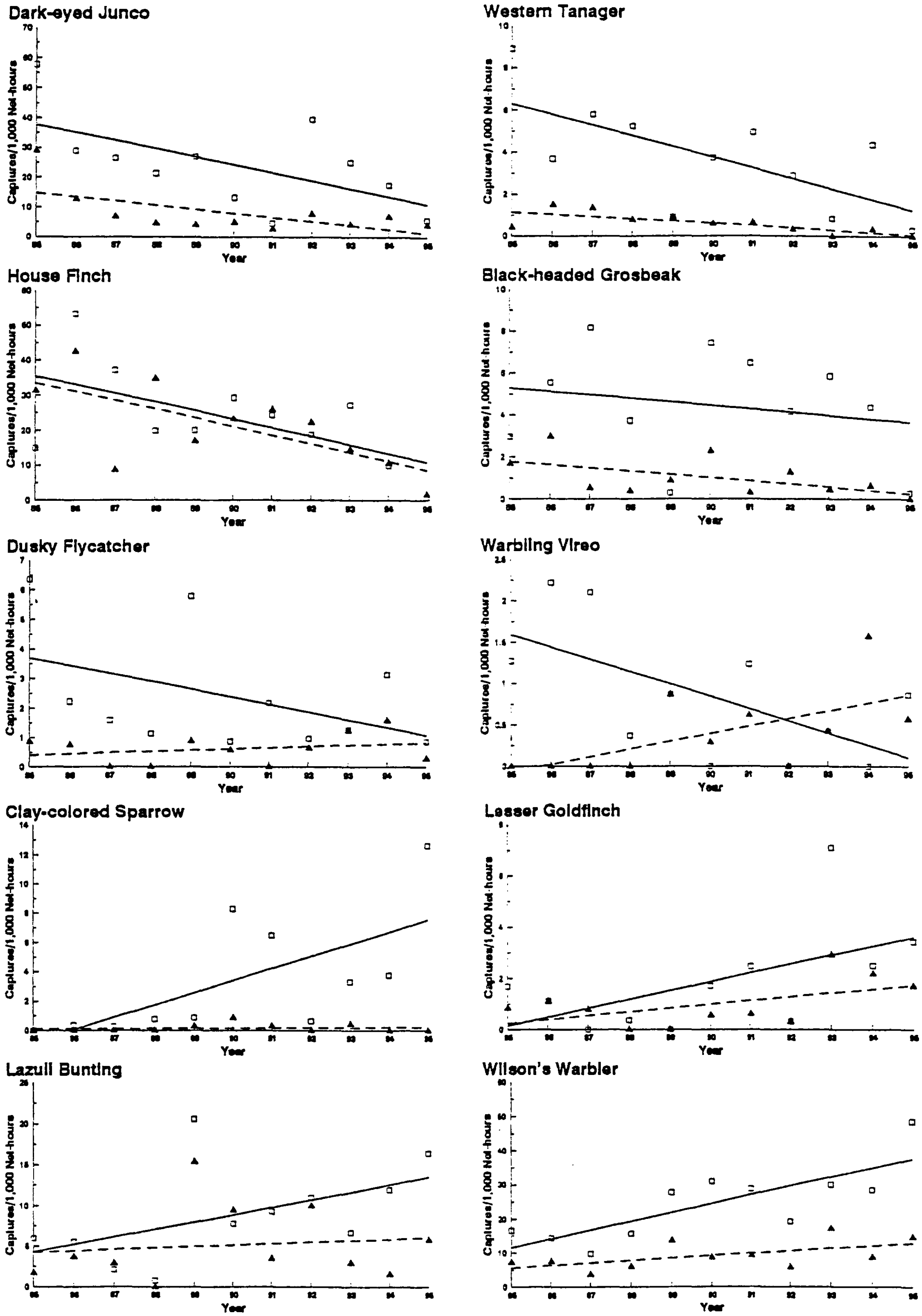


Figure 1. Population trends of migratory landbirds captured during fall migration from 1985 to 1995 at Rio Grande Nature Center, Albuquerque, NM. The open squares/solid lines and the solid squares/dash lines represent hatching-year and adult populations respectively. See Table 1 for statistics.

migratory birds. If population changes can be detected early due to initial warnings from trend data, the species has a greater chance of population recovery through close monitoring and prompt conservation actions.

RESULTS

A total of 5,136 birds of the ten selected species were captured during the study period. The overall ratio of adult (1,624 individuals, 32% of total captures) and hatching-year birds (3,512 individuals, 68% of total captures) was about 1:2. Negative population slopes were detected in six species -- Dusky Flycatcher, Warbling Vireo, Western Tanager, Black-headed Grosbeak, Dark-eyed Junco, and House Finch -- and were significant ($p < 0.1$) in all except Dusky Flycatcher and Warbling Vireo (Fig. 1). Most of these species breed or winter in forested habitats (American Ornithologists' Union 1983, Ehrlich et al. 1988). The other four species, Wilson's Warbler, Lazuli Bunting, Clay-colored Sparrow, and Lesser Goldfinch, had significant population increases. These species primarily use secondary growth, thickets, chaparral, or shrub habitats. Of the ten species, seven were classified as Neotropical migrants. No consistent trend patterns could be distinguished between temperate migrants and Neotropical migrants (Table 1).

Adult populations declined significantly in four species, Western Tanager, Black-headed Grosbeak, Dark-eyed Junco, and House Finch, whereas two species, Warbling Vireo and Wilson's Warbler, had significant adult population increases (Table 1). The annual change of hatching-year populations was significant in eight species including Warbling Vireo (-), Wilson's Warbler (+), Western Tanager (-), Lazuli Bunting (+), Clay-colored Sparrow (+), Dark-eyed Junco (-), House Finch (-), and Lesser Goldfinch (+). Positive or negative slopes of hatching-year populations corresponded to slope direction for total populations (adult + hatching-year) of every species (Table 1).

Although two species, Warbling Vireo and Black-headed Grosbeak, had total population trends that were not significant, age-class analyses showed that both adult and hatching-year populations of Warbling Vireo and adult populations of Black-headed Grosbeak showed significant annual changes (Table 1). In Warbling Vireo, adult populations increased whereas hatching-year populations decreased. Populations of Dark-eyed Junco and House Finch had annual decline rates that were similar between adult and hatching-year populations. In contrast, the declining rate of the hatching-year population of Western Tanager was almost twice that of its adult population (Table 1).

Among the four species whose total populations had positive annual-change slopes, adult population increases were significant in Wilson's Warbler only, whereas hatching-year populations increased significantly in each of the four species (Table 1). The positive total population trend of Clay-colored Sparrow was mostly due to an increase in its hatching-year population, while total population change in Wilson's Warbler was explained by increases of both adult and hatching-year birds (Table 1).

In four species, Warbling Vireo, Western Tanager, Black-headed Grosbeak, and Dark-eyed Junco, the number of adult captures in a year was significantly correlated with total captures of the previous year. This relationship was positive in Western Tanager, Black-headed Grosbeak, and Dark-eyed Junco, that is, if more (or fewer) birds were captured in a given year, more (or fewer) adults would return to the study site in the following year. This relationship was negative in Warbling Vireo, i.e. if more (or fewer) birds were captured in a give year, less (or more) adults would be captured in the following year.

Species	Correlation between year & captures[a] Total	Adults	Young	Correlation between total capture & following-year capture[b] Age-ratio	Adult	Young	Annual % change Total	Adults	Young	Mt[c]
Dusky Flycatcher										
Empidonax oberholseri	-0.29(102)	0.23(20)	-0.43(79)	-0.20	-0.01	-0.33	-4.45	2.29	-6.43	N
Warbling Vireo *Vireo gilvus*	-0.21(43)	0.65(14)**	-0.59(29)*	-0.76***	-0.57*	0.07	-4.64	1.70**	-7.55*	N
Wilson's Warbler *Wilsonia pusilla*	0.76(1,185)***	0.56(312)*	0.79(846)***	0.48	0.11	0.59*	10.69***	6.99*	10.88***	N
Western Tanager *Piranga ludoviciana*	-0.71(154)**	-0.77(21)***	-0.63(125)**	0.43	0.61**	0.04	-13.46**	-6.63***	-11.55**	N
Black-headed Grosbeak										
Pheucticus melanocephal1us	-0.38(192)	-0.57(34)*	-0.24(153)	0.52*	0.58*	0.13	-7.81	-7.55*	-4.75	N
Lazuli Bunting *Passerina amoena*	0.56(489)*	0.48(252)	0.51(136)*	-0.38	0.27	0.46	22.89*	13.93	16.43*	N
Clay-colored Sparrow *Spizella pallida*	0.76(131)***	0.15(6)	0.77(123)***	0.61**	-0.08	0.32	23.36***	0.95	23.06***	N
Dark-eyed Junco *Junco hyemalis*	-0.61(1,143)**	-0.61(250)**	-0.57(784)*	0.01	0.69**	0.21	-9.83**	-10.17**	-11.51*	T
House Finch *Carpodacus mexicanus*	-0.66(1,594)**	-0.65(682)**	-0.61(781)**	-0.23	-0.04	0.45	-15.90**	-15.23**	-14.21**	T
Lesser Goldfinch *Carduelis psaltria*	0.55(103)*	0.48(33)	0.55(60)*	-0.17	0.46	0.11	12.58*	6.48	11.33*	T

[a] Correlation between number of birds captured and year(sample size), see text.
[b] Correlations of the total capture of the species in year x with the adult capture and hatching-year capture in (year + 1).
[c] Migration type: migratory species wintering mainly north of 25° are classified as temperate migrants (T) and all others are Neotropical migrants (N).
* P <0.10, ** P <0.05, *** P <0.01.

Table 1. Population trends of landbird migrants captured during fall migration along the middle Rio Grande of central New Mexico.

Age ratio (hatching-year/adult) increased in Black-headed Grosbeak and Clay-colored Sparrow and decreased in Warbling Vireo during the study (Table 1). These results suggest that increases or decreases in adult or hatching-year populations were disproportionate in these species. In Clay-colored Sparrow, hatching-year birds had a much higher rate of increase than adults, such that the age-ratio trend was positive. However, in Black-headed Grosbeak, the positive age-ratio trend resulted from a higher rate of decline of adults than of hatching-year birds, rather than from an increase in the hatching-year population. Matching the negative annual changes of adult and hatching-year populations, the age-ratio trend of Warbling Vireo was also negative because of a slower rate of increase in the adult population than in the hatching-year population.

DISCUSSION

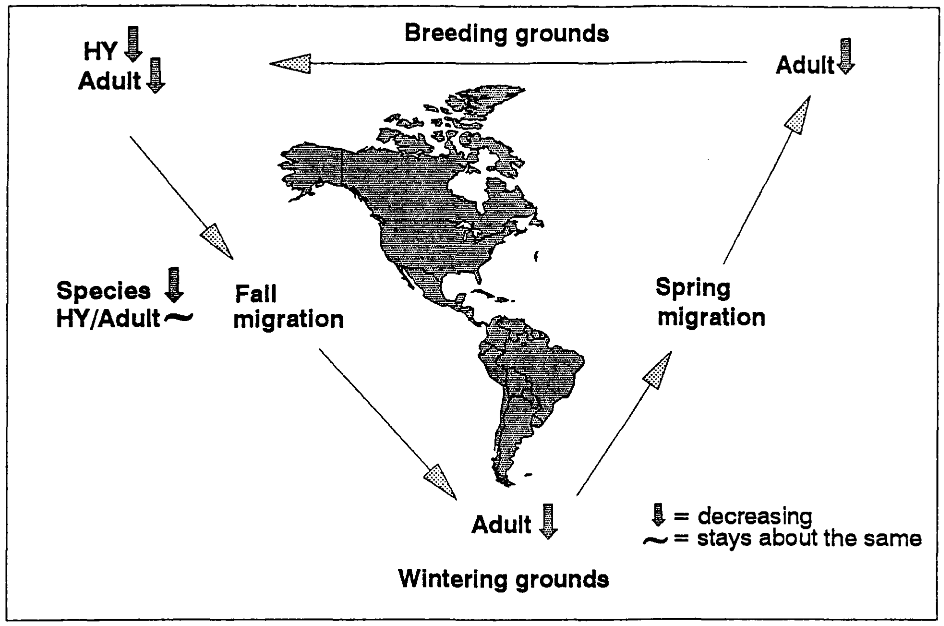
Our results demonstrated that population increases or decreases of migratory landbirds captured during fall migrations along the middle Rio Grande between 1985 and 1995 varied among species and in some species, between adult and hatching-year populations. Within the group of seven Neotropical, long-distance migratory species, population trends were also inconsistent. We suggest that similarities in habitat use rather than in migration distance prompted similarities in population trends among the ten species. In previous analyses of the same data set, we showed that several forest-dwelling bird species showed declines in population trends from 1985 to 1994, whereas species that used thickets, shrubs, chaparral, or secondary-growth were more likely to show increases (Yong and Wang in press, (Finch and Yong in press).

Population declines of forest migrants have been attributed to 1) low survival rates on the wintering grounds owing to widespread loss of tropical habitats, and 2) low reproductive success on the breeding grounds or on migration routes due to loss and fragmentation of North American forests (Askins et al. 1990, Finch 1991). However, factors affecting populations of migratory landbird species are poorly understood because of temporal and spatial variability among habitats, regions, land uses, and demographic factors. Using a long-term demographic approach, Sherry and Holmes (1992) found that breeding abundances of American Redstarts (*Setophaga ruticilla*) declined in an unfragmented eastern forest and concluded that the decline was related to low breeding success.

We suggest that analyses of age-class trends provide important information for interpreting total population changes of migratory species. In some cases, total population trends can mask trends that differ by age class within a species. In our study, for example, Warbling Vireo and Black-headed Grosbeak showed no significant population trends when analyses were based on species' total capture, but age-class analyses revealed that hatching-year populations of Warbling Vireo declined and adult populations of Black headed Grosbeak declined.

Age-related population trends have potential to help identify where and when migratory populations may be limited. To illustrate, declines of both adult and hatching-year populations of the Western Tanager in this study contributed to the decline of its total population. Tanager hatching-year declines are mostly likely related to declining nesting success and juvenile survival at breeding sites, whereas adult declines could be related to higher mortality during other seasons. Based on the nonsignificant age-ratio trend and the significant correlation between number of adult captures and number of total previous-year captures, we suggest that the total population decline of this species was more likely to be related to reduction in survival rate during wintering and/or migration seasons than to changes in breeding productivity. In other words, as fewer and fewer tanager adults returned to their breeding grounds each spring, the adult population declined over

a. Unfavorable wintering and migration conditions



b. Unfavorable breeding conditions

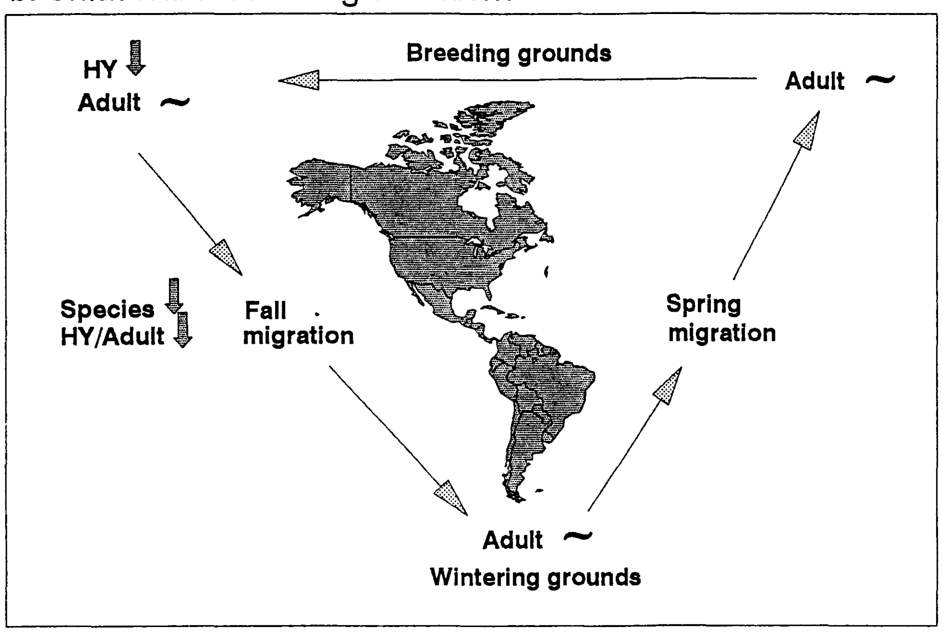


Figure 2. Predictions of age-structure and population changes of migratory landbirds detected during fall migration in relation to conditions on the breeding and wintering grounds, and migration routes. a. Unfavorable wintering and migration conditions (low survival rate): fewer birds return to breeding ground. The population of the species should decline and the age-ratio should be relatively stable. b. Unfavorable breeding conditions (low breeding success): fewer hatching-year birds would migrate south from the breeding grounds, and the population of the species and the age ratio should both decline (see text for more information).

time. As a consequence of declining adult populations, the number of young tanagers migrating south from the breeding grounds was proportionately lower (no age-ratio trend and negative hatching-year trend) and the number of total captures was lower accordingly (an overall negative species trend). The lack of an age-ratio trend suggested that breeding success did not increase over time, i.e., no age-related compensation in population size. Therefore, hatching-year tanagers did not replace numbers lost due to adult mortality, and this led to further reductions in the number of adults returning to breed in the following years.

In the Black-headed Grosbeak, the population trend of hatching-year grosbeaks was not significant, but the adult population declined. We observed a positive age-ratio trend in this species which suggested that the rate of decline of hatching-year birds was lower than that of adults.

On the other hand, the potential factors limiting Warbling Vireo populations seemingly pertained to conditions on the breeding grounds because the hatching-year population and the age-ratio declined significantly during the study period. Given that the adult population showed the opposite trend, it was apparent that limiting factors had not yet exceeded the ability of vireos to recruit sufficient numbers to maintain a stable adult population. However, if the age-ratio continued to decline, we predict that a point would be reached where adult populations would start to decline as well. Winter or migration resources may have helped to offset reductions in hatching-year populations such that the total population remained stable.

Among the species that had positive total population trends, increases of adult populations paralleled increases in hatching-year populations in most of the species. We suggest that increased production of hatching-year birds on the breeding grounds resulted in more adults on the wintering grounds and more birds returning to the breeding grounds the following year. Because of increased breeding populations, more hatching-year birds would be expected to be reproduced in subsequent years. Improvement of wintering habitat quantity and quality could further magnify this increasing trend.

The hatching-year population of the Clay-colored Sparrow showed a relatively large yearly increase while the adult population had a small nonsignificant increase. Increased production of young birds suggests that breeding conditions for this species may have improved over the study period. Limiting conditions on the wintering grounds and/or migration routes may have offset breeding season gains, resulting in a relatively stable adult population. The positive relationship between total captures of a given year and adult captures of the following year suggests that the adult population would likely have increased had the wintering/migration conditions improved.

This study provides an example of using population and age-structure data from a long-term fall banding program to identify when and where populations of migratory landbirds may be limited. Not all migratory species can be expected to respond in the same way; different factors may be at work in different regions of North and Latin America (Rappole and McDonald 1994). Migratory populations could be affected by unpredictable weather conditions during migration (Buskirk 1980, Moore et al. 1995) or by long-term climatic fluctuations. However, we believe that these factors are relatively stochastic and would not lead to systematic trends. Furthermore, if weather and climate factors affected observed population trends, the effect should be similar for all age classes.

Migrations can result in dramatic mortality (Moore et al. 1995). Unfortunately, no direct data on conditions during migration and population periods are available. The demographic studies by Sherry and Holmes (1992) suggested that American Redstart mortalities during fall and spring migrations were relatively unimportant for the recruitment of new adults from hatching-year birds of the previous year. However, Johnson (1973) found that mortalities of immature Western Flycatchers were higher than those of adults during spring and fall migrations.

We developed a model illustrating how age-structure and population changes detected during fall migration related to potential events or conditions on breeding and wintering grounds and along migration routes (Fig. 2a: unfavorable wintering and migration conditions; Fig. 2b: unfavorable breeding conditions). If a migratory species is adversely affected by conditions on wintering grounds and/or migration routes, two possible outcomes are expected. One, the species' population should decline because fewer adults return to the breeding grounds and/or fewer new breeders are recruited into the reproductive population. The age-ratio (hatching-year/adult) detected during fall migration would remain relatively stable. Second, if the adult population compensates for reduced population density by producing more young birds, or if the proportion of non-breeding floaters decreases as they fill vacant territories, the age-ratio in fall could actually increase while the overall population remains relatively stable.

On the other hand, if a migratory species is negatively affected by conditions on its breeding grounds, we predict that hatching-year populations should decline, which could lead to a reduction in age ratios and species' population size detected during fall migration. If declines of hatching-year populations are within the range at which sufficient numbers of hatching-year birds become adults on the wintering grounds and compensate for the mortality of the adult population, the adult population detected during the successive years should be relatively stable. Otherwise, the adult population should decline. If these patterns persist, the total and the hatching-year populations should decline and the age-ratio would be biased toward adults.

We suggest that existing banding programs standardize their operation procedures to facilitate future population analyses. In addition to fall banding data, long-term spring banding data could be used to measure return rate from wintering grounds and hence, wintering success. The combination of fall and spring banding data would provide additional information pertaining to reproductive success and wintering mortality, and further our understanding of the underlying basis for population dynamics of migratory landbirds. Capture and banding methods, in conjunction with other techniques such as measurements of nesting and fledgling success; Breeding Bird Survey; quantification of habitat availability and suitability on the wintering, migration, and breeding grounds; and population monitoring during winter; can help to clarify where and when landbird populations are limited. Such information should prove useful in developing priorities for implementing conservation plans.

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Wildlife Corridors Panel Discussion[1]

Moderator: Rod Mondt[2]

Steve Gatewood, the first speaker, is the director of The Wildlands Project (TWP). Steve came to TWP about six months ago from Florida where he was a former Disney Wilderness Preserve manager. Prior to that he was with Florida Heritage as the state wildlife ecologist, specializing in reserve design.

Steve described TWP as an effort to preserve and restore the native biologic diversity and integrity of North America by the establishment of a connected system of conservation reserves. TWP brings together conservation biologists and conservation activists to accomplish the overall objective. The reason for the union of science and activism is the failure of scientists to successfully blend science into public policy. Activists, by contrast, have the passion and the organizing skills to do that.

The traditional approach to conservation in the past has been to set aside somewhat small, relatively undesirable areas (rocks and ice), areas of mainly scenic value or places that were undevelopable (like the Everglades). The result of that approach has been a fairly consistent decline in natural communities. Sixty percent of Bailey's ecoregions are represented in wilderness areas, but if one looks at large areas, fewer than 20% are represented in areas of 100,000 hectares or more. Two percent of Bailey's ecoregions are represented in systems of greater than one million hectares. We haven't done a very good job of large system conservation. Wildlands tries to bring conservation biology principles to reserve design. Some of these principles are:

- large is better than small
- the presence of carnivores is better than an absence of carnivores
- contiguous habitat is better than fragmented habitat
- linked, connected habitats are better than non-connected habitats

By applying conservation biology to reserve design, we can look at much larger scales.

The goals of reserve design are:

- represent all ecosystem types across their variability
- maintain viable populations of all native species
- maintain biological and evolutionary processes
- allow for change - to build resiliency into the system
- A reserve should consist of core reserves, buffer zones, and areas of connectivity (corridors). Core areas allow very limited use activities. Buffer zones allow varying degrees of use. These areas are linked by corridors.

Processes such as fire require very large landscapes and resiliency. The ability to adapt to change will be important as processes such as global warming enter the picture.
One of the other concepts TWP employs is using large carnivores as umbrella species, i.e. if habitat for grizzly bears can be protected, habitat for around 80% of other species will also be protected. Corridors link meta populations.

To do corridor research, GIS is a necessary technology to manage the multiple layers of data.

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[1] Summarized by Susie Brandes, Sky Island Alliance, Tucson, AZ.

[2] The Wildlands Project, Tucson, AZ.

TWP has not gotten very far in terms of actual science yet, but is very well organized with about 33 groups participating. We know very little about what constitutes a suitable corridor because very little work has been done to define what constitutes the design, composition and structure of corridor systems. Steve showed successive maps of the Sky Island region that include parts of Arizona, New Mexico and northern Mexico. The corridors are conceptualized to anticipate the return of large carnivores like the Mexican wolf and the grizzly bear

The corridor concept brings up the question, how much area is enough for a reserve network? If reserve networks are linked together, core reserves might not need to be so large since meta populations can interact via corridors. However, this concept has not yet been tested in the field. What can we do now, without all the answers, to protect connectivity?

- maintain natural connections in the landscape
- when possible, restore natural connections that have been severed
- make corridors as wide as possible
- avoid artificial connections between habitats that are naturally isolated
- whenever possible, close roads and maintain habitat structure in the landscape
- it may be necessary to create bottlenecks in a corridor to stop the spread of epizootics if they should occur

We have to understand what changes are appropriate in the landscape and what are not appropriate and address those that threaten species the most. Reserve design is an iterative process that requires evaluation of effectiveness.

It will be necessary to include people in this matrix. To better explain the corridor concept to people, Steve uses the example of human populations being linked together by roads that bring essential goods and resources needed by communities to function. In Florida the state involved people in the process by creating the Greenways Commission which works on designing wildlife and recreation corridors together.

Deborah Finch, the second speaker, is a lead researcher for the U.S. Forest Service (Rocky Mountain Experiment Station) in Albuquerque. She has a BS in Wildlife Management from Humboldt State. She has an MS in Zoology from Arizona State and her Ph.D. in Zoology and Range Management from the University of Wyoming. She leads a research unit focusing on disturbance and restoration of grasslands and riparian ecosystems. She helped to organize a conservation organization called Partners in Flight, a widespread international coalition designed to conserve neotropical migratory birds and most songbirds. Her personal research emphasis is on songbird migration. See her complete paper in this chapter.

Sheridan Stone, the final speaker is the wildlife biologist at Ft. Huachuca and has been there for about nine years. He was formerly employed by the National Marine Fisheries Service where he did management and research on marine mammals and sea turtles. He did his undergraduate work at the University of Montana and graduate work at the University of Minnesota.
Sheridan's talk describes the Ft. Huachuca/Canelo Hills Track Count, a program in which volunteers look for lion tracks and other "on the ground" information. The effort is important not just because of the actual data gathered, but because of the interaction of volunteers from many backgrounds, and the sharing of information and perspectives.

The impetus for the track count came from a workshop held in Prescott in 1988. While statewide reconnaissance had been done by Harley Shaw, a wildlife biologist, and Arizona Game and Fish, Harley felt that a useful methodology could be tested and perhaps implemented: training people as observers who could then work with wildlife managers to gather better information than traditional harvest data to estimate the stability of lion populations. Fort Huachuca was chosen as a testing ground. Volunteers have been used from the start, including Sue Morse of "Keeping Track" in Vermont, and members of the Phoenix Zoo Animal Observation team. The Sky Island Alliance joined the group with a strong conservation focus and an interest in corridors.

Track counts don't provide a lot of rigorous statistical data to perform an analysis although the information gathered is being evaluated by a biometrist. Optimally, the goal at the start was to use track counts to get an idea of population number, composition, trend, sex and age distribution, movement between areas, and presence or absence from an area, In actuality, the goals are focused as much on methodology, i.e., what can volunteers be reasonably trained to do, setting a basic standard, and accumulating a long term data base. Over time, perhaps using running averages, a data base is established that can be used when questions arise about the presence of lions, reproduction, or corridors and their use.

Tracking is a very inclusive activity. People from many backgrounds around the state have participated. Information exchange, training (what to look for, how to see things, when and if to draw conclusions) are important. Technique instead of technology is a strength of the program. It is also cheap. No budget is necessary so it can be carried on for a long time and various methodologies can be tried without worry about budgetary concerns.

The Ft. Huachuca count is focused on where prey species are most common. Tracking is done on dirt road substrate over an area of about 35 miles on the base. About 15+ miles of routes are covered each day of the count. People look for scrapes and other sign as well as lion tracks. Other tracks such as bear, coatimundi, turkey, fox, raccoon, bobcat, and coyote are often found and are important not only in teaching people to recognize tracks but as motivation and reward for volunteers. Quality control is built in by having more experienced people included in each group.

The Canelo Hills track count is a specific project of the Sky Island Alliance. They have eight routes established in the Canelo Hills (over a year) where deer habitat is good. The Canelo Hills were chosen as a track count site because of their proximity to other ranges such as the Huachucas, Santa Ritas, Whetstones, Mule Mountains, and the Patagonias. None of these individual ranges are large enough to support a viable mountain lion population. It is clear that the linkage of the habitat connectivity would be important to the long term recolonization of the species should there be local extirpation. Routes are laid out to transect the movement of lions away from the mountain ranges. Volunteers have found an estimated .12 tracks per mile over a year, primarily in the drainages. They have detected bear track primarily outside the drainages. Over one year of effort the group is starting to define certain areas where animal sign either does or does not appear - a start toward possible corridor identification.

The value of this project is in the effort and number of people who have participated. There have been 110 volunteers involved on the ground, engaging their minds, and asking questions about what the information they gather means. The project is long term, cheap, and flexible, and volunteers are its strength.

The track count is being used elsewhere in Arizona and in other parts of the country to involve ordinary people in learning more about the biology and habitat requirements of local wildlife. It is a way to build constituencies for properly managing land by getting ordinary citizens involved on the ground.

Grazing and Fire Management

Larry Allen[1]

ABSTRACT

Natural and man-caused fires have been an important component of grasslands and forests for many years. Fire suppression and grazing in the twentieth century have changed the character of those areas and the characteristics of fires that do burn. Fire is relatively new to the lower desert regions, with the introduction of exotic grass species. Many of the plants of these regions are not well-suited to fire and characteristics of the low deserts have changed in some areas.

A change in attitudes toward fires is needed. In many cases they must be allowed to burn. This approach, however, must be tempered by a full understanding of the characteristics and needs of specific areas and the actual and perceived impacts on encroaching population areas.

INTRODUCTION

We have heard today that a number of factors have influenced southwestern ecosystems. Certainly cattle grazing is one of the bigger ones. There have also been a lot of other man-made disturbances to the environment - mines, railroads, cities, farms, a lot of different things have influenced these ecosystems. Probably one of the greatest influences has been fire, and in the last century or so the exclusion of fire. It was said earlier, many of these fires were caused by lightning. When I first started to work for the Forest Service, about 85 or 90 percent of our fires were lightning caused. That's not the case any more. But, I think a long time ago we had man-caused fires too. So, we had man-caused fires and then we had lightning-caused fires. But we had frequent fires in southeastern Arizona.

We think that the Indians occasionally might have used fires for vegetation manipulations, but probably more commonly for hunting and for war. We have the incidences that Kris showed us. Another well known one is when the cavalry was at Bear Springs in the Whetstones and the Apaches set that Bear Springs Canyon on fire. That's where lieutenant Cushing was killed, and as a result he got a bar named after him.

FIRE SUPPRESSION

Now, the tree ring studies show some interesting phenomena on our mountain tops. And, as we heard, they are now starting to look at lower elevations too. But, the thing that interests me is the near cessation of fire in these ecosystems starting about 1900. Many people attribute that to fire suppression and they blame the Forest Service. About 1907, when we assumed management

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[1] USDA Forest Service, Coronado National Forest, Tucson, AZ. Transcribed from conference tapes.

of these lands, we had one or two rangers with a horse and a shovel in charge of a whole mountain range who sent out here to put the fires out. Later on, about the time I came along we had more modern equipment. But, obviously we weren't very effective at it. Although we prevented the spread of some fires, I don't think that caused the dramatic decline or decrease that the tree ring studies show. Smokey Bear has had a big influence, but he didn't come along until about the 1950's. So, I think that probably what we are seeing is a pattern caused more by livestock grazing. Livestock have been in Arizona since about 1540, and they have been fairly prominent in Arizona since the 1700's. But, the big build up was about the time of the Civil War. That kind of coincides with the tree ring data. After about 40 years of intensive livestock grazing, fires ceased.

There has been a lot written and studied about what are the factors that brought about the changes in these ecosystems. I think that there are many varied factors, and that anyone who espouses any one factor is guilty of an oversimplification. A combination of climate changes and man-caused factors has resulted in, not total elimination, but certainly a marked decrease in the effect of fire on these Sonoran grasslands since around the turn of the century.

MESQUITE SAVANNAS

We at one time had mesquite savannas. We think in many of our foothills type areas, this is probably a fairly natural kind of a situation. If you have a combination of excessive grazing and drought, you get a situation where it wouldn't matter what the humidity was, you can't burn this kind of place without doing something to change the situation first. We improved livestock management. I agree with Jerry, we have a lot of good research and I think we also have a lot of good range management in the area. By the mid- 1950's or so, we had created enough fuels that fires probably could have started to spread again. But, by then the agencies were becoming pretty efficient at putting fires out. So, just about the time that the livestock ceased to be a problem, the agencies became the problem.

FIRE IN THE SONORAN DESERT

In our Sonoran area we have several different ecosystems, and one that has not evolved with a lot of fire is the Sonoran desert. This desert does not naturally support very much perennial grass. So the years that it will burn very hotly are pretty rare. As a result the desert plants that we really value in the Tucson area are pretty susceptible to fire, easily killed. This causes a problem to those of us who advocate reintroduction of fire. Another problem with fire in the Sonoran desert is the great abundance of exotic species such as Lehmann's love grass in Arizona and buffelgrass in Sonora. These areas have a fuel base that they never had naturally, and these exotic species have spread. We saw some examples of that this morning of damaging fires as a result of buffet grass. This can happen in some of the Lehmann's areas too. And, as Jerry said, unfortunately we have not been able to find a way to use fire as a tool to manage Lehmann's. It seems to thrive on fire.

Another challenge to us is the great public interest. When fires start to bum, whether they are good or bad, the local publics get very interested. Some people are concerned about what they perceive as forest destruction, other people are concerned about their homes and the improvements they have built close to the fire. The public scrutiny that we have nowadays complicates the situation quite a bit.

THE CHIHUAHUAN DESERT

In the Chihuahuan desert areas, we don't have the spectacular cacti, but we do have some plants that are also susceptible to fire. There has been a lot of concern expressed in the literature about black grama. They think that burning the stolons can significantly damage black grama. Our experience in the Malpai area, at a little higher elevation, and a little higher rainfall, suggests that it doesn't seem to be as bad a problem as it is down in the desert. Anyway, we need to be sensitive to the fact that some of our grass species are more susceptible to fires than others. So, reviewing these factors, then, if we for a variety of reasons, remove fire from the ecosystem, we no longer have the natural pristine kind of an ecosystem. The result of having this bare soil, eventually is the encroachment of woody plants and probably encroachment into areas that didn't support them or didn't support them in any numbers in the past, with deterioration of wildlife habitat and watershed values as well as forage.

WOODLAND AND RIPARIAN AREAS

In our woodland areas, we think that where you have a mosaic of open grasslands, savannas, and then some dense woodlands is probably a natural state, and certainly a very desirable situation both for livestock and wildlife, and kind of pretty to look at too. The ecologic tendency in our woodlands is towards these dense woodlands. If you remove fire from those ecosystems, you get denser growth. Our riparian areas seem to be naturally fire resistant. The humidity is a little higher, the plants that are there are not as flammable. Fire burns through these areas periodically, and they seldom do much damage. In our prescribed burning efforts we try to prescribe cool fires in the riparians and exclude fire from a few critical ones. But, most of the time fire is not a big problem in the riparian area.

CONTROLLED BURNS

As we start to do management-ignited fires, we have to consider all of these factors together, and it gets to be a complicated planning process. The last fire that I planned took about nine months. The current one we are working on has taken almost two years to get through all the hoops. I think that fire can and should be used to maintain and enhance biodiversity and it should be recognized as a natural part of the ecosystem. It is a desirable part, unlike the Smokey Bear syndrome that we have been living with. I am encouraged by recent policies coming out of Washington, although I have seldom in my career been very encouraged by anything out of Washington. The Department of Interior, and Agriculture and Army, have recently come out with a unified fire policy, which has a lot of common sense, a lot of advocation of prescribed natural fire and use of fire as a tool. I am very encouraged by that. I'm not particularly encouraged by the fact that is has been out for 6 or 8 months, and the agencies are slow to respond. But, I think we are on the right track. I would emphasize that folks in southern Arizona really value the Sonoran desert vegetation, and we need to recognize that and be careful. These fires have the potential to set back our burning program because of the possibility that cacti will be killed. But, I think all of the agencies recognize the value of putting fire back into the ecosystem that evolved with fire. We also recognize the fact that you can't do it overnight. I hear people advocate that if suppression is the problem, then just say no, and quit suppressing fires. Particularly on our mountain tops, that doesn't work without some fuel modification first. But, we need to be headed towards much less suppression.

We also need to be aware of the needs of our neighbors south of the border. I've been involved in fire training and providing tools to our counterparts in Sonora. I am trying hard to avoid the impression that what the Forest Service is saying to the Mexican Forest Service is you ought to put the fires out. I will be involved this winter in meetings in small towns in Sonora and will talk to people about fire management as opposed to fire suppression. I think working together, we have an opportunity with the agencies working together with the folks who live and use the land, to really bring about some improvement in these ecosystems. Through a little more sensible fire management and the application of fire as a tool, and then we'll create habitat for all these interesting animals that inhabit the border area.

Historical Patterns of Surface Fire in Canyon Pine-Oak Forests, Savannas, and Intervening Semiarid Grasslands of the Southwest Borderlands: An Abstract of Work in Progress

Mark Kaib, Christopher H. Baisan, Thomas W. Swetnam [1]

Researchers have long speculated about past fire regimes in the canyon pine-oak forests, savannas, and intervening semiarid grasslands. Although these mesic canyon pine-oak forest environments contain high biodiversity, certain endemic species, and increasing rates of ecotourism (Felger et al 1997; Fishbein et al. 1996), little research has been conducted within these areas when compared to the adjoining grasslands. Many authors have suggested a grassland fire-return cycle of roughly 10 years (e.g., Bahre 1995, 1991, 1985; Baisan and Swetnam 1990; Hastings and Turner 1965; Humphrey 1987, 1963, 1958; Leopold 1924; Marshall 1963, 1962, 1957; McPherson 1995; Moir 1982; Swetnam et al. 1992, 1989). Lack of paleoecological evidence and sole reliance upon seasonal, sporadic, sometimes rare, and often biased historic records have resulted in disparities.

Dendrochronologic (tree-ring dated) reconstructions of fire and climate, and historical records, date back prior to Spanish colonization (circa 1600's; Swetnam and Baisan 1996a, 1995b; Meko et al. 1995; Bancroft 1889, 1884). Patterns of widespread and frequent (i.e., every 5-10 years) low intensity surface fires were recorded for centuries by fire-scarred pines in these areas until the 1870's and 1880's, when increased land-use and primarily livestock production led to rapid near extinction of fires of this nature (Cooper 1960; Dieterich and Swetnam 1984; Leopold 1924, Swetnam and Baisan 1996a; Weaver 1951). American fire suppression policies became effective by the 1930's (Swetnam and Baisan 1995a) further ensuring fire cessation and exacerbating forest and grassland change. Unfortunately recent extraordinary wildfires in the Southwest have threatened and taken human lives (e.g., Peak, Dude, Rattlesnake, Storm King). Additionally these anomalous fire events incinerated large patches of forested landscapes far different in character from past fires. After more than seventy years of discourse elucidating the need and destiny of fire in these ecosystems, recently funds have been allocated specifically for ecosystem fire management and research in the Southwest Borderlands (USDA 1992, 1993; Stephenson 1996).

This region is of special interest for cross-border comparisons. Similar biophysical conditions but often unique land-use history in some cases has resulted in very different ecosystem processes and structure. Mexican and Native American land-use practices were and continue to be more diverse and in some cases less intensive than American production systems. Research on fire and

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land-use history in Mexico may demonstrate alternative and possibly more sustainable ecosystem management approaches. Some areas in Mexico have continued to experience common surface fires over the last century due to remoteness, varied land-use, economics, culture, and lack of fire suppression. Additionally traditional fire use by past and present cultures provide insight to potential human influence on fire history in these areas. Although recent fire-history investigations of anomalous fire patterns have considered anthropogenic sources (Baisan and Swetnam 1990, 1995; Kaib et al. 1996a; Morino 1996; Seckleki et al. 1996; Swetnam et al. 1989), limited historical and ethnographical synthesis has often resulted in inconclusive results.

The relative roles of humans verses climate and lightning in controlling past fire patterns has been increasingly under debate (e.g. AA Society Meeting 1996; Fish 1996; Williams 1994). Fire history reconstructions may in some cases contain anthropogenic patterns that can be supported jointly by tree-ring, historical, and ethnographic evidence. The Laboratory of Tree-Ring Research has an extensive network of fire chronologies (Swetnam and Baisan 1996a, 1996b) that document regional ecosystem fire patterns predominantly controlled by regional climate (Grissino-Mayer and Swetnam 1997; Swetnam 1993; Swetnam and Baisan 1996b; Swetnam and Betancourt 1997, 1990). In some periods and places the fire history chronologies are likely enhanced by anthropogenic influence (Baisan and Swetnam 1995; Kaib et al. 1996b). Cultures and ecosystems are dynamic but also uniquely bound by regional geomorphic, edaphic, and climatic conditions (Fish 1996). Moreover human populations are confined by spatially limited water and food resources (Castetter and Opler 1936). Indeed it may well be the case that human impacts due to the utilization of fire, as with other past Native American land-use patterns in these areas (Betancourt and Van Devender 1981; Betancourt et al. 1986; Savage 1991; Swetnam 1984), were primarily site and time specific, and not generalizable to broader areas or long time spans. Because these complex relations vary by locality and culture, anthropogenic fire patterns must first be resolved at specific well documented sites before regional ecosystem influences can be invoked.

Tangible evidence has been recovered from remnant fire-scarred stumps, logs, and snags of Apache (*Pinus engelmannii*) and Arizona pines (*P. arizonica*) along canyon pine-oak forests. We selected six comparable canyon sites connected by lower intervening semiarid grasslands that span the international Sulfur Spring and San Pedro basins. Given the topographic barriers typically separating these canyon habitats it is likely that many fires spread primarily into and between these lower canyons from intervening grasslands as opposed to intramontane fire spread. Historical records and Forest Service reports indicate that past lightning- and human-caused grassland fires commonly spread over vast areas in this region (Bahre 1995, 1991, 1985; Barrows 1978; USFS Coronado National Forest, fire reports on file, Tucson, Arizona). Furthermore lack of fire has been commonly cited as the driving force behind extensive increases in woody trees and shrubs within semiarid grasslands (Archer 1994, 1958; Bahre 1995; Humphrey 1963, 1958). Synchronous fire dates between sites, combined with these lines of evidence, provide a basis for inferring fire frequencies sustained by the intervening semiarid grasslands (Kaib et al. 1996b). Preliminary analysis of fire reconstructions from Rhyolite, Pine, and Turkey Creek Canyons in the western Chiricahua Mountains indicate past surface fires in these areas were more frequent than previously thought, ranging between one fire every 4 to 7 years (Kaib et al. 1996b). These canyons were occupied seasonally for centuries by the Chiricahua Apache, and fire reconstructions are likely influenced by their use and occupation of these areas (Cole 1988).

The robust cultural history of this region together with multicentury fire-history reconstructions also suggests the influence of humans in some areas and times. Decadal episodic intervals of elevated fire frequencies were associated with well documented borderland wartime periods (tentatively; 1680-1710, 1748- 1786, and 1831-1876; Bancroft 1889, 1884; Basso 1971;

Griffen 1988a, 1988b, 1979; Naylor and Polzer 1986; Spicer 1962). Fire was a tactical tool used by most cultures (Pyne 1982) and commonly in warfare during these periods. Anthropogenic fire patterns were also perhaps tied to traditional Chiricahua Apache cultural practices (Castetter and Opler 1936, Opler 1941) associated with these periods. Each identified wartime period was unique but often linked to shorter intervals of political unrest (Spicer 1962), increased Apache raiding (Griffen 1988a, 1988b, 1979), general warfare (Basso 1971; Binckerhoff et al. 1965), episodic drought and famine (John 1975; Meko et al. 1995), and increased fire frequency (Kaib et al. 1996b).

Fire reconstructions from these unique canyon pine-oak forests document the decadal to century scale variability of past fire regimes sustained by these interconnected ecosystems. In conjunction with regional and higher elevation fire reconstructions these chronologies will increase our knowledge of fire spread across these borderland basin and range vegetation gradients. Fire history research in Mexico by comparison illustrates land-use patterns and livestock production systems which did not exclude recurrent 20th century fire patterns and processes from these ecosystems. Ecological, historical, and cultural research in the Southwest Borderlands demonstrate comparative, alternative, and perhaps in some cases more sustainable ecosystem management practices. Furthermore these sites contain several centuries of fire and cultural history that together will help shed light upon the spatial and temporal influence of anthropogenic fire and the interaction of biophysical and cultural fire patterns.

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Experimental Fire Research in Semi-arid Shortgrass Prairie

Paulette L. Ford[1] and Guy R. McPherson[2]

ABSTRACT

Resource managers need reliable scientific information to effectively manage plant and animal communities and ecological processes. Ecologists must accept the challenge of providing sound scientific and relevant information to resource managers in a manner that allows prediction of the effects of land management techniques on ecosystems. Our research on the Kiowa National Grassland is designed to experimentally analyze the effects of season and frequency of fire on vegetation, small mammal, reptile, and arthropod communities in shortgrass prairie. The research should provide resource managers with information that will allow them to predict the effects of prescribed burns on semi-arid shortgrass prairie ecosystems.

INTRODUCTION

Today, semi-arid grasslands are managed for a variety of organisms including livestock, birds, reptiles, and mammals. Resource managers need reliable scientific information to effectively manage plant and animal communities and ecological processes. Ecologists know that determining the mechanisms underlying observed patterns (i.e., invasion of non-native grasses, declining diversity) is fundamental to understanding and predicting ecosystem responses to changes in the physical or biological environment and is necessary for improving management (McPherson in press). However, most scientists seek generality to their research, which is contradictory to the site-specific information needed by land managers (McPherson in press). In addition, ecologists typically fail to conduct experiments relevant to managers (Underwood 1995). This is especially evident when considering the lack of experimental research on the ecological impacts of fire in semi-arid grassland communities.

Fire can be a powerful force in structuring ecological communities (Figure 1). Depending on management goals, fire can be counterproductive, e.g., detrimental to reforestation efforts by reducing woody vegetation (Janzen 1986), or very productive, e.g., maintaining open grasslands by reducing woody vegetation (McPherson 1995). Linking fire, science, and management provides a unique opportunity to combine research on an ecologically interesting phenomenon with important management goals. Our research on the Kiowa National Grassland uses an experimental framework to analyze the effects of season and frequency of fire on vegetation, small mammal, reptile, and arthropod communities in shortgrass prairie.

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FIRE

Figure 1. Prairie fire (photo by Harvey Payne).

The effects of fire on an ecosystem depend on the current physical and biological environment, and on present and past land-use patterns (Ford and McPherson in press). Fire interacts with numerous other factors, including topography, soil, insects, herbivores (rodents, lagomorphs), and herbaceous plants to restrict woody plant establishment in grasslands (Grover and Musick 1990; McPherson 1995; Wright and Bailey 1982). Currently, there is agreement that the use of fire is necessary, though usually insufficient, to control the abundance of woody plants and maintain most grasslands; in the absence of periodic fire, most grasslands become dominated by woody plants (McPherson 1995).

Although recurrent fires are historically prevalent natural components of grassland ecosystems, fire size and frequency have diminished in semi-arid grasslands since the 1880s due to active fire suppression by Anglo settlers and removal of available fuel by livestock grazing (Bahre 1991; Ford and McPherson 1996). The use of prescribed fire has increased recently, primarily as a management tool to control invasion of woody plants into grasslands and to increase rangeland productivity.

Weltzin and McPherson (1995) pointed out that disturbance by fire today may fail to produce the same responses as in the past, due to profound changes in physical and biological environments over the last century. These changes include increased concentrations of atmospheric greenhouse gases (i.e. CO_2, methane), increased abundance of native (i.e., woody perennial), and non-native plants (i.e., lovegrasses, buffelgrass (*Cenchrus ciliaris*), several herbaceous dicots), and decreased abundances of some plant and animal species.

Considerable non-experimental research was conducted to address fire effects on vegetation in shortgrass prairie before 1980 (reviewed by Ford and McPherson 1996). In general, these studies indicate that fire leads to decreased herbaceous production for 1 to 3 years, and that herbaceous response is strongly influenced by precipitation. Fires also contribute to reductions in woody plant cover and to increases in density and diversity of herbaceous dicots (Ford and McPherson in press).

In addition to vegetation, animals (i.e., arthropods, mammals, birds, reptiles) are also important components of semi-arid grassland ecosystems. They function as decomposers, pollinators,

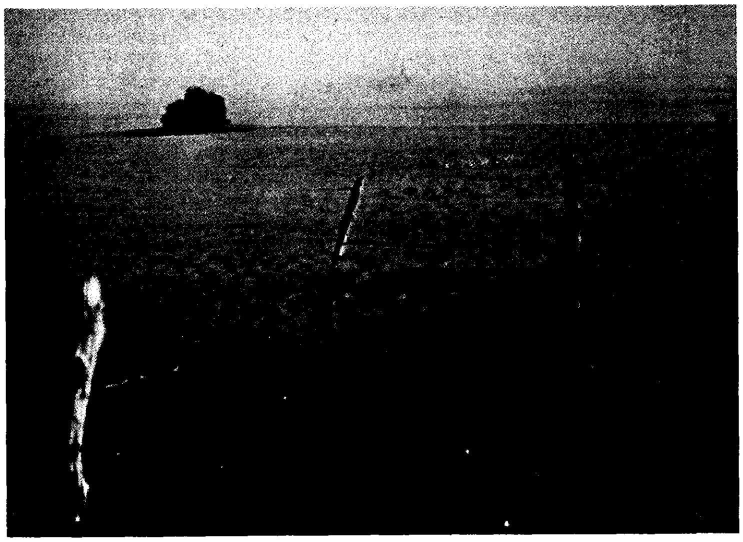

Figure 2. Southern Great Plains circa 1930 (courtesy of Kiowa National Grasslands).

herbivores, predators, and prey; cycling nutrients and forming valuable links among trophic levels. Numerous studies have indicated that animal species, populations, and communities respond differentially to disturbance by fire (reviewed by Ford and McPherson 1996), partly because fire can have both direct and indirect effects. Direct effects are acute and ephemeral i.e., fire induced mortality. Indirect effects (i.e., alterations in habitat) are long-lasting and usually more important. Therefore, fire in semi-arid grasslands may directly or indirectly elicit major or minor population or community structure changes depending upon the vagility, life history, habitat requirements, and trophic level of the animal, and the season, extent, and intensity of the fire (Ford and McPherson 1996).

Fire Season and Frequency

Grassland communities are usually influenced by seasonality and frequency of fire due to their evolutionary adaptations to particular habitat features and conditions (Ford and McPherson 1996). Fire has been a consistent enough event in semi-arid grasslands for communities to develop structural adaptations to its periodic stress (Steuter and McPherson 1995). For example, the forb component tends to be more diverse and has a higher number of individuals following fire than in long-term unburned communities (Bailey and Anderson 1978; Collins and Barber 1985).

In addition, the season in which the fire occurs has the potential to generate a dynamic spatial and temporal mosaic within the landscape (Steuter and McPherson 1995). The fuels of semi-arid grasslands may support high rates of fire spread when cured (Rothermel 1983), or be too discontinuous or actively growing to carry a fire (Andrews 1986), depending on plant growth form and phenology (Steuter and McPherson 1995). As a result, native communities probably develop under a characteristic range of fire size and frequency for the different seasons (Steuter 1986).

Regardless of the season of burning, variability in the population dynamics of some plant species appears to be related to variation in fire behavior (i.e., intensity, percent of area burned, fuel consumption). In contrast, other plant species are least vulnerable to dormant-season burning and most vulnerable to burning early in the growing season (Glitzenstein et al. 1995). In general, plant species in semi-arid grasslands are more strongly influenced by fire season and frequency than behavior (Steuter and McPherson 1995). Responses of arthropods to season and frequency of fires appear to vary by species (Warren et al. 1987). To our knowledge, no studies have focused on the issue of seasonal effects of fire on small mammals (Kaufman et al. 1990) or reptiles.

Figure 3. Kiowa National Grasslands Experimental Research Area, spring 1996 (photo by Paulette L. Ford).

Experimental Research

Previous research on vegetation responses to fire in shortgrass prairie of the southern Great Plains is non-experimental (descriptive) in nature. In addition, many of the previous studies analyzed response patterns only after natural or catastrophic fire, an anecdotal approach with limited applicability. Most of this previous research was conducted before 1980, and was primarily focused on the use of fire as a tool to increase forage value of vegetation (Ford and McPherson 1996).

As discussed by McPherson and Weltzin (in press), descriptive research is suitable for identifying patterns, but is considerably less useful for determining underlying mechanisms. This type of research has limited predictive power, and consequently, is of limited value to land managers. In contrast, identification of the underlying change mechanisms enables prediction of community responses to driving variables with levels of certainty and on spatial and temporal scales useful to resource managers.

Figure 4. Box turtles are marked with notches on their shells for identification (photo by Paulette L. Ford).

Experimentation (i.e., artificial application of treatment conditions followed by monitoring) is an efficient and appropriate means for testing hypotheses about ecological phenomena; it is often the only means for doing so (Simberloff 1983; Campbell et al 1991; McPherson in press). Manipulative field-based experimental research will help determine important driving variables because of strong correlations among factors under investigation (Gurevitch and Collins 1994).

Some important questions can be addressed only at scales that may be incompatible with experimentation (Ford and McPherson 1996). McPherson (in press) points out that in the absence of experimental research, managers and policy-makers must rely on the results of descriptive studies. Unfortunately, these studies often produce conflicting interpretations of underlying mechanisms, and are plagued by weak inference (Platt 1964): descriptive studies (including "natural" experiments, sensu Diamond 1986) are forced to infer mechanism based on pattern (McPherson in press). Therefore, they are poorly-suited for determining underlying mechanisms or causes of patterns because there is no test involved (Popper 1981, Keddy 1989). Even rigorous, long-term vegetation monitoring is incapable of revealing causes of vegetation change because of confounding interactions among the many factors that potentially contribute to shifts in species composition (e.g., Wondzell and Ludwig 1995).

There are many examples of "natural" experiments in the ecological literature, but results of these studies should be interpreted with caution. As discussed by McPherson (in press), grassland researchers have routinely compared recently burned areas to adjacent unburned areas and concluded that observed differences in species composition were the direct result of the disturbance under study. Before reaching this conclusion, it is appropriate to ask why one area burned while another did not. Pre-burn differences in productivity, fuel continuity, fuel moisture content, plant phenology, topography, or edaphic factors may have caused the observed fire pattern. Since these factors influence, or are influenced by, species composition, they cannot be ruled out as candidate explanations for post-fire differences in species composition.

A current example of the difficulty facing managers as they attempt to tease apart actual versus perceived effects of fire in semi-arid grassland is the invasion of Lehmann lovegrass *(Eragrostis lehmanniana* Nees.) into southern Arizona. Lehmann lovegrass was introduced into Arizona in the 1930s from southern Africa as a potential source of forage and erosion control. The lovegrass is now the most common perennial grass in southern Arizona (McClaran 1995).

Widespread establishment of the non-native Lehmann lovegrass is perceived as detrimental to many management goals, including maintenance of livestock grazing values, wildlife habitat (e.g., masked bobwhite quail), and restoration of historic community structure. All available evidence, including results from field experiments, indicates that Lehmann lovegrass increases with application of prescribed fire (Ruyle et al. 1988; Biedenbender and Roundy 1996): it is a species that seems to benefit from the high-light environment associated with disturbances (Sumrall et al. 1991). Nonetheless, many managers currently advocate the use of fire to restore historic community structure, including decreased abundance of Lehmann lovegrass. There appears to be a disparity between scientists (who have found that Lehmann lovegrass increases after fire) and

Figure 5. Systematic sampling using mark-recapture techniques provides quantitative estimates of small mammal species composition and abundance (photo by Paulette L. Ford).

managers (who are using fire as a tool to reduce Lehmann lovegrass). Why should scientists and managers differ?

We propose several hypotheses that may explain the disparity between scientists and managers.

Hypothesis 1: the pattern reported by scientists (Lehmann lovegrass increases after fire) may not be a general one. Because experiments are necessarily restricted to a subset of the geographic range of a species, different patterns may be observed in association with different soils or climate regimes.

Hypothesis 2: Many managers, students, and scientists do not recognize that experiments engender more confidence in identifying mechanisms than observational studies or anecdotal efforts.

Hypothesis 3: Many managers and most lay people adhere to a Clementsian view of vegetation dynamics that is inconsistent with contemporary ecological theory. Contrary to the Clementsian view, restoring the disturbance regime (e.g., frequent fires in semi-arid grassland) will not necessarily restore the historic community structure.

Hypothesis 4: Considerable variability in environmental conditions may mask or override the effects of fire regime. Some precipitation patterns undoubtedly favor native grasses more than others. Therefore, managers may observe increased abundance of native grass or decreased abundance of Lehmann lovegrass and incorrectly attribute these climate-induced shifts in community structure to management. Unfortunately, programs that use prescribed fire as a management tool have not monitored vegetation response in sufficient detail to differentiate between climate- and management-induced patterns.

Our research on the Kiowa analyzes community structure of vegetation, mammals, arthropods, and box turtles before and after fire treatment, to ensure that changes in community structure and population dynamics can be correctly interpreted as responses to fire.

STUDY SITE

The study site for our research is in the southern Great Plains on the Kiowa National Grassland Ranger District of the Cibola National Forest in Union County, New Mexico. The area consists of approximately 400 acres (160 ha) of shortgrass prairie that has never been plowed, though it was grazed by livestock until approximately six years ago. Because the area was not cultivated, it did not experience major soil loss typical of adjacent sites during the "Dust Bowl" of the 1930s (Figure 2).

The site is relatively homogenous and nearly flat, with no slopes exceeding 1%. The uniform conditions at the site present an excellent location to evaluate the effects of prescribed fire (Figure

3). The site is an example of the semi-arid, buffalograss-blue grama ecological land type, occurring on a relatively level site of low physiographic and edaphic variability (Figure 2). Elevation ranges from 4,775 ft (1,455 m) at the southwest corner, to 4,830 ft (1,472 m) at the northwest corner. Mean annual precipitation is 15.4 in (391 mm).

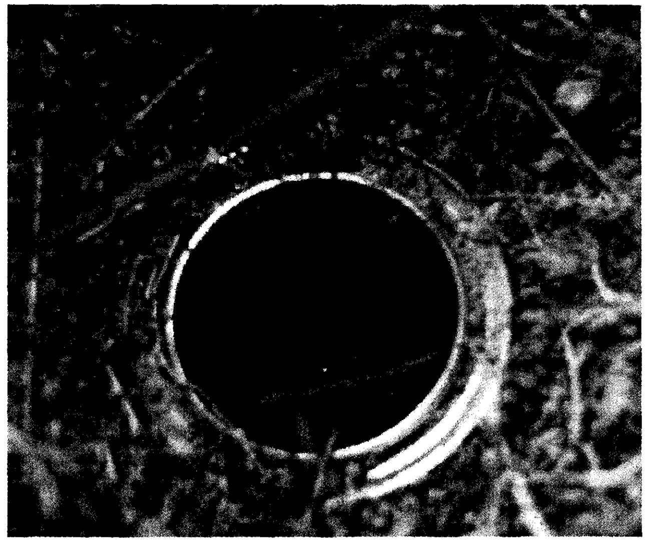

Figure 6. Arthropods are collected with pitfall traps (photo by Paulette L Ford).

Soil and Vegetation

The soil series for the area consists of approximately 5% Dioxice (Acridic Calciustolls) loam, 25% Gruver (Acridic Paleustolls) loam, 35% Sherm (Torrertic Paleustolls) clay loam, and 35% Spurlock (Ustollic Calciorthids) loam (Maxwell et al. 1981). Most of the soil types contain small pockets of other soil types resulting in a mosaic. Overall, the deep, well-drained loam soils support an almost shrubless grassland with a relatively tight sod of pure blue grama (*Bouteloua gracilis* (H.B.K.) Lag. Ex Steud.) and buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.). These species average 85% of the cover throughout the site. Depending on the location on the site, galleta (*Hilaria jamesii* (Torr.) Benth.) ranges from 0 to 12% ground cover; bottlebrush squirreltail (*Sitanion hystrix* Nutt.) 0 to 8%; and sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)0 to 5% (Maxwell et al. 1981). Other grasses include hairy grama (*Bouteloua hirsuta* Lag.), three-awn (*Aristida* spp.), ring grass muhly (*Muhlenbergia torreyi* (Kunth)), sand dropseed (*Sporobulus cryptandus* (Torr.) A. Gray), and occasional annual grasses (Maxwell et al. 1981; Dunmire 1991).

Study

Fire is known to affect a variety of ecosystem structures and processes. In this study, the variables of primary interest include the responses of arthropod, small mammal, box turtle, and vegetation communities, before and after dormant- and growing-season fires on the Kiowa National Grassland. The experimental fire treatments will be applied to the site during the spring and summer of 1997 and every three years for up to 18 years.

The design for this long-term experiment is a completely randomized design with four replicates. The treatments are designed to allow examination of the optimal time interval between fires and include one fire every three, six, and nine years, and an unburned treatment. In addition to fire frequency, season of burning is evaluated by burning half the treatment plots during the growing-season (June to July) and the other half during the dormant-season (March to April). Plots are 140 m x 140 m with at least 60 m of unburned area between all plots. Pre-treatment sampling of box turtle, small mammal and arthropod communities began in 1995-1996 (Figures 4, 5, 6).

Results

Fall 1995, and spring and summer 1996 data collection on the Kiowa National Grassland has yielded over 100 species of arthropods to date (see Ford and McPherson 1996 for a list of species collected fall 1995), and at least 22 new arthropod locality records (state or county). Several individuals of the ornate box turtle (Terrapene ornata) population on the study site have been marked and measured. Small mammals trapped on the site include hispid pocket mice (*Chaetodipus hispidis*), Ord's kangaroo rats (*Dipodomys ordii*), northern grasshopper mice (*Onychomys leucogaster*), silky pocket mice (*Perognathus flavus*), deer mice (*Peromyscus maniculatus*), and thirteen-lined ground squirrels (*Spermophilus tridecemlineatus*).

CONCLUSION

The effects of fire on animal community structure in grasslands are related to trophic relationships and plant community structure. Conceivably, the effects of fire on arthropods influence birds and small rodents that rely on arthropods as their prey base. This in turn will affect larger mammals and raptors. Because these relationships change rapidly as vegetation establishes and grows in recently-burned areas, community structure is temporally dynamic (Ford and McPherson 1996). Change is normal for most ecological systems (Connell and Sousa 1983), which makes understanding and managing ecosystems challenging (ESA 1995).

Land managers face a difficult dilemma as they attempt to incorporate scientific knowledge into management decisions (McPherson in press). Ecologists must accept the challenge of providing sound scientific and relevant information to resource managers in a manner that allows prediction of the effects of various land management techniques (i.e. prescribed fire, grazing) on ecosystems. Some examples of information that can be provided to resource managers from our research include: evaluation of the population responses of arthropods, box turtles, and vertebrates to prairie restoration using prescribed fire; identification of plant and animal species that are fire-dependent, neutral, or exhibit positive or negative responses to fire; evaluation of length of time after fire before positive or negative responses are produced; evaluation of the use of prescribed fire to benefit sensitive, threatened, or endangered plant and animal species; and determination of whether fire suppression or differences in season and frequency of prescribed burns will continue to contribute to population declines of some species (Ford and McPherson 1996).

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Burning Policies of the Natural Resources Conservation Service

Dan Robinett [1,2]

ABSTRACT

I am going to talk about the agency I work for and our workload here in Southern Arizona. We are working with private ranchers on non federal land, to get fire back on those ecosystems, and mesh it with grazing management. One of the biggest problems confronting us is to use fire on a large scale off federal lands. The agency I work for (Soil Conservation Service) is now called the Natural Resources Conservation Service and is in the Department of Agriculture. It was established in the 1930's as a federal agency (that did not own land) to work with private lands owners (people on non federal lands) to help them better manage their natural resources. In southeastern Arizona, we work on about 10.5 million acres of non federal land. That includes state land, private land, and Native American land, in Cochise, Gila, Graham, Greenlee, Pima, Pinal and Santa Cruz counties. In this area we have, including myself, seven range management specialists working at the various offices. Each one of these range specialists works with from 40 to 70 private ranchers. In each of those workload areas, during my career which spans 25 years, only about two or three ranchers, have done or and are doing any prescribed burning. So, that's a pretty low number and I would like to talk about the reasons for that. And, maybe just throw this information out to see what kind of ideas it will generate from people as to how we might improve.

PAST AND CURRENT PRACTICES

The extent of burning in the past 15 years within this 10.5 million acre area ranges from 1,000 to 10,000 acres per year. That's a pretty small percentage. In drought years we don't do any. The ranchers who are practicing prescribed burning, tend to have some characteristics in common. They tend to have very large land areas, which means they have a lot of flexibility. They tend to conservatively stock their land, which means they have a lot of grass left over in June when its time to burn. They are people who have been there a long time, they have had a long tenure on the land, and are from some of the older families. And, they tend to be strong in range management. They are a little more progressive, and are looking to go beyond simple grazing management practices.

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[1] Summarized by Carolyn Painter, Center for Environmental Studies, Arizona State University, Tempe, AZ.

[2] Natural Resources Conservation Service, Tucson, AZ.

These ranchers have to integrate fire management and grazing management. They have to defer areas that they are going to burn to accumulate fine fuel. Typically on our desert grasslands that means you have to defer a piece of ground out a year or two. After the fire, they have to defer from grazing for at least two growing seasons to allow the plants that we are trying to encourage to replace the plants we have removed. This has a cost. For some comparative figures, here in southern Arizona we value an Animal Unit Month of grazing to a rancher that owns his ranch at between $2 and $3. An Animal Unit Month of grazing is enough forage to sustain one cow for one month. On a 2,000 acre area, with a carrying capacity of ten animals to the section, the pasture is providing the rancher about 375 Animal Unit Months (a year) of grazing. At $2.50 an AUM, that's worth about $940. To defer that pasture for the three years needed to accumulate fuel and get the benefits from the prescribed burn, the grazing value equals about $2,800 dollars.

Other costs associated with the burn include construction of fire lines, and the actual cost of burning. Usually they do the burning by themselves. We may have help from various federal agencies that might be near by. State Land Department has helped us, as well as the BLM, Forest Service, and Fish and Wildlife Service. But, the actual cost to the rancher on these burns usually comes out to anywhere between $2 and $3 an acre. That doesn't sound like a lot of money, but when a ranch is making $50 a cow a year out there, that is a lot of money. What are the returns to the rancher from prescribed burning? What kind of benefits do they need to make this a decent investment? If an Animal Unit Month is worth $2.50, with even a low rate of return on that 2,000 acre burn, the rancher would have to generate an additional 1700 or 1800 Animal Unit Months of grazing over the life of the practice (seven or eight years) to make a 2% or 3% return on the investment. In my experience, that happens very seldom. We have a few plant communities where we have enough shrubs that are easily killed by fire and it is easy enough to get grasses back in their place to generate that much additional carrying capacity. The prescribed burns are not very cost effective practices, and that is one reason why we are not seeing a lot of ranchers doing it.

There are a few other benefits to prescribed burning that can figure in. They have not been quantified very well. One of them includes making it a little easier to find livestock and handle them. With a lower density of brush and cactus out there, sometimes it's a little bit easier to round them up, and move them from pasture to pasture. Livestock do a little better on burned areas for a few years. Increased performance and increased calf crops can result. That has not been quantified that very well. Even those returns are pretty minimal compared to the cost of investment.

There are some real risks associated with prescribed burning. Ranchers assume most of the risk themselves. There is a risk involved in damaging the basic resources. We work closely with ranchers to try to minimize those risks. But, there have been some prescribed burns that have been done at the wrong time, on the wrong sites, in the wrong years. Mistakes are going to happen. We are learning and as time goes by, we can improve our skills to minimize the risks. A good example was the drought last year. I think that in these lower elevation grasslands, when there is a real wet winter, the next summer season is going to be real dry. It has certainly been that way for the last fifty years in southern Arizona. That is just one simple thing to remember - don't burn after a real wet winter, because it will probably be a dry summer and the fire effects will be bad. There is a liability that there is going to be some resource damage. There is a real liability in loss of property and loss of life. Ranchers on private lands can buy insurance that can help spread that risk, but that is another cost associated with the fire.

In the last ten years, I've had two ranchers work with me to try to do prescribed burning, who had all the right qualifications. They had the right plant communities, the right soils, the right kind of conditions to make it a good tool, they had the right management philosophy, the right kind of stocking. Everything was good. But, their ranches happened, unfortunately, have some private land sold off years ago before they bought them, and now there are some rural subdivisions out there. The potential risk to light a fire out there when there is a 200 acre subdivision with homes and property is just way too great. That is something we need to think about here in southeastern Arizona. This has really affected the use of this tool in many areas in southern Arizona.

We can have unfavorable climatic events after a fire. Drought is certainly a factor. In some plant communities, if the fire is followed by dry summers and warm winters, chances are we are not going to replace the cool season shrubs we've burned with warm season perennial grasses. Chances are the shrubs will come back in five or ten years. We are making some inroads at predicting what climate will be after fire, but we do not yet have the skill to do that reliably. Another risk is smoke pollution from fires. Burning around big population centers like Tucson is a risk, and you must know what your smoke is going to do at different times of the day and the night. When burning a large area, you may produce smoke for a few days. It is not a good thing to pump a lot of smoke into a big metropolitan area and have a lot of complaints. Also, it is a serious health hazard for some people. A lot of those people who are moving out here are elderly people who may have respiratory problems.

OPTIONS FOR THE FUTURE

What are some options that we might consider to increase reintroduction of fire on non federal rangelands? I think any option should attempt to reduce the costs to the land owner. I think an option should transfer the liability to groups, instead of the individual. I think these options should attempt to reduce the risks. Maybe a way to do that is through groups where there are a lot of people with a lot of skills who can work together. Maybe some of these options should compensate ranchers on non-federal land for the added public values and benefits that happen with prescribed burning. Some options might include things like grass banking, cost sharing, and maybe even some monetary reimbursement for improved wildlife habitat conditions.

I think the agencies and landowners need to work together in Southern Arizona, including non federal areas, on plans for large landscapes to manage wildfires. In some of the mountain ranges, grazing is limited to the winter season. If there is fuel enough to burn the next June and a wildfire occurs, it is automatically rested from grazing the following summer. Grazing in the dormant period is usually not a negative thing. This reduces considerably the cost to the rancher.

Wildfire management plans shift the liability from individuals to groups like land management agencies. I think that's something we should pursue and try to put together for not only our federal land areas, but our non federal land areas. Also by planning for fire management in larger landscapes we can go through the process of consultation for special status species, cultural resources, etc. on a large area one time, instead of going through the process every time a small prescribed burn is done.

Ranching in Santa Cruz County A Summary of Research Findings

Madelene Orton[1]

ABSTRACT

The goal of this document is to summarize the research findings of twenty graduate students who studied land-use issues in Santa Cruz County as part of a seminar course called "The Use and Management of Arid Lands." The research was conducted during the Spring semester of 1996, under the direction of Dr. Charles Hutchinson, a professor in the Office of Arid Lands at the University of Arizona's College of Agriculture.

INTRODUCTION

The purpose of the course was to introduce students to key concepts and issues related to land management in the world's arid and semiarid zones. Themes such as ownership (both private and public), tenure, access, leases, regulations, inter-generational transfers, and the impact of various policy agendas were explored. Rather than studying each of these topics in the abstract, they were examined in the specific context of the cattle industry in Santa Cruz County, Arizona.

The goal of the course was to develop a picture of land-use dynamics within Santa Cruz County and to explore how proposed alternative reforms in public policy might affect established patterns of land-use, especially grazing. The policy agendas of two land use policy perspectives (the "wise-use" movement and "environmentalism") were compared and contrasted in terms of their philosophies, histories, and potential impacts on the economic, social, and environmental future of land management in the county.

METHODS

The course was divided into four parts. It began with a series of lectures, field trips, reading assignments, guest speakers, and panel discussions that were designed to introduce students to land-use issues currently being debated in Santa Cruz County.

Students were then divided into six teams to study the cattle industry within the county and how it might have changed over the past 80 years. The six teams were responsible for gathering specific types of data. The first three teams were assigned to learn about the physical aspects of the land being studied, while the other three teams focused on cultural aspects of the area.

Team 1 was assigned the task of gathering existing published data on the land itself, including information about elevation, soil types, water sources, and precipitation.

Team 2 was put in charge of characterizing land-use. Published information about land-use categories was to be supplemented by field surveys and personal observations.

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Team 3 was instructed to design and conduct a survey to determine the condition of the land. Contrasts between sites were to be studied, in terms of differences observed in vegetation types, ground-cover, and severity of erosion indices.

Team 4 was responsible for understanding the demographic make-up of the county. Published census data enabled them to construct a profile of the general population, age structure and income of the residents of the county.

Team 5 was accountable for learning about patterns of land ownership, zoning and taxes. They attempted to find out how many ranches existed in the county, who owned them, how much they contributed to the tax base, and whether or not agricultural lands had increased or decreased over time.

Team 6 was asked to develop an understanding of ranching practices, and to identify the major issues and concerns facing the cattle industry today. They designed a survey questionnaire and conducted personal interviews with ranching families to learn about the structure, economy, and constraints on individual ranching operations.

Each team was then required to present their results to a general meeting of the seminar. Half way through the course, students were re-assigned to one of two new groups, each representing an alternative perspective to land management. One group would take the "wise-use" position of local control and privatization, while the second group would represent the "environmentalist" position of public control, non-consumptive uses, increases in fees, and stronger enforcement of existing regulations (Drake, 1996). Each group examined a variety of policy scenarios from their respective points of view, and assessed the types and magnitudes of impact that these policy scenarios might have on the future of Santa Cruz County.

Finally, based on what they had discovered during the course of their research, students were required to choose a topic that was of special interest to them and prepare a written report. Some students chose to present the information gathered in one of the original six research teams, while others opted to write about the policy alternatives they had examined as either an "environmentalist" or a "wise-user." Still other students chose to write about particular land-use issues or patterns discovered, such as urbanization, water law, or absentee ownership. Most reports were written by individuals, but a few represented a group effort.

A total of fifteen student research reports were submitted. An annotated bibliography (which summarizes the contents of each) is attached to this summary document. The original reports have been organized into a binder which may be accessed upon request, by contacting Dr. Charles Hutchinson, in the Office of Arid Lands Studies: 1955 E. 6th Street, Tucson (1-520-621-8568).

The remainder of this paper is devoted to a discussion of the major themes and issues that emerged from research conducted during this seminar. I hope that I have captured the essence of the individual reports that I summarized, and that the conclusions I have drawn are shared by most of my colleagues. Readers are encouraged to offer their feedback, corrections and complaints to the author.

THE PROBLEM

The grasslands of Santa Cruz county have been enjoyed and utilized by humans for thousands of years. In his essay entitled "Human Impacts on the Grasslands of Southeastern Arizona," Conrad J. Bahre (1995) traces this historical relationship between humans and their environment. Archeological records suggest that ancient people known as the "Clovis" hunted large grass-eating game such as bison, camels, horses, and mammoths eleven thousand years ago. Various other Native American civilizations lived in the region from pre-historic times until the Spanish occupation of the early 1500's. Human and wildlife population counts during that time, however, are only estimates. Furthermore, scientific and ethnographic records are incomplete. The extent to which these people relied on the grasses for sustenance and their impact on grassland ecology is therefore essentially unknown.

Cattle were introduced to the area by early Spanish settlers in the 1500s, but widespread ranching was discouraged by Apache hostilities. Cattle populations were clustered primarily around the rangelands adjacent to the presidios, missions, and villages. After Mexican Independence in 1821, several land-grants were issued by the new government. Each of these privately owned parcels of property supported thousands of cattle, but Apache raids, attacks, and harassment continued to discourage large-scale settlement of the area (Bahre, 1995).

The Gadsen Purchase of 1853 shifted ownership of modern day Arizona from Mexico to the United States. The new owners established various army posts in a concerted effort to assert control over the Apaches, and built a railroad to transport the resources (such as copper, silver, and cattle) that were now available for exploitation from the area. Cattle ranching in the region did not become widespread until the 1870's. The cattle industry flourished, but changes to the grasslands caused by overstocking and overgrazing were becoming apparent (Bahre, 1995).

To remedy this apparent environmental degradation, the U.S. Forest Service established reserves of rangeland in southeastern Arizona, incorporating them into what is today known as the Coronado National Forest. The Stock Raising Act of 1916 encouraged cattle homesteads on privately owned land. Through a system of low-cost permits, ranchers could also raise cattle on large tracts of public land, which they leased from the government. Competition for available forage on public land increased, so many cattle ranchers scrambled to accumulate the remaining patented parcels. The ranching industry was encouraged to grow, as a balance between maximum cattle production and environmental health was sought. Furthermore, in 1934, the Taylor Grazing Act implemented a system of grazing districts and permits to conserve and improve forage resources. Cattle-grazing dominated land-use in Santa Cruz County for the first half of this century. The number of cattle in Santa Cruz county have remained fairly stable, but the number of large, privately-owned cattle ranches increased until the 1950's (Bahre, 1995).

Changes in land-use patterns, however, emerged after World War II when advances in technology (such as the air-conditioner and efficient, low-cost water pumps) permitted increasing numbers of people to the region. A rapidly growing population placed increased demands on the finite amount of public and privately owned lands available in Santa Cruz County. Some large ranches were sold and subdivided for urban development. As privately owned land became more scarce, land prices increased. Ranchers who had conducted their business with little outside interference for decades, now faced increased scrutiny as urbanites, recreationists and environmentalists asserted their rightful claim to the use of a diminishing resource. A myriad of pressures and interest groups now challenge the ranchers' ability, and even right, to exist. Conflicting opinions of what might constitute "best use" of a finite resource have heightened tensions between land users, land owners, land management agencies, and outside interest groups. The future of land-use in Santa Cruz County will be decided by the manner in which these conflicts are resolved (Cowles, 1996).

Conflicting Land Use:

Although ranching has been the traditional use of Santa Cruz County grasslands for the past hundred years, it is not the only land use option. Recreation, environmental preservation, urban development, and industrialization are four alternative land-uses that have increased over the past few decades. Their feasibility on private lands, is to a great extent, determined by market forces. If the activity is economically viable and a demand exists, it will probably survive.

The recreation industry, for example, is sometimes seen as a viable economic option for private ranch owners. Ranchers have been known to supplement their operations by offering ranch tours, big game hunting, horseback riding, cattle drives, or bed and breakfast services.

Urban development and industrialization are two other viable economic alternatives to ranching on private lands. There are strong market forces pushing for development in Santa Cruz County. The scenic landscape, mild climate, sparse population, relatively low real-estate prices, and convenience to the US-Mexico border markets have attracted developers, industrialists, and retirees to the county. A shift of land ownership into the hands of people who live outside of the county seems to indicate that these properties will be developed in the future (Zheng, 1996). The tax structure of the county also encourages urbanization. Agricultural acreage is taxed at a significantly lower rate than residential parcels. Grazing land is assessed at a value of $20 per acre annually, residential parcels at $116, and commercial acreage at $1494 (Ellman and Kliman, page 12). There seems to be little incentive to discourage growth. For some ranchers this may mean new financial opportunities, while to others it represents a threat to traditional rural lifestyle and communities.

On public lands, land-use is controlled by public agency mandates, rather than market forces. Public grazing lands are controlled by one of three agencies: the US Forest Service, the US Bureau of Land Management, or the State Land Trust. All three agencies attempt to balance the conflicting interests of many users by incorporating a 'multiple-use' formula of land management. Grazing is but one of the multiple uses allowed on these lands. Ranchers must share the use of the land they lease for grazing with recreationists, the timber industry, and wildlife conservationists. Not surprisingly, the various groups who have access to public lands have different opinions on whose use constitutes the "best use" of the resource (Rosenbaum, 1995).

Conflicting Agendas

Two distinct policy agendas have emerged to serve the needs of the conflicting interest groups who vie for control of public lands. First is the policy perspective of "environmental preservation." Sometimes referred to as the "environmental movement," this agenda stresses the importance of preserving wilderness, wildlife habitats, endangered species, biodiversity, and pristine natural landscapes. The environment is seen to have intrinsic value "for nature's sake" and an emphasis is placed on nurturing caring relationships between humans and the land. A key concept to the environmental movement is that of sustainability. The movement prefers a centralized authority in the form of government agencies to ensure that land resources are protected for the future. The chief complaint of those who oppose this perspective has been that the preservation of nature has historically been done at the expense of humans. What is lacking, critics argue, is a focus on economic livelihood. Furthermore, many critics of the environmentalist movement believe it is anti-people, anti-private property, and in favor of a "democratic police state" (Black, 1996).

The "wise-use movement" emerged in the late 1980's in direct opposition to the environmentalist movement. Proponents of the new agenda represent the various "users" of public lands who want to see this resource base opened for further exploitation. Their philosophy is primarily anthropocentric, and stresses that man's use of the resource and the economic contribution of the resource are of the utmost importance (Black, 1996).

Many wise-use followers are working people who have strong economic ties to the public lands, including ranchers, farmers and loggers. Many believe that they represent the original and best environmentalists, who have proven themselves as responsible stewards of the land. They argue convincingly that it would not be in their best interest to degrade the resource upon which they depend for their livelihood. Some argue that our public lands are being under-utilized and that the resource base is infinite. Forests left to nature are seen as improperly managed (Black, 1996).

Conflicting Science

Not surprisingly, the various interests groups mentioned so far have turned to science to support their claims. Environmentalists argue, for example, that environmental restoration is needed to reverse generations of neglect and abuse (Cowles, 1996, pg 1). They might similarly describe the condition of the rangeland as productively depleted (Black, 1996, pg 14). Some may blame cattle for this degraded condition of the range, while others blame urban development.

Beaumont (1993) suggests that long-continued grazing has changed the vegetation cover in many regions, rendering the ecosystem less efficient than it used to be at providing food in times of drought. Cowles (1996, pg. 6) suggests that "...long-term directional changes, such as increases in woody plants in certain rangeland, the degradation of riparian wetlands, and the invasion and spread of exotics, have resulted from sustained and/or catastrophic human disturbances: overstocking and overgrazing of cattle, fuel wood cutting, wildfire suppression, agricultural clearing, construction of irrigation works and roads, logging, railroad construction and the intentional or accidental introduction of exotic plants".

Some people believe that cattle are inherently wrong for the ecosystem, and argue in favor of replacing them with native species of herbivores. Cowles (1996, pg. 6) raises the question: "If cattle have changed the landscape, should the emphasis be on returning the vegetation cover to some earlier condition and implementation strategies that would assure this goal, or should the management techniques for rangeland be modified to mimic natural systems?". The negative impact of cattle on rangelands occurs because "... livestock selectively defoliate the available herbage rather than indiscriminately consuming herbage according to its availability" (Walker, 1995 as cited by Black, 1996, pg 5).

Carmody (1996, pg 1) warns that it is easy "to take the path of least resistance" and follow the underlying assumption made by some environmentalists that grazing and cattle are bad for the land. She urges us to question the authority of such claims, and to critically analyze the available data.

Some insist that cows are actually good for grasslands, since they are able to harvest a natural resource that would otherwise go un-utilized (Hutchinson, 1996, as cited by Black, 1996, pg 1). Some insist that grazing is necessary to reverse the loss of riparian habitat, biodiversity and recreational opportunities on public and private lands (Daggett, 1995). One member of our class suggested that perhaps cattle are not the problem, but rather the limitations of the soil itself. "The only way to overcome the limitations of soils in Santa Cruz County is by keeping the plant's ecosystem healthy and by enhancing plant health and growth ...." (Al-Maharwi, 1996, pg 7). He cites Odium (1993, pg 95), who states that moderate grazing can actually enhance the quality and quantity of the plant species by enriching the soil through natural processes. The dung of cattle is a natural fertilizer, he argues, that contributes to soil fertility. Light to moderate grazing maintains grass root vigor and helps to maintain water and nutrient cycling needed for healthy grass growth and build-up of organic matter. It also increases energy flow by promoting vigorous leaf growth and healthier root systems, which support micro-organisms and other underground soil life. Grazing provides the additional benefits of seed dispersal, increased biodiversity, stimulated plant growth, and enhancement of the whole plant community (Al-Maharwi, 1996, pg 7).

Reports also differ on whether or not America's rangelands are healthy or not, and whether or not removing the cattle (or at least reducing the herd size) will help the condition of the vegetation. Range experts also disagree on the best grazing management methods. While some argue in favor of rotational grazing, others herald deferred grazing. Still others stand behind the controversial practice of Holistic Range Management.

Finally, there is a great deal of controversy about the impact of grazing on endangered species. While some environmentalists claim that endangered species are threatened by grazing, and hence grazing should be halted on public lands, ranchers and biologists argue that when an endangered species is found on a ranch, the environmental conditions of that ranch must be favorable to that species. It is interesting to note that quite a few endangered species are found on both public and private ranching land.

The opinions of scientists, therefore, sometimes conflict. Yet many agree that there is such a condition as "over-grazing" and that a carrying capacity for the land exists. What the ideal stocking rate should be, for a particular piece of land, of course, is also the subject of debate. Erosion is often an indicator of a range that has been severely overgrazed. Few would dispute that overgrazing leads to erosion. What is arguable is whether the current rangeland of Santa Cruz County is being overgrazed.

Our land-condition team (group 3) addressed this question in their report called "An Assessment of the Physical Condition of the Land in Santa Cruz County" (Carmody, et al, 1996). This paper reports the findings of a survey that was conducted during the Spring of 1996, in which areas of differing land ownership classes (USFS, BLM, State, and Private) were visually assessed to determine current vegetative composition and soil stability. The objective was to "evaluate how different management (practices) can influence vegetation while the primary use (livestock grazing) remains constant." Traditional grazing methods and rangeland management practices were observed, as well as a more controversial practice, Holistic Resource Management (HRM). A variety of sites were chosen for the study, and satellite imagery was employed as a tool to supplement visual ground-studies. Broad zones of forage were identified and mapped using a method developed by Anderson and Currier (1973). The land studied was scrutinized for signs of active erosion, such as rilling, litter dams, pedestals, and gullying. Good ground cover was observed consistently, as was soil stability (Carmody, et al, 1996). The authors insist "we could not find overgrazed land where cattle were being raised." The researchers did, however, find indications of soil erosion (particularly gullying and the presence of desert pavement) where grazing was not currently practiced. Areas dominated by small acreage parcels and suburban development were particularly affected. The authors concluded that urbanization is the most threatening disturbance to the current range condition, and that there was no marked difference in vegetative composition between the various land ownership classes where grazing was being practiced (Carmody, et al, 1996).

So what are the ramifications of so many differing opinions? Who should we believe? Is grazing an exploitive industry that leads to the depletion of a precious shared resource? Few would argue that the ranching industry has contributed to the economic well-being of county and state economies, but do these financial contributions outweigh the potential environmental costs of grazing? At stake are issues at the very heart of the dispute between environmental preservationists and the wise-use movement. Which do we value more? Preservation of a species or a way of life?

If an endangered species is found on public lands, which is the prudent course of action? To assume that cattle are harmful to that species, and halt grazing until evidence can be gathered to the contrary? To do so may save the species from the negative influences of the cows. But what happens to the rancher? Oftentimes, the rancher's only income is derived from the cattle he raises on public lands. To halt grazing in such a scenario will mean certain financial ruin for the cattleman while the study is being conducted. If the study concludes that the cattle and endangered species were not at odds with each other after all, should the rancher be reimbursed for his lost income? And what if no action was taken until further study was conducted? Could it then be too late for the species which is now not endangered, but extinct?

Cowles (1996) points out that critical information is currently incoherent, lacks standardization, is difficult to collect, or is unavailable. Coordinated efforts are needed, he argues, to assess what is valued, set realistic priorities, and gather further scientific data. He also urges research efforts at all levels, not just where there is a current threat.

Clearly, the advice to conduct additional research should be weighed against the costs and time constraints of such work. Scientific studies are often inconclusive, and are easily swayed by the perspectives and vested interests of those conducting the research. Some would argue that extinction is a natural process, but others point out that the extinction of too many species is happening at an alarming rate, unparalleled in human history. Such rapid changes in our fragile ecosystem could threaten biodiversity to a level whereby humans themselves become endangered.

Should Ranching be Preserved?

Ranchers of Santa Cruz County have survived a long time. The survey conducted by Group 6 of this class (Orton, Eisenberg, and Leon, 1996) contributed significantly to our understanding of current ranching operations in Santa Cruz County. Ranchers have a heritage of success in this activity that has been shared for several generations. The specialized knowledge that has been passed through the generations has kept the range healthy and the resource viable. Despite an extended drought and a depressed market, the ranchers are still in business. This is partially due to their own resourcefulness. They are willing to pursue outside income sources when necessary, and have investigated creative means to protect their assets, including land trusts and conservation easements. Equally important are the facts that the ranchers are well educated, organized, politically savvy, out-of-debt, and committed to the ranching lifestyle. Another factor that contributes to their success is the flexibility of the permitting system, which allows them to apply for a "non-use" status during hard times (without giving up their lease completely) and which gives heirs priority-status in securing the permit that has been in a family for generations. In spite of past success that the ranching industry has enjoyed, the combination of several forces paints a bleak picture for the future of ranching in Santa Cruz County.

The most stressful situation that the majority of ranchers experience is the relationship they have with the myriad of public agencies with whom they must work. The frustration they have expressed is due to the lack of control they feel in the day-to-day management decisions for the land they lease. From their perspective, the multiple-use philosophy allows too many people with conflicting interests a say in their business. They resent this because they feel they possess the necessary skills and knowledge to make responsible decisions about the land, without outside intervention. Decisions to reduce their stocking rates can be made without their consent, and with very little advance warning, forcing them to go out of business or suffer economic hardship.

Other economic forces are also at work to discourage the continuation of ranching as a lifestyle: high estate-tax rates could potentially force every generation to lose a portion of their land, high real-estate prices could preclude newcomers to the industry, and environmental activism threatens a diminished income. In the short-run, an important economic constraint they face is the existence of an oligopsony: too few buyers for their product. The handful of meat packers that control the industry and a single auction house in southern Arizona have created this situation. Beef prices have gone down steadily over the past year, but some ranchers believe this is part of the normal business cycle, and that these prices will recover in the future. Even Mother Nature seems to be conspiring against the ranchers through her long-term drought. Eric Ellman and

Susan Kliman (1996, pg 18) conclude: "The cattle industry is in crisis with ranchers finding it increasingly difficult to survive. Cattle prices continue to fall, fees for grazing lands continue to rise, and payment of the capital required to run a ranch remains constant".

Stuart Black (1996, pg 6) suggests that we "consider the impact of courses of action on the environment". So let's consider the impact of discouraging ranching. "To many environmentalists, the goal is to stop ranching at all costs. Unfortunately, those costs have all too often resulted in the conversion of hundreds, or even thousands of acres of ranch land to large scale housing developments. The environmental worth of such transformations (from ranches to urban development) is dubious. There is a serious question of whether the typical high density residential development is actually a 'wiser use' than the ranching it replaces " (Ellman and Kliman, pg 15). "Development of private lands is not a 'wise-use' (of the grasslands). Private lands are currently being developed into suburban acreages ... (where) the owner is more appreciative of the dollar ... than the inherent values of the rangeland resource. The undeveloped private land in these suburban regions is also being utilized in what appears to be a 'graze it hard and produce as much beef here until it sells' fashion" (Renken, 1996, pg 7).

Based on our research, then, we have concluded that the most threatening disturbance to the current range condition in Santa Cruz County is urbanization, not cattle grazing.

Common Ground:

The prospect of a sustainable future for Santa Cruz County will depend on the ability of the multiple land users to work cooperatively to resolve their differences. One way to approach this conflict resolution process is to scrutinize the vast array of opinions, beliefs, scientific evidence, practices, and needs: for themes held in common by all players. Not all needs can be met, of course, so careful prioritization and planning will be required.

First of all, we advocate the re-examination of the rather arbitrary (and emotionally charged) labels of environmentalism and wise-use movement. We would like to suggest that the aims of these two groups are not diametrically opposed, nor are they mutually exclusive. We doubt, also, that ranchers fit neatly into one category or the other. The terms simplify a very complex spectrum of issues and values into polarized opposites, suggesting an adversarial relationship where one should not exist. These "narrowly defined identities ... separate two groups who have much to gain from listening to each other and working together" (Black, pg 13).

Ranchers, environmentalists and wise-users have much in common: all three groups consider themselves to be good stewards, with a strong land-ethic and a desire to keep the resource-base healthy; all three groups have ties to the historical movement known as conservation which values sustainable resource development; and all three groups have an intimate knowledge base of natural history and ecological systems. They share common concerns, questions, interests, and reading lists. When they sit down to talk with each other one-on-one, many report how much alike they are. So it is not surprising to learn that "increasingly, cattlemen and environmentalists are on the same side of the fence, forming coalitions to preserve the open spaces they both cherish" (Ellman & Kliman, pg 1).

Ranchers have a caring relationship with the land that transcends generations. Although it is in their best interest to preserve the land, many face practical constraints that prohibit preservation efforts. If ranchers are not encouraged, they face going out of business. Current market conditions indicate that when a rancher is forced to sell his property, it is most likely the developers who will buy it, not other ranchers. When this happens, vast open spaces are fragmented into suburban lots, often causing soil erosion and vegetative loss in addition to visual blight. The continuity of those open spaces is then compromised. Until science proves definitively that ranching is inherently negative for an ecosystem, the ranching industry should be encouraged to continue in Santa Cruz County. Policy should be examined for the effect it has on individual ranchers, and re-written to recruit and reward ranchers for helping to preserve or to create biodiversity. For the time being, ranches constitute a "wise-use" of the existing grassland resource in that they preserve open spaces and the continuity of the range.

Policy Scenarios:

We believe that future policy should recognize the important role ranching plays in preventing further fragmentation of open spaces. Furthermore, we recommend that future policy focus on nurturing environmental responsibility and sustainability rather than punitive measures. A variety of policy scenarios were examined by the members of this course, and several are discussed below, in the context of encouraging the ranching industry.

Endangered Species Act. The current structure of the Endangered Species Act threatens the autonomy of the ranchers. An outside environmental group, under the guise of wanting to save a species, can stop a grazing operation until a thorough study has been conducted. Ranchers are put on the defensive by being forced to prove that a species is NOT on their land or NOT threatened. This can cost them a great deal of money for lawyers' fees, the hiring of scientists, and lost income due to a reduced herd size. The ranchers therefore see the presence of a purported endangered species on their land as a threat. This could potentially put the rancher and the endangered species in an adversarial relationship with each other, a counter-effect that was probably not foreseen by the authors of the Endangered Species Act (Orton, et al, 1996). One researcher gives us an example of a current lawsuit by the Southwest Center for Biodiversity which threatens the continued operation of 160 ranchers (Lindsey, 1996). As many as 57,000 acres could be affected by this one lawsuit. "Loss of the suit would put them (the ranchers) in the position of paying for their water. At the going rate which cities pay for water, ... cattle ranching would likely become uneconomical, and the incentive to sell to private developers would be irresistible" (Ellman and Kliman, 1996, pg 15). Perhaps environmentalists and wise-users alike could find a common cause in re-writing portions of this legislation.

Grazing Fees. Grazing fees can be raised with little or no warning, putting unexpected financial strain on a small ranching operation. Some folks argue that overall grazing will not be substantially decreased by raised fees because larger operations will simply replace the smaller ones on public lands (Renken, 1996).

An equally convincing counter-argument, however, is that raising fees encourages the continued fragmentation of rangelands. No ranching operation can obtain a lease to graze on public lands unless they own adjacent private land. If a small ranching operation is forced off of public lands, it may not own enough private holdings to sustain an economically viable herd. The rancher may be forced out of the ranching industry altogether, selling his private holdings to the highest bidder. Current real-estate prices are too high to encourage profitable sales to another rancher. The likely buyer will be a developer whose motive will be to sub-divide and fragment the parcel.

Private leases are another option for ranchers. If public land is no longer available to a rancher, he could secure a private lease from a neighbor. Private leases tend to be expensive, and require geographical proximity of the two ranches. Currently there is some incentive for private landowners to lease their land to a neighbor: they get a substantial tax break for putting their land into "agricultural status" on the tax roles. Ranchers also report relatively hassle-free negotiations with one landlord, compared with multiple landlords on public land (Orton, et al, 1996). Furthermore, private lessors tend to offer more services with the lease. "The grazing permit on federal land is simply a permit to put cattle out. The federal government pays for the materials for improvements, but the ranchers construct and maintain them. The private leases (by contrast) provide these structures and maintenance, and therefore cost more. Therefore, raising federal grazing fees is like camping on BLM land without facilities, but paying the same as staying at a KOA campground" (Renken, pg 8). The biggest problem with private leases, then, is that market forces are always providing a temptation or pressure on private land owners to sell. When the market conditions are ripe, or when the land owner has the need to raise cash, it will be too easy to sell the land to developers, continuing the process of fragmentation.

Intergenerational Transfer. Most ranchers we spoke with expressed a desire to keep the ranch in the family. None expressed a desire to sell off their property, although they were clearly aware of the pressures to do so.

Those who bought or inherited the land years ago face substantial capital gains taxes if they choose to sell. And estate taxes add an additional worry. "As the older generations of ranchers die, their heirs face the harsh realities of estate taxes. Many have discovered that payment of the 55% estate tax on properties valued above $600,000 requires subdivision of their land, a step which may destroy the viability of the enterprise.... This dilemma could topple the single largest ranch in the San Rafael Valley, and begin the domino effect that has consumed so many other rolling grasslands" (Ellman and Kliman, pg 15). One obvious solution would be to repeal both taxes, or to raise the financial brackets to a level which reflects current price structures.

Cluster Development. Stricter zoning is another suggested alternative to unplanned urban development. One option would be "to construct a few very expensive homes ... in a cluster development with open land, at least partially dedicated to grazing, surrounding them. This type of development is perhaps the most sustainable option because it minimizes infrastructure requirements and it maximizes open space" (Ellman and Kliman, 1996, pg. 19). This option is seen as a compromise between environmental and economic interests. Some would argue, however, that it is a short-term solution, and has limited potential. What will happen, for instance, when the rancher runs out of land to devote to such clusters? Every generation is still faced with a stiff estate tax which often forces heirs to sell-off their private land holdings until there is not enough land left to ranch. Two other options that have been discussed are to sell the ranch to the US Forest Service or the Nature Conservancy while retaining homestead rights and conservation easements.

Water: A long-standing tenet of western water policy has been the notion that whoever controls the water controls the range. Ellman and Kliman (1996, pg 4) discuss the Groundwater Management Act (GMA) of 1980 which "expanded and strengthened previously existing regulations intended to curb the fraudulent practice of selling subdivided land without adequate water" (Eden and Wallace, 1992).

Curt Reynolds (1996, pg 15) also investigated water policy in Arizona. What he reports is that " ... it appears ranching is less destructive to the environment than urban subdivisions, as demonstrated by the fewer number of boreholes drilled by ranchers". The Groundwater Management Act, he claims, is ineffective as a deterrent to growth, however, since it does not effectively control the drilling of small bore holes, and because enactment of the policy occurs too late. He argues that prior-appropriation water law is therefore outmoded. Furthermore, he warns us that if an area is outside of an AMA, groundwater mining is still allowed. This affects nearly 50% of Santa Cruz County. "If stronger groundwater laws are not enforced in the future, large numbers of boreholes will be drilled for urban expansion which ultimately will destroy most of the fragile arid and semi-arid ecosystems of the southwest". Strengthening existing water legislation, including local zoning ordinances, he suggests, may be one way to curb urban development and to preserve open ranges.

Agencies. While some ranchers argue that certain federal and state agencies are not very "user-friendly," most would agree that they have been encouraged or educated at one time or another by an outside agency. Most ranchers appreciated the help received by organizations such as the NRCD (Soil Conservation Service) and the University of Arizona's cooperative extension. A great deal of frustration was expressed, however, over the "new" Forest Service (since the 1970's) and the Fish and Wildlife Service. Ranchers felt patronized and ignored, and resented the lack of autonomy they experienced when dealing with these agencies. Perhaps the natural resources in the area would be better served if a congenial working partnership between agencies and ranchers were encouraged.

Local empowerment. The ranchers themselves have given us a glimpse into possible strategies for preserving their way of life. Grassroots efforts to establish priorities for land-use have sprung up all over the county. Organizations such as the San Rafael Valley Association are working to minimize the chances of high density development by requiring developers to re-plat and get prior approval from the county before building. They are making it difficult for developers to obtain the "agreement of the majority of the adjacent neighbors" by organizing resistance to such activity (Ellman and Kliman, pg 18). The Sonoita Valley Planning Partnership is establishing priorities such as wildlife habitat preservation, and is working with other organizations to set common goals and objectives. Some ranchers are working with the Sonoran Institute to set up land trusts and conservation easements in order to protect their lands from inter-generational fragmentation. Finally, traditional ranching associations, such as the National Cattlemen, the National Cattle Growers, and the Cowbelles provide lobbying support and a mechanism through which ranchers can keep abreast of changes in legislation.

FUTURE STUDIES

The research conducted by the students who participated in this seminar was by no means exhaustive. We recognize that due to time constraints and limits to expertise, many important research questions remain unanswered. We would like to recommend, therefore, further study in several areas:

First, we regret that we were unable to establish the total data-base of ranchers in the county. Tax records provided us with a list of over 800 parcels of land with an "agricultural" status. Yet we had no way of determining which of these parcels were actual working ranches. Some may have been bought for speculation (as evidenced by absentee owners), some may have been sub-divided acreage, and some may have been hobby ranches. We were able to obtain two additional lists of ranching operations from the County Assessor's Office, each containing over eighty ranch names. When the two lists were compared and contrasted, however, we found discrepancies which left us wondering how accurate these lists were.

We would also like to know if the eleven ranchers we interviewed in our survey represent the "average" situation in Santa Cruz County or Arizona. They were selected using a technique that makes generalization difficult. We were curious about the "new" buyers of private grazing lands that several ranchers described as "dudes" ... presumably hobby ranchers from the east. Their perspectives are not represented in our study.

We would also like to see additional research conducted on the social and economic contributions that ranching provides to Santa Cruz County. If ranching were to fade from the landscape, would it be missed? More research is needed, we believe, on the legislation that affects ranchers. We were just beginning to understand the positive and negative impacts of a few pieces of legislation, but know we did not begin to do this subject justice. Nor did we adequately survey the land-management agencies to understand their policies and perspectives. We also believe that a more in-depth review of the existing literature needs to be made, to understand what is considered to be the "best science" related to grazing practices.

One researcher (Salo, 1996) would like to see additional information about the State Land Trust. She wonders about the boundaries, sizes, actual A.U.M.'s, and who the leaseholders are. She recommends that we build GIS maps of a variety of sites, including BLM grazing leases, USFS grazing leases, the Audubon Research Ranch, the Sonoita Creek State Natural Area, ranch units, and deeded lands.

Finally, we recognize that our six research groups gathered piles of pamphlets, maps, and literature ... more information than we had time to organize. We believe that it would be helpful to catalog the information gathered so far, to write an annotated bibliography of reference materials to supplement the annotated bibliography of our own research papers, and to locate this body of literature in a centralized library which is accessible to future researchers.

CONCLUSIONS

Human activities such as grazing and urbanization have impacted Arizona's grasslands throughout history. Increased population pressures in Santa Cruz County since the 1950s, however, have created a scenario in which new players are competing for the use and control of both private and public lands. At stake is the continuity of the range itself, a valued economic resource and environmental treasure.

Long-term solutions depend on determining what is valued within the community, and setting realistic priorities. Sustainability of the resource base and continuity of the range should be of utmost concern. Finding a common ground between those who have vested interests (ranchers, environmentalists, members of the wise-use movement, and developers) will increase the likelihood that conflicting interests and needs can be resolved. A variety of options need to be explored, and compromise will be needed. Bureaucracy and legislation, although sometimes difficult to live with, may provide ranchers with a mechanism by which to keep developers at bay.

More research is certainly needed to understand the complex dynamics of land-use in Santa Cruz County. Scientific studies are often time consuming, expensive, inconclusive, and conflicting. Assumptions about the "best science" available should be scrutinized critically, and the costs and benefits of proposed research weighed carefully.

Above all, ranchers should be encouraged because grazing of public and private lands discourages subdivision. Urbanization is the greatest threat to open spaces and the continuation of ranching as a viable economic activity. The ranching industry in Santa Cruz County is experiencing other pressures as well. If permit costs go up, or if ranchers are otherwise discouraged from using public lands for grazing, few will survive on just their private holdings. Market forces on beef and real-estate prices have increased land values to levels that make it attractive for ranchers to sell their patented land. The problem is that this is a one-way mechanism. Once private lands are sold and subdivided, they will never again be available to the cattle industry. The goal to preserve the open range, therefore, is the common ground shared by environmentalists and ranchers.

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Views of a Non-traditional Traditional Rancher

Joe Parsons[1, 2]

ABSTRACT

Ranching has a long and honorable tradition in the West and ranchers have distrusted environmental groups who threaten to endanger the ranching way of life. Ranchers and environmentalists are going to have to get to understand each other in order to protect the lifestyle and the land from new threats, such as urban sprawl. Understanding each others backgrounds, philosophies, and agendas is vitally important to dealing with the many concerns which we share.

Mac had asked me to come speak as a traditional rancher, and George is right, I don't think I am very traditional. I'm very delighted to be here, I am excited to be here. I want to thank Barbara and Diana for including me and the Southern Arizona Cattlemen's Association to be part of this conference, and to actually cosponsor this conference. We didn't get our name on the plaque, but we are happy to be here. I apologize that I don't have quite as many slide shows and all that, because I am new at this. This is kind of a new era for cattlemen and ranchers. The change that we are making, how we are getting involved, becoming more proactive, and traditions are changing, and I assure you that we are changing with them.

When they first contacted me, I was somewhat skeptical when I read the sponsors' names: The Audubon Society, The Nature Conservancy, because through many years we have had a line drawn between those groups, because we have sat back and been somewhat passive, and they have got a lot of press. And, there has been a line drawn that said, "Environmentalists/ Ranchers are ruining the west. " And, we have just sat there and let that happen. So, I called my board of directors and said, "Do we want to be a part of this, or are we getting into a hornets nest, or what?" And we agreed that no, it's time that we stepped forward and let everybody understand where we are from, what values we have and what interests we have. And, exclude this activism and actually sit down and learn about each other and talk. I really have a good feeling through the last few years about public lands ranching.

Ten years ago, I wouldn't have said that. Back in the 1980's in the Cattle Free by '93 , and all of that was making such headlines, I really thought that there probably wasn't a lot of future in the west. But, now that I have spent more time and understood it and traveled the west and learned everything and got myself more educated, I'm excited about it. I think the public in general, as I traveled the western states in my business, I found out that everywhere I go, the activism is being pushed aside. People are working together, people are having meetings just like we are having here today. They are talking and they are learning about each others views, we are learning to have

[1] Southern Arizona Cattlemen's Association, Tucson AZ.
[2] Summarized by Carolyn Painter, Arizona State University, Tempe AZ.

some dialog. And, I think that's important, and that's why I agreed, after talking to Barbara and Diane, that's what this conference is going to be about. Grasslands was the issue, but really it is a people conference where we can get together and get some opposing views. And do it in a civil way, that when we leave here, we leave here open minded and we take it back to different organizations and pass it on that, maybe those guys aren't quite so bad. Maybe I will change my views on some of the environmental groups, which I already have. And, we will start to make some progress.

One of the things that I do want to tell you is, ranchers in the past have not always been a hundred-percent correct. And, it's not always their fault. My dad had an eighth grade education, my granddad never even went past fifth grade. So, as time came on we have had the opportunity to learn, to advance. The work they did, I got to go to school, I got to go to the University of Arizona. So, we are learning every year, we are learning more. You know we've come out of a five or six year drought, started to come out of it this summer. And, the first thing my dad sees is the grass starts growing on the desert, and it's time, let's get some cattle out there. And, that's still a philosophy that he has, and it's hard for him to break that. And, I think that we've got to manage for sustainability, and not manage with the idea that when you see grass, let's go and get it. So, that is a different approach that we are taking.

In order for us to work together and learn where each other is coming from, I think we have to understand what our backgrounds are, and what our philosophies are, and what our agendas may be. So, real quickly, so you know who I am, you know what my background is. When you hear that Joe Parsons said something, you will know the basis of that. If you hear me say that I think the government should mandate that the land is produced on, for the benefit of the public, you won't say, "He's a radical rancher trying to rip off the land." You will know the basis of why, you'll hear me say that.

My grandparents, I'm not going to get into a lot of history, I want to share this with you so you can understand, please. My grandparents on my mother's side are immigrants from Italy, they came to New York, it was crowded, they ended up in the Pecos Valley, in Carlsbad, New Mexico. They are still there, we still have tons of family there that homesteaded that area at the turn of the century. They still own the farms up and down the Pecos. My dad's side they were from Kentucky to Alabama, to the Big Bend Country in south Texas. When Pancho Villa raided, he took all the small ranches and drove the cattle across the line in to Mexico. We were out of business when my grand ad was a young man. My great-grandad moved, kept on moving west, with the thoughts that things were going to be better. He landed up in Catron County, which is a familiar place to everybody now. We were one of the first ones there. He started the first saw mill in Catron County. Just did a small little lumber yard there by the creek. Cut trees, shipped them into Albuquerque and El Paso, and as those cities started to boom, who moved out? Bigger companies. They forced him out of business and ended up forcing him to have to sell, because he could not compete in a small way with the big companies. So we ended up in Douglas, and then on to Winkelman, Oracle. The mines started to be building, and that's how we ended up here in Tucson.

There's one thing that I can say, that I feel like I'm keeping up with the family tradition on the Parson's side. Everywhere he went and worked for, somebody else wanted and took it away. Now I feel kind of, that public lands ranching in the west, we're working for it, now somebody from Washington, D.C. is figuring out a way to take it away from us. But, I've got more faith in the system, I don't believe that's going to happen or I'm not quite as "Doomsday" as Steve is, I think it's going to turn around.

Now, that's where I'm from, you know that I have agriculture in my background, years and years of it. And, even though we were removed from it for twenty or thirty years, my family is back into now. And, it's in your blood, you feel that there's nothing better than being able to produce something, to grow something that's going to benefit somebody else. And, Steve's right, it's not all monetary, it's not all the money. One thing that I have done a little different than my grand ad and dad did, is, when you look at my name tag, it says: "Rancher, Steel Contractor. "

So, if we remove ranching, I'm not going to be in the position my granddad was, and have to go somewhere else. If you take ranching away, and build developments, I will be here benefiting from the building of the developments. So, I have leveraged my family and my kids to a different position. That's not the one I want, I want to see cattle, and grazing and wildlife, and ranching here. I think the alternative with the building, would be, development of urban sprawl would devastate this country, on what we perceive we want it to look like.

Now, I'm going to tell you quickly about our ranch, how we manage it, because I know that's what specifically I was asked to talk about. We, currently, ranch on approximately 75,000 acres of private, public and state trust land, on three different ranches. The one that I am specifically going to talk about is the Empirita Ranch, which is in the Benson area between Pima and Cochise County, and we border the Empire Cienega on our south boundary.

About ten years ago the ranch of the deeded land had been bought by some developers, that were going to assure a water supply with the Cienega. They were going to build developments. They had a lot of land converted to commercial uses, from just the regular Rezoning's, the rural zoning's. And they had a big planned development going. So in the interim, while they were getting everything ready, they had kept the ranching operation. They had a foreman, they had about a 130-140 head of cattle, on 32,000 acres of land, and they had three water supplies working. Needless to say, with absentee owners, with a foreman that probably hadn't had a lot of ranching background, when we took it over, it was basically unusable. We made a deal with the developer, to lease it, we made a year long agreement with him. We saw that it was going to take a tremendous amount of money to get it back into operation, and negotiated a ten-year lease with them, so we could afford to put the improvements on the property that it needed to get it functioning again, and be an economic asset to the county. So, what we did first was, we found out, we got all of our windmills and water supplies working in the upland areas away from the Cienega creek. And, we basically shut off all the water supplies down low, which had been operating, because that's where the cattle had congregated. Approximately 50 to 70 cattle in an area with no rotation. It was just basically, the cattle were there because it fit the agricultural status. The man was in the agriculture. business, so he had his taxes they way they should be. We shut that off and moved the cattle up.

What we found out was it was hard to keep the cattle up there, because they were used to being in the bottoms. So, the cattle would either come back in there, live without water, starve to death from no water, because they wanted to be in the bottoms. Or, they would go through the fence to Donaldson's, and we'd have to go and get them over there. So, Clay and I, (my brother), said, every cow that we can't manage and control, teach her to stay where we want her to stay, we're going to get rid of her. So, we ear tagged them, given them one more chance, if they went through the fences, we sold them. We started off with a new herd of cattle, Heifers. Taught them to live in the upland areas and gave the bottoms a chance to replenish itself, and got a functioning herd going. About that time, the Pima County Flood Control bought some of that land. The BLM bought the deeded land from the developers, they assumed the state leases. And, we were part of the take. When they got the land, they took our lease, and took us with it. So, at that time, I was concerned with what was going to happen. And, I met with the Range Conservationist, and I said, "where are we going to go from here, what are we looking at, at the end of this time frame?" He said, "Well, we need to get a management plan in place. We need to look at the ranch as a whole, and we need to get started. " Well, I will be honest with you, at that time I didn't know everything that was available to a rancher, I really didn't. We started out, we called the Soil Conservation Service. Kristin Egen was our Range Con. She said the first move was to get with Phil Ogden at the University of Arizona. We had Phil's class do a total range inventory. Kristin took the preliminary work that the kids had done in class. Her and I worked the ranch, drove the ranch, we talked about our goals, what our plans were. She did a complete inventory of the ranch, it's current forage. And, collectively we sat down with Grant, from the BLM, Wally with State Lands. Kristin and myself, we worked out a management plan, where it is a rotational management plan. And, I'm sure most people understand that.

We rotate from pasture to pasture by the use of fences and water supplies. We can shut off certain waters, and the cattle, once they learn the cycle, believe it or not, come May, once those cattle have been through the cycle, there may still be all the feed in the world up at a certain area, but they start working there way, knowing that the time is coming that they are going to change to another area. So, I have to disagree with Steve, tremendously. I think there is a tremendous amount of knowledge at the University, and through the Natural Resource Conservation Service. A tremendous wealth of information. I know the Santa Rita Experimental Range has got information in boxes down there, that they say they have been studying since 1913. We need to be taking that information and using it. I've got a whole lot more, I'm a whole lot more excited about the future. I'm not near as dismal and bleak. At our little ranch, I say it is a little ranch, we produce enough beef to feed 4,500 people a year, just our little small operation. So, if you take that out of the production cycle, it may be just 4,500 people that I don't feed. But, then the rancher next to me. In Arizona, alone, we feed 4.6 million people. That's not my numbers, that's not my statistics, those are government statistics. So, I don't think it is as simple as just saying we are going to take cattle off the land, everything is going to be good.

I would hope that we could collectively focus all of our energy beyond a specific grassland species, or any simple, any individual species, and look at the whole area, the whole ecosystem. And, I would hope we can keep people as part of that planning process. Thank you very much.

Ecological Characteristics of Invasive Alien Plants

John H. Brock[1]

ABSTRACT

An influx of alien plant material to the North American flora accompanied the settlement of the continent by immigrant peoples during the latter part of the 19th century. Plant materials were introduced as ornamentals, agronomic crops, land conservation material, and many were accidentally introduced as contaminants in seeds of desirable plants such as small grain crops. In the early 20th century introductions continued as people wanted to improve on the natural vegetation, and have plants that seemed to be better adapted to habitats than were components of the native flora. Several of these well-intended introductions are now considered as invasive. This paper presents information about some of the general characteristics of invasive plants including: pollination strategies, regeneration strategies, seed and propagule dispersal, formation of ecotypes, the lag time from introduction until the plant is termed invasive, and some aspects of the physiology of invasive plants. Many alien plants have naturalized to the environment of North America, and are so widespread that vegetation management strategies to control the whole population are probably not feasible. However, strategies to control the further invasion by the alien species are needed and will most likely incorporate integrated weed management techniques that are socially and politically acceptable.

INTRODUCTION

When taking a global view, there is a question among plant ecologists if a species is ever truly an "alien". However, in studying invasion ecology, an introduced species of a flora must be treated as alien to an ecosystem because it would not be there without human intervention (Pysek 1995). Some alien plants grow only for one season and fail to establish and these are termed "accidentals" if included in a floristic survey. Some of the alien plants establish but are very passive in their new ecosystem, while others adapt with a broad ecological amplitude and invade man-made and natural areas. When native plants widen their historic range the term *expanding* is suggested, and when an alien plant is becoming more common on the landscape the term *invasive* is more appropriate (Pysek 1995). Where and under what circumstances alien plant species are likely to attain a weed status has emerged as a central question for those studying plant ecology

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(de Waal *et al.* 1994).

Alien invasive plants have been a concern to land managers in the western United States for the past 100 years. The largest immigration of alien plant species to the United States accompanied the "taming-of-the-west" from about 1870 through 1900. Alien invasive plants are also a global concern, since plant materials have been relatively freely exchanged between varying ecosystems and the continents. In many cases the alien plants have provided many benefits to mankind, but some of the plants have displayed an invasive nature which has created management problems.

Alien invasive plants often have ecological characteristics that allow them to be colonizers on disturbed sites, and in some cases are truly invasive, by literally invading existing stands of native vegetation. Through direct competition they become dominant plants in the habitat. Many alien invasive plants are classed as weeds, or as colonizers, that is, they are often plants found in the pioneering stages of succession (Rejmanek 1995). There is another class of alien plants that while not particularly invasive, alter the environment in undesirable ways. Lesica and DeLuca (1996) discuss a plant of this nature, which is probably the most commonly planted exotic grass in western North America, *Agropyron cristatum, A. desertorum* (crested wheatgrass). *A. cristatum* is a strong competitor that modifies soil resources to the disadvantage of native species limiting their recruitment and establishment in mature stands of this exotic grass (Lesica and DeLuca 1996).

The receptor area where alien plants colonize has often undergone some type of disturbance that has allowed open niches or spaces in the community. The type of disturbances are mostly man induced, but variations in weather patterns, natural fire frequencies, and flooding can result in receptive areas for alien plants to become established. Man-induced disturbances include anything that contributes to bare soil such as: agriculture, urbanization, development of transportation corridors, modification of natural landscapes through extraction of minerals, timber harvest, and poorly managed livestock grazing. For successful establishment of alien plants the following factors (Mooney and Drake 1986) are required: (1). An opening in the community, (2). Climatic conditions at the receptor area similar to the source area, (3). Vegetation lifeforms of both areas should be similar, (4). Soils of the areas are not significantly different, and (5). Similar latitudinal range is also a good predictor of invasiveness (Rejmanek 1995).

While these factors are very important for an alien plant to establish on the new area, the ecological traits of alien invasive plants are what is largely responsible if the new plant is to function as a weedy species. Baker (1986) presents information related to patterns of plant spread into North America, and Pysek *et al.* (1995) evaluated invasion success in relation to plant traits by analysis of flora in the Czech Republic. The purpose of this paper is to review the ecological characteristics of alien invasive plants. The characteristics of the plants to be discussed include: (1.) Pollination strategies of alien invasive plants, (2). Regeneration and development of seed banks, (3). Seed and propagule dispersal, (4). Adaptability of alien species through ecotype formation, (5) Lag time from introduction to invasive status, and (6). Physiological ecology of invasive plants.

DISCUSSION

Pollination Strategies

Alien invasive plants that are most successful have generalist pollination strategies. They may be wind pollinated as is often the case with invasive grasses of the western United States, such as *Bromus tectorum* (downy brome), *Eragrostis lehmanniana* (Lehmann's lovegrass), *Cenchrus ciliaris* (buffelgrass), and *Taeniatherum asperum* (medusahead rye). Plants may be self pollinated, or like

Tamarix chinensis (salt cedar), may be a generalist for insect pollination. In general, successful alien invasive plants do not have specific insect pollinators, or specific pollination requirements.

Regeneration

Typically successful alien invasive plants produce either large numbers of viable seeds that will readily germinate, or seeds with dormancy requirements so that when dormancy is overcame they produce large populations of seedlings. *T. chinensis* fits the first case, in that it produces a nearly continual seed rain during the growing season, and the seeds will rapidly germinate on a moist media (Brock 1994). *E. lehmanniana* may fit the second case, in that the plant produces many small hard seeds that contribute to a seed bank. Conditions for favorable germination of *E. lehmanniana* is achieved on almost a yearly basis in its adopted ecological range, but seems to be more prolific in seedling establishment following a period of soil heating resulting from fire (Ruyle *et al*. 1988). Invasive plants often display early sexual maturity, such as can be observed in *T. chinensis*. Rejmanek (1995) reported on the genus of *Pinus* and found that invasiveness in this genus is predictable based on a small number of factors such as small seed mass, short juvenile growth periods, and short mean intervals between seed crops. This may well apply to other woody species of seed plants in disturbed landscapes (Rejmanek 1995).

Not all alien invasive plants spread because of successful sexual regeneration. In some cases, alien plants with no or very little viable seed production are invasive and have become noxious weeds. The case in point is illustrated by *Reynoutria japonica* (Japanese knotweed), listed as *Polygonum cuspidatum* in Whitson's (1991) "Weeds of the West" book, and also as *Fallopia japonica* in European weed science literature. This plant in North America and Europe reproduces almost exclusively by vegetative means (Bailey *et al.* 1995). The most commonly known reproduction strategy of *R. japonica* is from its extensive rhizome/root system (Beerling 1990). Brock and Wade (1992) reported that even pieces of rhizome tissue of 1 cm provided about 40 % regeneration success. In 1991, vegetative regeneration from stem portions of R. *japonica* was only hypothesized. Greenhouse research was initiated in the spring of 1992 to test this hypothesis. From the greenhouse research by Brock *et al.* (1995), it was found that *R. japonica* also regenerates from stem tissue. Over all treatments, *R. japonica* had the capability to successfully reestablish rooted shoots from 6% of the stem portions, but in water (the most probable dispersal mechanism for stems along water courses) 63% regeneration success was observed. *R. japonica* occurs in the United States in areas of temperate and humid climates. It is known in the Pacific Northwest and is found in the deciduous forest ecosystem of the eastern United States.

Seed and Propagule Dispersal

Seed and propagule dispersal is the result of both passive and active processes. Passive seed dispersal results from seed being blown about by wind as is very common for seeds of the *Asteraceae* family, and *T. chinensis*. Passive dispersal is often accomplished by seed falling into moving water which is important for riparian and wetland plants. Seed dispersal by water provides a spread mechanism for *T. chinensis* and is considered to be a major way *R. japonica* stem segments spread along riparian corridors. A third passive agent for seed dispersal is gravity.

Active seed and propagule dispersal is primarily aided by members of the animal kingdom (Rejmanek 1995). Many animals eat plant fruits containing seeds and the seeds may pass through the digestive system largely intact and germinate from the fecal deposits of the host animal. This is one of several dispersal mechanisms employed by *B. tectorum* (Bazzaz 1986). Seeds attach to the skin or pelts of animals and spread across landscapes as the animals either migrate, or establish new territories. In the case of domestic animals, the seeds may be deposited where the animals are first introduced to the new habitat. This seed dispersal strategy is one working hypothesis concerning the introduction of *Halogeton glomeratus* (halogeton) from Asia to the Great Basin region of the western United States, possibly in the wool of Karakul sheep (Mack 1986).

In many cases, the main seed dispersal mechanism of alien invasive plants has been the willful, or unknowing action by people. Many plants have been introduced accidentally because of contaminated agronomic or forage crop seeds. This is believed to be the case for *B. tectroum* which probably was a contaminate in winter wheat. The phenology of *B. tectroum* fits the culture of winter wheat and the rapid spread of this plant is considered to be from many introduction loci rather than one large locus (Bazzaz 1986). *Salsola iberica* (Russian thistle) and *Kochia scoparia* (kochia), two species of the *Chenopodiaceae* family introduced from Eurasia are also tied to the introduction of small grain crops to North America. People are further implicated in the spread of these 2 species since they were repeatedly first observed along transportation corridors (railroads and highways) in landscapes remote to agricultural areas.

Many invasive weeds are actively spread during construction in man built areas. The spread of *R. japonica* follows this pattern in urbanized areas of Europe. It is also interesting to note that Kowarik (1995) stated that *Ailanthus altissima* (tree-of-heaven) expressed its invasive nature after the industrial revolution was firmly in place in Germany and the "heat island" effect had developed in the cities (annual average temperature is 1.5° C greater in metropolitan Berlin). Man both accidentally and knowingly spreads alien invasive plants. The saving argument in some cases for plants like *E. lehmanniana, C. cilaris, T. chinensis,* and *R. japonica* is that the alien plants were being introduced as beneficial organisms, and their weedy nature came as a surprise.

Ecotype Formation

Many alien plants adapt to their receptor areas and after several generations experience ecotype differentiation (Baker 1986). This action probably involves genetic recombination and as a result the species becomes better adapted to the environment of the new habitat. This is hypothesized to be the case for *B. tectorum* and other plants that have undergone plant breeding selection processes since introduction to the United States. Another hypothesized example involves *E. lehmanniana* ecotypes currently growing in Arizona. These may ecologically react differently compared to the native strains if they were now reintroduced to South Africa. The process of ecotype formation allows the alien plants to more specifically adjust to the environmental characteristics of a new area and perhaps become better competitors.

Kowarik (1995) and Pysek *et al.* (1995) both reported on woody alien species in Europe. Kowarik (1995) from work in Germany reported that 41% of alien woody plants had successfully moved from their introduction site indicating that successful ecotypes had formed. Of these 41% successful plants, 19% were only naturalized on man made sites, and 12% had successfully naturalized to natural sites. In the report by Pysek *et al.* (1995), of the 132 alien plants studied in the Czech Republic, 80% were not successful in establishment. For the 20% that were successful, 14% were found on man made sites, with the remainder being found in natural sites. One successful species from North America, invading natural sites in the Czech Republic is *Robina pseudoacacia,* the black locust tree.

LAG TIME FROM INTRODUCTION TO INVASIVE STATUS

There is much variation in the time lag of introduction until a species is clearly recognized as being invasive. Some species that acted as weeds in their original habitats acted as weeds almost immediately after introduction to the United States. This is apparently the case for common crop weeds such as *Amaranthus sp.* (pigweed) and *Chenopodium album* (lambsquarters). Other plants experienced lag times to allow for seed dispersal and for populations to reach a critical number for wider dispersion in the new landscape. Research in Europe (Kowarik 1995), indicates that often there is a lag time of 50 years from introduction until a plant is invasive. For tree species introduced to Germany, this time period was found to be an average of 170 years. The development of lag times for species commonly believed to be alien invasive plants to the western parts of North America would provide an interesting research topic.

PHYSIOLOGICAL ECOLOGY OF INVASIVES

Most of the knowledge about the physiological ecology of invasive plants is inferred from studies dealing with colonizer type plants compared to those of late successional stages. In general, the physiological ecology of specific alien invasive plants is not well understood. Generally, early successional plants have high photosynthetic, respiration, transpiration rates, and behave opportunistically to disturbance. These plants have great ability to acclimate to changes in the environment, and quick response to changes in environmental resources, water and nutrients as examples.

Climatic change may also be having a large impact on plant physiology and the invasive nature of some plants. This topic was reviewed by Mayeaux (1995) with plant invasiveness related to changes in the earth's atmosphere and by Patterson (1995). Both Mayeaux and Patterson indicated that global warming and related climatic changes would affect the growth, phenology, and geographic distribution of weeds. Carbon dioxide (CO_2) at the current level of about 350 ppm is increasing in the atmosphere at about 0.4 %/year from a pre - industrial revolution level of 280 ppm (Ashmore 1990). Another greenhouse gas, methane (CH_4) is increasing at 0.9 %/year from the current level of 1.7 ppm (Ashmore 1990). Crop plants with C_3 and C_4 photosynthetic pathways have increased average biomass by 40 % for C_3 plants and by 11 % for C_4 crop plants (Kimball 1983). Response in doubling CO_2 in the air of C_3 and C_4 weedy plants resulted in a mean biomass increase of 130 % and 115 % respectively (Patterson 1995). With increased CO_2 (350 to 675 ppm) and limited water, the following weedy grasses, *Echinochola crus-galli* (barnyardgrass), *Eleusine indica* (goosegrass), and *Digitaria sanguinalis* (crabgrass) increased dry matter production by 43, 46, and 37 % respectively (Patterson 1986). These data support Mayeaux's and Patterson's hypothesis that changing atmospheric conditions will alter the physiology of invasive plants and perhaps change their distribution, so that the geographic range will expand northward, such as *Impatiens glandulifera* (Himalayan balsam) and *F. japonica* (Japanese knotweed) in the British Isles (Beerling 1994), and a subtropical alien plant like *Pueraria lobata* (kudzu) will invade deeper into the North American continent.

The following material related to physiological aspects of plants is adopted from Bazzaz (1986) and summarizes some of the characteristics shared by invasive species: (1). High rates of photosynthesis, respiration, and transpiration, (2). Rapid response to available environmental resources, (3). Fast population growth rates, (4). Relatively short life cycle, (5). Early reproduction capability, (6). Allocation of growth activity to reproduction in favor of foliage growth, (7). Self, wind, or serviced by generalized insect pollinators, (8). Seed dispersal mechanisms that provide for establishment of large ecological ranges, (9). Generalists in resource use (broad niches), and (10). Readily adapt to changes in the environment.

CONCLUSION

Alien invasive plants have changed many of the habitats of the western United States. In many cases there may have been an associated lost of biodiversity, and that loss may be at a rate that is barely discernible. For example, what is the impact of *Bromus rubens* (red brome grass) on the recruitment of *Carnegia gigantea* (saguaro cactus) in desert habitats? It is a rare riparian plant community in Arizona that does not have either or both *Cynodon dactylon* (Bermuda grass) or *T. chinensis* represented in the vegetation. On the uplands, especially in southeastern Arizona, *E. lehmanniana* is common. In the Phoenix area, many horticultural plants are currently displaying invasive characteristics. Some of these plants include the tree *Rhus lancea* (African sumac) and *Cenchrus setaceum* (fountain grass). Alien invasive plants have become parts of our landscapes, and land managers need to learn how to manage those lands in the presence of those plants, or devise strategies to return native plants to the habitats through the practice of ecological restoration.

Alien invasive plants have become firmly naturalized in most of the habitats of the United States and the world. Management attempts that extol eradication of these alien plants most likely will be futile. Management to control the plants on critical portions of the habitat can be achieved with economic, ecological, social, and perhaps political costs. Many times the ecological and economic costs are bearable, but the social and political costs curtail widespread successful vegetation management programs. It is my belief that existing management tools will effectively control alien invasive plants if there is both a political and social consensus for vegetation management.

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Stowaways and Invited Guests: How Some Exotic Plant Species Reached the American Southwest

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ABSTRACT

Introduction of non-native plant species has occurred throughout the world for thousands of years. This poster describes the introduction and spread of nine invasive exotic plant species to the American Southwest.

Filaree (*Erodium cicutarium*)

Some introduced plants actually preceded the Spaniards. Ships that docked off the California coast brought seeds in their ballast, packing materials or on the fur of animals. Plants established near the shore were spread by birds on the great migratory flyways. In this way, the plants spread inland years before the people did. Filaree was found in California when the first missions were built and was plentiful enough to be incorporated into the adobe bricks.

In March 1844, Captain John Fremont found filaree as he came down from the California foothills towards the valley. He wrote "... we discovered three squaws in a little bottom, and surrounded them before they could make their escape. They had large conical baskets, which they were engaged in filling with a small leafy plant (*Erodium cicutarium*) just now beginning to bloom and covering the ground like a sward of grass." By April 12 he had descended into the valley and again reported filaree saying "instead of grass the whole face of the country was closely covered with *Erodium cicutarium*, here only two or three inches high.

In 1886, the Leitch brothers introduced it to Arizona in a big way as fodder on their ranch. Filaree quickly became a popular range plant and was promoted in Agricultural Extension bulletins. But it was found in Arizona long before that, having come on the wings of birds, the wool of sheep and via many other paths.

Bermuda Grass (*Cynodon dactylon*)

Bermuda grass was considered a sacred plant in the Veda of ancient India, where it was called "the preserver of nations" and the "shield of India," because of its forage value. It also has a long history in African medicinal lore and was probably introduced to Africa on Arab merchant ships before 500 A.D. It is now found worldwide and on every continent except Antarctica.

Georgia Governor, Henry Ellis, introduced it to Savannah in 1751. (Actually his neighbor, a man we know only as Mr. C., an ardent plant collector who frequently traveled to distant places such as Bermuda probably gave it to the Governor). It spread rapidly and within 50 years a botanist found it "frequent on roadsides and cultivated ground" in the East and Southeast. In 1856 it was sold in San Francisco for $5 a flat. By 1880 it had become a troublesome weed near San Bernardino, in Southern California. Rivers and canals were ideal dispersers, as the seeds spread rapidly in water.

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By 1911 it had become a serious problem as it invaded fields and canals.

Extension agents recognized it as a problem before 1911, but believed they had found a way to control its spread, writing in a special bulletin "Following the practice outlined above, we have ceased to dread Bermuda grass at Yuma, finding it not only possible but practicable to keep it in subjection." It is now found through the lower elevations of Arizona.

Johnson grass (*Sorghum halapense*)

Johnson grass first appeared in Southern states under the names Guinea grass, Means grass, Bankruptcy grass and many other names before 1840. The South Carolina Means family played a major role in its introduction. One family story relates that a relative, John Davis, brought back "fine Swiss watches packed in Johnson grass seed." Another story says that John Means introduced it in contaminated hemp seed from Egypt shortly after the Revolutionary War. One of the Means daughters became Mrs. Johnson and moved to Alabama. In 1880 Herbert Post stated that he had managed the Johnson farm" near Selma Alabama on which Johnson grass had been grown for 40 years. In areas where frost didn't kill it, it became a noxious weed, which could survive drought, grazing and even a little freezing.

The Arizona Gazette in 1890 wrote "In the last two years farmers in the Salt River Valley have been greatly annoyed by the appearance of Johnson grass on their ranches. The grass is far more of a pest to the farmer than is sour clover or fox tail grass (both introductions from the Old World) to a blue grass lawn. Investigation as to the cause of the grass spreading over the valley developed the fact that there are two ranches away up at the head of Salt River, above the Tonto Basin, which are covered with Johnson grass, and from these ranches the seed has been carried down by the water to the farms."

Tree of Heaven (*Ailanthus altissima*)

Father Pierre Nicholas de Chevron d'Incarville was sent to Peking in the 1740s as a Jesuit missionary. For ten years he labored on both his religious mission and his personal mission to introduce hitherto unknown plants to Europe. Because of China's strong isolationist policies, seven years passed before he was allowed to travel to areas where plants could be collected. Shortly before his death, he entrusted some seeds to a confidant in a Russian caravan, making the long trek across Siberia and finally to England.

From those seeds Philip Miller grew the first successful European *Ailanthus* trees in all of Europe in 1751 at the Chelsea Physic Garden. William Hamilton's plantings of offspring of those trees on American soil in 1784, were viewed as "great novelties from a far distant land." Soon they became common throughout the Eastern U.S. About 75 years later the tree was introduced far more easily to the West Coast by Chinese gold miners who planted them along California streams. It has naturalized in Arizona along the Verde River, Sonoita Creek and elsewhere and is rapidly becoming a problem species.

Saltcedar (*Tamarix ramosissima*)

Some early researchers believed the Spanish introduced tamarix, but National Herbarium specimens do not support for this hypothesis. While Spaniards certainly traveled to places where tamarix is common, the pattern of distribution does not show a spread from Mexico as a central source location.

Although the original collector is unknown, several species were advertised by U.S. nurseries by the 1820s. The Old American Nursery of New York offered French tamarisk for sale in 1823 and Bertram's Botanical Garden and Nursery listed French and German tamarisk "much admired" for 37 cents. By the 1830s many nurseries were offering tamarix, but seldom made clear which species they had. The U.S. Department of Agriculture grew tamarix at the National Arboretum in Washington and in 1868 reported that six species had become established at. It released *Tamarix pentandra (ramosissima)* for cultivation in 1870.

It escaped cultivation in 1880 in Utah and in 1897 in Texas. In 1901 it was "common in river bottoms," from the Salt River in Arizona." The Arizona Agricultural Extension Service recommended several species of *tamarix* for landscaping. Tamarix naturalized most rapidly from the 1930s to the 1960s, most often in areas disturbed by human activity, such as upstream and downstream of dams.

Local ranchers reported that tamarix first appeared along the Gila River after the floods on 1916. It is now found along many rivers throughout the West and northern Mexico up to about 5000 feet in elevation, and sometimes even higher, especially in disturbed areas such as upstream and downstream of dams.

Russian Olive (*Elaeagnus angustifolia*)

The Russian Forestry Department conducted extensive research on the *Elaeagnus* and in 1887 published a pamphlet in which the tree was considered "a valuable tree for hedges in south Russian steppes." In the late 17th Century, Prussian Mennonites migrated to south Russia seeking religious freedom. Less than 100 years later, again under religious persecution, they again migrated to Canada and the northern United States. A small group settled in South Dakota and other Plains states, bringing with them not only their religion, but many crops and farming practices, including Russian olive. N.E. Hansen, of the South Dakota Agricultural Extension office traveled to Russia and experimented with it extensively and recommended it highly as a drought, animal, and frost tolerant ornamental plant in 1901. He said, "As a hedge it will turn any stock that Osage orange will. Horses or cattle will not attempt to go through it, and it does not sap the ground like Osage orange." It was easily available in South Dakota nurseries by 1900.

In Utah and Arizona Mormon communities, it was widely used as a landscape plant after 1900, with cuttings passed from one community to another by plant lovers such as W.H. Crawford of St. George, Utah, who introduced hundreds of plant species in the Virgin River area.

Extension agents recommended it for Arizona in 1909. It remained a cultivated landscape plant for several decades, but escaped cultivation by 1941 in Oak Creek Canyon. The National Park Service planted it in Canyon de Chelly for soil stabilization in 1964. By 1974 it was one of the dominant trees of the canyon bottoms.

Tumbleweed (*Salsola kali*)

Another introduction to South Dakota from Russia was tumbleweed, probably brought by the same Mennonite farmers. One of their crops was flax, which did not develop into a major agricultural crop, but planting flax did have a lasting effect, as the seed was contaminated with tumbleweed, also called "Russian thistle," "Wind Witch," or "Leap the Field." It first appeared in Bon Homme in southeast South Dakota. It spread from there within ten years to neighboring Nebraska. The Nebraska Extension Service published a bulletin in 1982, with a 10-point plan for fighting the weed, including the last directive to familiarize "...every child in the public schools, with the appearance of this pest in order that he may destroy it wherever he finds it." It became a noxious weed so quickly that its spread has been carefully documented.

It reached California and Oregon on the west and Minnesota and Ohio to the east by 1895. An 1898 Arizona Agricultural Bulletin reported that "there is no direct evidence that this weed has as yet found its way into Arizona," but it did quote a report from the Philadelphia Ledger "Russian thistles, a patch of which has flourished for some time near Whipple, Arizona have overgrown well trodden paths there and made them impassable either for man or animals" and warned farmers to be alert for its appearance. Within a few years it was common.

The newly built railroad was an ideal vehicle for spreading tumbleweed throughout the West and tumbleweed's early distribution pattern shows it moving outward along railways and roadways. In at least two documented cases, new colonies were established after train wrecks in which wheat cars were overturned. Wind was also a good dispersal method, especially on the Great Plains with its high winds traveling for miles.

According to an 1891 U.S.D.A. study, the form of *Salsola* in the U.S. was for more troublesome than its counterpart in Russia where it could be found mingled with wormwoods, sages, mulleins, true desert thistles and a multitude of other plants. Along roadsides there, the plant was not allowed to ripen. In southern Russia the plant did cause problems and severe measures were taken to protect sugar beet fields. In the United States, however, no such measures were taken. By 1894 it was estimated to have caused over $2 million in damages to wheat fields in the Great Plains states.

Camelthorn (*Alhagi camelorum*)

While it is tempting to relate the introduction of this legume to Beale's 1850 great camel expedition from Texas to California, and theorize that it accidentally came on the fur of those camels, there is no evidence that it entered Arizona or California before the twentieth century.

In the 1890s, University of Arizona horticulturalist, Robert Forbes, and others introduced dates to California and Arizona. The survival rates were very low during the long ship voyages and land journeys. A new packing method developed by Walter Swingle, using local plant materials, brought the survival rate up to about 90%, but apparently was also ideal for dispersal of weed seeds, among which was *Alhagi*. Swingle described his new method in 1898: "The awkward wooden tub method was eliminated in favor of wrapping the roots of offshoots in cocoons of damp moss or palm fiber. The relatively light plants were then hauled by camel over 90 miles of desert to the town of Biskra where they were...loaded into a special railroad car for another journey of over 200 miles to Algiers ..." just the beginning of a long journey.

Camelthorn probably also came in alfalfa seed from Turkestan, which was a prime source of weeds. N. Wykoof of Napa Valley, California wrote in his diary: "In the winter of 1854, I sowed 4 acres with alfalfa or lucerne, as it was then called, seed brought from Chile. As far as I know, it was a part of the first parcel of seed brought into this country. My sowing proved so foul with weeds that I plowed it up and did not resow until 1864."

It spreads both by seeds carried in water and vegetatively. It quickly became a pest in the date-growing areas of California and Arizona, and later spread to the Gila River and as far north as the San Juan River in Utah. It was listed as naturalized near Gillespie Dam along the Gila River in 1940, and can still be found there along irrigation canals today, downstream from an abandoned ranch with many old palm trees as well as alfalfa fields. It recently reached the Grand Canyon.

Buffel Grass (*Pennisetum cilliare*)

Arizona's most recent invasive plant introduction is Buffel grass. In the 1940s the Soil Conservation Service (SCS) brought it to the United States from the Turkana Desert of Kenya (where it was adapted to grazing by large herds of about 30 species of ungulates), as part of a major plant introduction program. It was formally released from the SCS nursery in San Antonio in 1946, as a forage crop for semi-tropical and tropical areas of the southern U.S. and Mexico. The plant was found to be cold-hardy up to about 3000' elevation. Attempts begun in 1983 to develop a cold-hardy strain from South Africa were dropped by SCS in 1991 due to lack of interest and increased environmental concern. Mexican ranchers have enthusiastically replaced thousands of hectares of Sonoran Desert vegetation with this invasive grass, which can now be found throughout southern Arizona and northern Sonora where winters do not get too cold. In some areas of Sonora, fires have increased many-fold and native vegetation has usually lost out to this aggressive grass, which is well adapted to fire. Cacti and other native plants have been almost eliminated from some areas.

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The Influence Of Climate, Soil And Grazing On the Distribution Of Lehmann Lovegrass

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ABSTRACT

Overstocking of the range at the end of the nineteenth and beginning of the twentieth centuries led to a decline in perennial grasses. To replace those grasses, new species were introduced from Africa and Asia. The purpose of this paper is to describe factors which have contributed to the spread of Lehmann's lovegrass and to discuss relationships between soils and climate which may influence the long-term persistence of the grass in Arizona.

INTRODUCTION

Between 1860 and 1930, large numbers of cattle and sheep were stocked on southwestern USA rangelands (Cox et al. 1983). Overstocking and drought caused a decline in perennial grasses and a subsequent decrease in livestock numbers. Because rangeland productivity could not be restored with native species, Lehmann love grass *[Eragrostis lehmanniana (LL)],* a perennial warm-season bunch grass from southern Africa, was introduced to Arizona (Cox and Ruyle 1986).

In 1932, F. J. Crider, Director of the Boyce Thompson Southwestern Arboretum at Superior, Arizona received LL seed collected in the Griqualand West Region of South Africa (Crider 1945). Crider planted LL seed on the arboretum grounds and observed that seedlings produced seed heads during the first year or growth. In 1935, Crider joined the USDA-Soil Conservation Service (currently named the USDA-Natural Resources Conservation Service) and organized a series of screening tests at the Plant Materials Nursery in Tucson. Of the many LL accessions tested, Crider selected one that matured quickly and produced abundant seed under irrigation. The accession was named "A-68", and the USDA-Natural Resources Conservation Service (NRCS) initiated a seed production program in 1937.

Between 1937 and 1950, approximately 136 kg of LL seed were produced at Tucson and distributed to soil conservationists and scientists within USDA-NRCS for field plantings. By 1940, LL seed had been sown in Arizona, New Mexico, and Texas (Cox et al 1982). Between 1940 and 1950, the grass began to appear on areas which had not been seeded.

Early seeding successes sparked interest and the demand for LL exceeded what NRCS could supply. Between 1951 and 1984, the USDA-NRCS provided 1,197 kg of seed to commercial seed growers, and growers produced 75,069 kg (Cox and Ruyle 1986). Approximately 70% of the

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commercially available seed was sown on rangeland and along highways in Arizona, New Mexico and Texas. The majority of the remaining seed was transported to Mexico and planted in the northern frontier states of Chihuahua, Coahuila, and Sonora (Cox et al. 1982). As more and more stands were established, Cable (1971) predicted that LL wold spread naturally to adjacent rangelands.

With this natural spread of LL, it was suspected that a subsequent decline in native grasses would occur. Both of these predictions have come to pass. Since about 1975, this scenario has occurred on an alarmingly large acreage in southeastern Arizona.

DISTRIBUTION FACTORS

In 1986, we hypothesized that five major factors have significantly contributed to the spread of LL in southeastern Arizona (Cox and Ruyle 1986). Since then, several studies have been published, both supporting and rejecting our original tenets.

Of the direct factors contributing to the spread of LL, mechanical soil disturbance and sowing of LL seed are perhaps the most obvious. These seedlings have provided the seed source and the multiple loci largely responsible for setting the stage for LL invasion (Moody and Mack 1988, McClaran and Anable 1992).

Approximately 69,000 ha of shrub land have been cleared and sown to LL in Arizona (Cox and Ruyle 1986). Mechanical treatments were used to reduce shrub competition, increase water infiltration and prepare a seedbed to enhance LL seed germination and seedling growth.

Mechanical soil disturbances due to highway, pipeline, and power line construction began to accelerate after 1960 in southeastern Arizona. Because of soil erosion on disturbed areas the Arizona Department of Transportation began to seed LL in 1965. The majority of the seeded area (75%) was along Interstate 10 between Tucson and the New Mexico border, and along Interstate 19 between Tucson and No gales. Approximately 3,060 kg of LL seed have been sown along highways in southeastern Arizona.

The total land area successfully sown to improve rangeland is more than 31 times greater than that area sown along highway, pipeline and powerline right-of-ways because highway, pipeline and powerline plantings established continuous corridors into rangelands, and traverse many environmental gradients, whereas field plantings were made in rectangular shapes and were confined to localized areas (Cox and Ruyle 1986). Additionally, vehicular use of these corridors likely increases seed dispersal from existing stands into new areas (Robinett 1992a).

Seeding of LL continues, both along disturbed right-of-ways and on privately held rangelands for forage production, although higher elevation seeding is discouraged. Seeding the exotic lovegrass on public lands is no longer routinely approved. It was also previously suggested that, on suitable sites, brush control without soil disturbance can influence LL invasion (Cox and Ruyle 1986). Cable and Tschirley (1961) reduced mesquite *(Prosopis juliflora)* competition with a herbicide and aerially applied LL seed to treated and untreated areas. LL production was nil in the treated and untreated areas in fall 1954. LL production increased from 125 kg/ha in fall 1955 to 475 kg/ha in fall 1959 on treated areas, and from 20 kg/ha in fall 1955 to 210 kg/ha in 1959 on untreated areas. Native grass production during the same period varied from 350 to 910 kg/ha on the treated, and from 130 to 740 kg/ha on the untreated areas. Cable (1975) reevaluated the study 21 years post treatment and found that LL had replaced native grasses on both treated and untreated areas. Cable (1976) speculated that LL would continue to invade native grasslands at elevations between 1,200 and 1,500 m with or without chemical or mechanical brush control.

It appears that brush control is not the primary factor influencing LL movement onto a site. The presence of native perennial grasses on the site and the availability of a nearby LL seed source interact with management and climatic influences to determine subsequent invasiveness of LL. Cox and Ruyle (1986) also suggested several indirect factors that may contribute to LL invasion. Of these factors, drought and fire appear to be most important.

Drought conditions severe enough to kill both native perennial grasses and LL periodically occur in southeastern Arizona. Droughts of this magnitude occurred during the 1950's and 1960's. Anecdotal accounts made subsequent to these drought cycles indicated a substantial decline in both native grass and LL populations. When growing conditions improved, especially after the later dry cycle, native grasses did not re-establish as quickly or completely as did LL. Studies to document the influence of drought on LL are few, but mostly support this premise (Cable 1971, Robinett 1992a and b).

LL plants growing on shallow soils are particularly susceptible to drought. About 90% of the plant population on shallow soils died during a mid-summer drought in South Africa, but seedlings quickly re-occupied the site when soil moisture improved (Fourie & Roberts 1977).

The loss of perennial grasses including LL was documented due to drought conditions in 1988 and 1989 in southern Arizona (Robinett 1992a and b). By the fall of 1990, the dead patches had filled in completely with mature LL plants. Native species reduced were primarily black gram a *(Bouteloua eriopoda,* and three awn *(Aristida)* species but also included hairy gram a and spruce top gram a *(B. hirsuta* and *B. chondrosioides).* However, McClaran and Anable (1992) found consistent increases in LL over time, on the Santa Rita Experimental Range, including a dry period during 1979 and 1980, perhaps indicating that drought did not hasten the spread of LL.

Natural or man-caused fires that occur prior to the summer growing-season, when the soil profile is dry, are known to kill mature LL plants (Humphrey and Everson 1951, Cable 1965 and 1967). However, plant populations do not decline because new seedlings from available seed, which germinate during the summer growing-season, quickly replace dead plants (Cable 1965, Ruyle et al. 1988b). Where native grasses occur, fire creates bare areas that are quickly colonized by LL.

Since 1986, numerous studies have supported this claim. For example, Robinett (1994) found that LL increases as fire frequency increased on certain range sites. The increase in LL was at the expense of native grasses. Biedenbender and Roundy (1996) determined that LL seedling establishment increased after burning as did studies by Ruyle et al. (1988b) and Summrall et al. (1991). Increased fire-fuels in Lehmann love grass stands seem to have increased the fire on sites formerly dominated by native grasses (Anable et al. 1992). Evidence exists that a fire-induced positive feedback pattern may develop where heavier stands of LL lead to higher fire frequencies leading to still heavier stands of LL (Anable et al. 1992).

Cattle grazing has also been suggested as a mechanism that enhances the spread of LL. In pastures where LL occurs with native grasses, selective cattle grazing may favor the establishment and spread of LL. Under conventional year-long grazing management, cattle prefer native grasses during the summer growing season and lightly graze LL (Martin 1983, Ruyle et al 1988a). In contrast, cattle utilize LL in fall, winter and spring because the foliage remains green longer than the native grasses (Cable and Bohning 1959). This seasonal pattern of animal selectivity reduces native-grass vigor, because plants are repeatedly grazed during active plant growth. Consequently, LL may obtain a competitive advantage.

Further study only partially supports this assumption. McClaran and Anable (1992) have demonstrated that the adventive spread of LL does not require livestock grazing. However, increased grazing intensity increased the proportion of lovegrass in the total grass population, albeit due to decreases in native grass densities and not from absolute increases in LL density with grazing intensity. Additionally kangaroo rats (*Dipolomys* spp.) appear to be critical to increased LL stands in Chihuahuan Desert shrub habitat (Brown and Heske 1990).

RELATIONSHIPS BETWEEN SOILS, TEMPERATURE, PRECIPITATION AND THE SPREAD OF LEHMANN LOVEGRASS

Surface soils at 33 sites where LL was successfully established in southeastern Arizona are sand to sandy loams, and soil depth varies from 0 to 120 cm (Cox and Ruyle 1986). At one-third of the sites, LL has spread from the seeding site to surrounding rangeland. Where the plant spreads, the sand to sandy loam surface soils are at least 15 cm deep, the soil profile is greater than 50 cm deep and soils are well drained. Soils are classified as either Comoro, Forest, Sonoita, Tubac, or Whitehouse series (Soil Taxonomy 1975, Richmond 1976, Richardson et al. 1979.) Surface soils at the remaining sites are sandy, but soil depth is either less than 6 cm or greater than 30 cm. At these sites, LL has been slower to spread to surrounding rangeland.

Elevation, mean annual winter temperature, and mean summer precipitation for the 33 planting sites was evaluated by Cox and Ruyle (1986). Elevation is less than 1,000 m at 6 sites, greater than 1,000, and less than 1,500 m at 21 sites, and greater than 1,500 at 6 sites. Annual winter temperatures are less than 12 C at 8 sites, greater than 12, and less than 14 C at 21 sites, and greater than 14 C at 4 sites. Total summer precipitation is less than 200 mm at 13 sites, greater than 200, and less than 250 mm at 15 sites, and greater than 250 mm at 5 sites.

CONCLUSIONS

It is commonly believed that LL will continue to spread in the southwestern USA because the plant is adapted to a wide range of climatic and soil conditions (Cox 1984, Cox and Martin 1984, Martin and Cox 1984, Frasier et al. 1984 and 1987, Cox et al. 1990, Ruyle et al. 1988b, Roundy et al. 1993). In southeastern Arizona, approximately 90% of the area where summer rainfall ranges between 200 and 300 mm is currently occupied by LL. Because of shallow soils, dense shrub stands, and low summer rainfall, we do not believe LL is likely to invade at elevations below 1,000 m, except in localized cases. We suspect that subsequent population increases will largely be through increased stand densities and continued invasion of areas above 1,500 m.

There is little to indicate that LL will decline under natural successional processes where it has dominated favored sites. None-the-less attempts to reduce LL stands and favor native perennial grasses continue. Spring burning, moving or heavy grazing, herbicide treatments after the onset of summer rains and LL seedling emergence, followed by seeding native grasses may be the best suggestions to date to accomplish the above objective (Biedenbender and Roundy 1996).

As Anable et al. (1992) and Robinett (1992a) suggest, seed arrival appears to be a major influence on LL invasion at elevations above 1,000 m in southern Arizona regardless of perturbation levels or management practices. Where seed sources are available we believe that the primary factors influencing continued invasion of LL are drought and a positive feed-back response to fire.

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Riparian Areas, Watersheds and Water Quality: a Panel Discussion

Roy Jemison, Moderator[1]

Introduction to the Panel

Riparian areas within desert grassland ecosystems provide many useful functions and benefits on which we depend and which we enjoy. To unsure the availability of these ecosystems now and in the future, we must understand how they function and be willing to work in harmony with them.

Water in excess of the surrounding ecosystems in combination with soils, geology, and other site conditions determines the location and extent of riparian ecosystems. However, it is not enough to know that water is present in excess. We also need to know the quantity, quality, and source of the water. As we investigate these parameters, we will find that they are linked inseparably to parameters in the surrounding ecosystems. For example, water quantity can be linked to watershed area, water quality to non-point source pollution, soil erosion to excessive runoff and land misuse. Continued investigation can show that riparian areas, in many instances, are the results of delicate balances between water and multiple environmental parameters.

Reference (exemplary) riparian systems should be noted during investigations. These areas can then serve as barometers by which other sites are judged and as examples of the potential of other sites with similar conditions. Monitoring of environmental parameters such as water quality and quantity and/or the health and abundance of dependent species can serve as indications of when these ecosystems are unbalanced. Simulation models can be used to predict the future of these systems based on our past and current understanding of them.

A logical approach to address the maintenance of our riparian grassland ecosystems and waters is to involve an informed public. The papers and comments which follow provide a foundation on which to build an understanding of the hydrologic concerns of grassland riparian areas and their adjoining ecosystems.

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Hydrology and Watershed Management in Semi-Arid Grasslands

Malchus B. Baker, Jr.[1]

ABSTRACT

Ecosystems in the semi-arid southwestern United States and northern Mexico are sustained in a delicate balance under a limited water regime and a highly variable climate. This balance has frequently been overwhelmed by past land use and abuse, resulting in severe and widespread watershed degradation. This paper discusses existing hydrologic and watershed information for the semi-arid grassland vegetation type and provides suggestions for the restoration of severely degraded watershed areas.

INTRODUCTION

The climate of the southwestern United States and northern Mexico is mainly arid, with the isolated higher elevation mountain ranges being subjected to a more semi-arid climate (Baker et al. 1995). This biogeographic region, also known as the Madrean Archipelago, is especially sensitive to climatic fluctuations and human impacts. Therefore, a knowledge of the hydrologic processes regulating these water-limited ecosystems is essential to understand the soil-vegetation relationships that are responsible for sustaining landscape stability in this region (Ffolliott and Thorud 1975). The hydrologic response of this region to potential, global, climate changes is also important because of the delicate equilibria and interrelationships existing between precipitation and soil-vegetation assemblages.

Only a few comprehensive hydrological studies have been reported for the semi-arid grassland type (Lopes and Ffolliott 1992). Probably the best known study is the long-term research effort at the Walnut Gulch Experimental Watersheds in southeastern Arizona (Renard 1978). The objectives of this paper are to characterizes the hydrology of the semi-arid grassland type by summarizing existing information obtained from within the vegetation type, and to supplement this information with data extrapolated from associated ecosystems in the region.

VEGETATION

Brown (1982) indicates that the semi-arid grasslands in the southwestern United States and northern Mexico were historically found at elevations of between 1,000 and 1,600 m on level plains and along the larger river valleys. These areas are typically grass-dominated systems with scattered woody plants--a savanna landscape. Since the root system of grasses is generally shallow, and of woody plants is generally deeper, removal of grasses by animal grazing can reduce

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water loss near the soil surface. As a result, more water becomes available for use by the deeper and more extensive root systems of the woody plants, and scrub or bush encroachment begins. If grasses are not allowed to recover and the likelihood of lightning or human-caused fires to increase, woody plants will continue to spread at the expense of the grass species (Brown 1982).

CLIMATE AND HYDROLOGY

Precipitation

The southwestern United States receives an average of less than 100 mm of annual precipitation in the lower desertscrub to over 800 mm on the higher mountain peaks (Sellers et al. 1985; Brown 1982, Ffolliott and Thorud 1975) (Figure 1). One-half or more of the annual precipitation falls during the growing season between July and September (Osborn et al. 1980). These precipitation events are mainly high intensity, short duration convectional storms originating in the Gulf of Mexico. Winter precipitation is generally rain that comes during November through April, with occasional snow occurring in the higher elevations. Winter precipitation normally comes as frontal storms from the Pacific Ocean.

Precipitation supplies moisture for plant maintenance and growth and in turn vigorous plant growth tends to reduce soil erosion. However, the high intensity precipitation events that frequently occur in this region often create overland flow from both vegetated and nonvegetated areas, and as a result, significantly increase erosion.

Plants growing in semiarid grasslands are engaged in a race against time. Green and Martin (1967) show that the effectiveness of precipitation in relation to plants varies with season. The length of time that the soil remains wet after a rain is much longer in winter than in summer. Evaporation from a free water surface in Tucson is eight times greater in June than December, and soil moisture after each rain is available only until it evaporates or is used by plants. Plants grow little in December and January, regardless of the availability of water, because ambient temperatures are low. Although plants can grow rapidly during the summer, they only have a few days to use water made available by rain because of high evaporation losses.

Green and Martin (1967) pointed out that heavier rains will often produce visible growth on shrubs or perennial grasses, and provide conditions for the germination of annual grass and forb seeds. A deep wetting of the soil in summer can produce significant amounts of perennial grass herbage, but it rarely produces substantial annual plant growth. Most southern Arizona soils require from 6 to 8 mm of

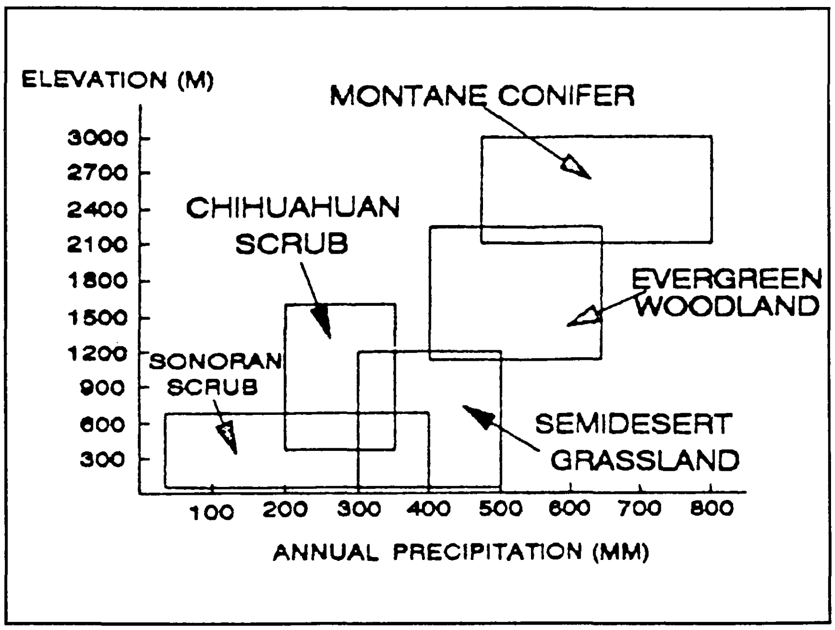

Figure 1. Elevation and precipitation relationships of biotic communities in southwestern United States and northern Mexico.

precipitation to wet the surface 8 cm of soil (Green and Martin 1967). However, rains of 6 mm or even less a day or two apart, interspersed with heavier rains, can maintain usable soil moisture levels. The surface layers of many soils in the region hold about 38 mm of water per 30 cm of soil at field capacity, and 13 mm of water per 30 cm of soil at the wilting point of herbaceous plants (Green and Martin 1967). Therefore, about 25 mm of water per 30 cm of soil is available to support plant growth.

Summer rains produced 90 percent of the perennial grass herbage on the Santa Rita Experimental Range (Culley 1943) and are responsible for major plant growth in New Mexico (Nelson 1934). Green and Martin (1967) showed that the amount and distribution of rainfall affects not only the amount of forage produced, but composition as well. Perennials account for only 20 percent of the grass herbage at the lower elevations, compared to 70 percent at the higher elevation where rainfall is greater. An additional 25 mm of summer rainfall can increase average perennial grass yields by about 140 kg/ha.

Temperature

Freezing temperatures in the grassland savanna can be expected during any winter, but these freezes are not of a long duration and temperatures rarely drop far below -4°C (Brown 1982). Killing frosts are infrequent. Therefore, evapotranspiration loses can occur year-long in this region.

Evaporation

Information on water losses from the soil, by both evaporation from the soil surface and transpiration from vegetation, has been used to calculate water balances. Buol (1964) calculated annual potential evapotranspiration (PET) values (by the Thornthwaite (1948) method) for Arizona from available climatic records. Calculated PET in the southwestern United States ranges from 760 to 1,020 mm of water per year, while actual evapotranspiration ranges from 250 to 760 mm per year. In general, these values are within the range of measured annual ET values of 989 mm from an area supporting riparian grasses along the Gila River (Leppanen 1981), and of 493, 389, and 335 mm for actual ET measured in a 150-day growing period from a forested area, a clear cut forest area, and a cienega, respectively, in the White Mountains (Thompson 1974). Estimates of evaporation from a free water surface in this region range from 1,525 to 1,780 mm (NOAA 1982).

Interception and Throughfall

Precipitation falling on a watershed is partitioned into water intercepted by leaves, twigs, or stems and returned to the atmosphere by evaporation; water channeled to the soil surface as streamflow, or drip from the foliage; water passing through the foliage to the soil surface as throughfall; and water falling directly on the soil surface in areas having sparse vegetation (Brooks et al. 1991).

Throughfall in taller vegetation can be intercepted by low-growing vegetation, litter, or the soil surface. Crouse et al. (1966) indicated that the water storage capacity of grasses is proportional to the product of the average plant height and percent of ground cover. Interception losses vary from 0.2 to 9 mm. Corbett and Crouse (1968) found that the amount of water evaporated from surface litter is governed primarily by the moisture-holding capacity of the litter, and the evaporation potential during and following storms. Interception losses from small storms are normally much higher (i.e, up to 90 percent), while those from larger storms range between 2 and 5 percent.

Approximately 20 percent of the gross precipitation intercepted in the coniferous woodland canopies is lost to evaporation (Skau 1964) and from 10 to 25 percent is lost from the ponderosa pine canopies (Aldon 1959).

A study of rainfall distribution in the evergreen woodlands of southeastern Arizona, plant communities that are largely evergreen or a mix of evergreen and deciduous species (Brown 1982), showed that up to 70 percent of the late summer-early fall rains are intercepted directly under the canopies of Emory oak trees (Haworth 1992). Throughfall varied from 100 percent (all trees, large storms) to about 30 percent (large trees, small storms). Rainfall was distributed evenly under and around trees in storms generally larger then 25 mm.

Infiltration

Once precipitation reaches the land surface it can infiltrate into the soil, evaporate, or contribute to overland flow and eventually runoff. The rate that water enters the soil depends upon the nature of the precipitation, vegetation, topography, and soil properties (Brooks et al. 1991). Important soil properties are texture and restricting subsurface layers.

Desert grassland vegetation generally grows on alluvial soils (Hendricks et al. 1985). These are well-drained soils on valley bottoms and floodplains in the Santa Cruz, Sulphur Springs and San Simon Valleys. Native vegetation is mainly grasses at the higher elevations, while desert shrubs and cacti dominate the lower elevations. These soils support the best rangeland in the Southwest.

Beutner et al. (1940) studied infiltration in a wide range of Arizona desert soils. All of their infiltration curves for dry soils began with high infiltration rates, which declined rapidly during the first 10 minutes until a nearly constant infiltration rate was reached. Infiltration rates varied from 7 to 56 mm/hr when rainfall was applied to dry soils compared to 5 to 32 mm/hr when applied to soils at field capacity.

Infiltration rates are also influenced by grazing animals that remove plant material and compact the soil (Branson et al. 1981). As a result, runoff often increases as range and soil condition deteriorates. Hendricks (1942) found that infiltration is improved if grazing management allowed for the accumulation of grass litter on semi-arid rangelands.

Soil wettability is a phenomenon found on many rangelands and forested areas. In more arid climates, water repellency has been found particularly under various species of oak, chaparral, and coniferous woodland communities and often affects water infiltration into the soil (DeBano 1981).

Runoff

If water reaching the soil surface does not infiltrate or evaporate, it becomes runoff. Of the three major components of runoff--(surface or overland flow, storm seepage or interflow, and groundwater flow)--surface runoff is the most common runoff component in arid environments. Surface runoff normally occurs only briefly during summer rainfall events when intensities exceed the infiltration capacity of the soil, or during periods of rapid snowmelt in the spring.

Studies of runoff relationships in arid and semi-arid areas are complicated by the variability in precipitation and by the infrequent nature of runoff events. Studies using comparable amounts of artificially applied rainfall on small, adjacent plots show that differences in runoff can occur, and that these differences are attributed to variations in soils, plant type, and range condition (Branson and Owen 1970; Kincaid and Williams 1966; Schreiber and Kincaid 1967).

Much of the surface runoff originating in the mountain tops of southwestern United States and northern Mexico flow into ephemeral stream channels in the lower elevation woodlands, grassland,

and desertscrub types (Baker et al. 1995). Therefore, it is important that watershed management practices protect these areas from accelerated erosion and sedimentation because of their eventual negative impact on water quality and on long-term site productivity (Lopes and Ffolliott 1992; Marsh 1968).

Osborn et al. (1980) reported that ephemeral stream channels in arid and semi-arid regions can accommodate large volumes of runoff in their normally dry streambeds. Storm movement (i.e., direction that a storm moves across a watershed) has little effect on major flood peaks from small watersheds. However, storm movement can affect flood peaks and volumes for smaller storm events. If storms move too rapidly across a watershed, reduced surface runoff can be entirely (or mostly) absorbed by the channels above the watershed outlet.

Streamflow in southwestern United States is often linked directly to groundwater regimes (Davis, 1993), as is illustrated in the upper San Pedro River Basin (Jackson et al. 1987). Local citizens and government officials are concerned about groundwater depletion resulting from accelerated pumping in this river basin in both Mexico and the United States. A University of Arizona study (1991) indicated that pumping water from the regional aquifer in the Sierra Vista area is depleting stored groundwater reserves, and that future water pumping will only accentuate this trend. Although the depletion rate of groundwater is currently small compared to the total volume of water in aquifer storage, these withdrawals can directly affect surface flows in the San Pedro River, which are particularly important to the riparian vegetation and existing wildlife.

Erosion and Sedimentation

As mentioned, streamflow in southwestern United States is generated mainly from the higher elevation forested areas, while the majority of the sediment originates in lower elevation ecosystems (Branson et al. 1981). For example, Dortignac (1956) found that the Rio Puerco watershed in New Mexico, which represents less than 20 percent of the Upper Rio Grande Basin, contributes nearly half of the total sediment supply but produces less than 8 percent of the total water yield from the area. Langbein and Schumm (1958) concluded that maximum sediment yields, under natural vegetation regimes, occur at about 300 mm of annual precipitation. Sediment yields decrease on the dry side of this curve because there is a lack of runoff to transport sediment, and decrease on the wet side of this curve because the naturally denser vegetation produced by higher precipitation regimes has a greater ability to protect the soil from erosion. This relationship is complicated by removal of vegetation by such activities as grazing and logging (DeBano and Wood 1992). As a consequence of all these factors, sediment is frequently the major product of non-point source pollution in southwestern streams (Branson et al. 1981).

Sediment yields at Walnut Gulch decreased from an average annual production of 3,740 to 290 kg/ha following vegetation conversion of brush to grass (Simanton, Osborn, and Renard 1977). Although runoff increased during the transition period, it decreased once grass became established--contributing to the reduction in erosion.

Clary et al. (1974) reported annual sediment yields from the woodland vegetation type on volcanic soils of 2,000 to 4,500 kg/ha. Vegetation conversion treatments on these volcanic soils did not increase sedimentation, however, sediment losses on other soil types (such as sedimentary soils) following conversion were greater.

Chaparral brushlands intermingle with evergreen woodlands on the flanks of isolated mountain ranges in southeastern Arizona. Sediment yields from chaparral watersheds with soils derived from granitic parent materials are often of the same magnitude as those observed in the coniferous woodlands. Sediment production, however, can be greatly accelerated immediately after treating chaparral vegetation, especially when burning is involved (Overby and Baker 1995; Hibbert et al. 1974; Morenno 1968).

Sediment yields depend upon the magnitude of overland flow and the stability of stream channels. Important climatic, geomorphic and hydrologic parameters controlling sediment production and transport are: high intensity thunderstorms, which can produce large peak discharges per unit area; limited areal extent of rainfall which can result in partial area runoff; transmission losses in normally dry stream channels, which can decrease downstream sediment transport capacities; steep channels, which can produce high flow velocities with increased potential for transporting sediment; and unconsolidated stream channel material and unprotected stream banks, which can produce a large supply of sediment (Lopes and Ffolliott 1992).

WATERSHED MANAGEMENT

Watershed management in the semi-arid grassland region must consider the soil and water resource as related to livestock production, wildlife habitats, and recreational use on the watershed and along the riparian areas of the stream channels. Conservation of the soil and water resource is important because of the fragile nature of the soils and limited amounts of available water in the region (Lopes and Ffolliott 1992). Therefore, watershed management practices should be carefully planned and implemented to ensure protection and (wherever possible) enhancement of the soil and water resource.

Riparian areas are closely related to their surrounding watershed area (LaFayette and DeBano 1990). These riparian plant communities stabilize stream channels, provide repositories for sediment, serve as nutrient sinks for surrounding watersheds, and improve quality of water leaving the watersheds. Riparian areas also provide temperature control through shading, reduce flood peaks, and serve as recharge points for renewing ground-water supplies. Riparian areas, however, must be managed within the context of the entire watershed because all tributary effects cumulate to influence riparian plant stability (DeBano and Schmidt 1989). A delicate balance exists between the riparian community and its surrounding watershed. DeBano and Schmidt (1989) describe this scenario, upland watersheds in satisfactory condition absorb storm energies, provide regulation of stormflows through the soil mantle, and bring stability to the entire basin. This condition results in sustained flows necessary for supporting a healthy riparian ecosystem.

In contrast, watersheds receiving past abuse have developed more extensive channel systems throughout the watershed, including ephemeral, gully networks. These gullies are formed in response to increased runoff resulting from the production of more rapid and concentrated surface runoff. These gully networks also produce higher peak flows and increases in erosion and resulting sedimentation. Past abuse and overuse of wildlands throughout the southwestern USA by grazing, trail and road construction, timber and fuelwood harvesting, mining, and other land uses have destroyed plant cover, increased soil erosion, and in the process have reduced riparian habitat (DeBano and Schmidt 1989). Riparian communities in the southwestern USA are particularly sensitive to overuse because they exist in a semi-arid climate and are subjected to wide variations in annual precipitation (Leopold 1946).

The sensitive hydrologic interrelationship that exist between watershed condition and the health of associated riparian areas has been illustrated by DeBano and Schmidt (1989) and the use of watershed treatments and properly designed, constructed, and maintained structures for enhancing riparian habitats have been presented (DeBano and Schmidt 1990; DeBano and Hansen 1989; DeBano and Heede 1987). Objectives of the use of these structures are to affect streamflow hydraulics and sedimentation, and therefore, create a more favorable environment for riparian habitat establishment. Beneficial uses of man-made structures have been used extensively throughout the Southwest and play an important role in management of riparian areas. However, some structures have produced less desirable influences.

WATERSHED IMPROVEMENT PRACTICES

Watershed improvement practices can be grouped into two general categories, those which minimize adverse impacts to the soil and water resource and rehabilitation practices used to improve watershed condition.

Minimizing adverse impacts

Fragile soils and limited water make it important to protect the semi-arid grasslands from further deterioration of the soil and water resource. Past degradation has been contributed to overgrazing by livestock, reduction in wildfires by man, and precipitation events at both extremes--high intensity rains and droughts. Therefore, a positive plan of action is needed to protect this unique resource from further degradation. Management practices that minimize adverse impacts on the soil and water resource are similar to those used to prevent excessive rates of erosion (Lopes and Ffolliott 1992). Roads should not be constructed in or near stream channels. When roads are closed to public travel; roadways should be seeded with native herbaceous plant species to protect against erosion. Grazing and recreational use should be monitored to minimize impacts on stream channels, riparian areas, and water quality. These practices are all essential components of an integrated watershed management program that accommodates multiple uses.

Numerous attempts have been made to control erosion with various types of structures and management practices, particularly on rangelands, but failures have been frequent (Branson et al. 1981). Peterson and Hadley (1960) reviewed the effectiveness of a number of erosion abatement practices (including nearly 200 erosion control structures) on semi-arid rangelands in the Upper Gila River Basin. They found that vegetation was often not benefitted appreciably by structures and that excessive maintenance costs often make there use prohibitive or resulted in no maintenance being applied.

Peterson and Branson (1962) evaluated the effectiveness of various land treatments undertaken by the Civilian Conservation Corps in the mid-1930s. Treatments included earth fill dams, earth dike spreaders, loose rock spreaders, hand placed rock spreaders, brush spreaders, "cement worm" spreaders, cable and wire spreaders, and rock rubble gully control structures. More than half of these structures breached within a few years after construction. However, vegetative cover was improved where earth dikes were not breached and water was distributed by the spreader system.

Lusby and Hadley (1967) studied the influence of low dams and barriers on sedimentation. They concluded that slope of deposition was largely dependent upon the particle-size distribution of transported sediment, and the rate that steep-sided gullies filled was dependent upon availability of material approaching the size of the original channel bed material. Deposits behind low permeable barriers had steeper surface gradients than the original stream channels, and deposits behind low dams had lower gradients than the original channels.

As previously mentioned, properly constructed and maintained structures can have a positive influence on riparian vegetation (DeBano and Schmidt 1990; DeBano and Hansen 1989; DeBano and Heede 1987). Therefore, why have so many failures been observed? The key is in understanding where and how to use structures. One needs a good understanding of the hydrology of the area and the interrelationships with and between the geology, soils, and native vegetation. Monitoring of the short- and long-term functioning of the structures can also provide more specific information about the functioning of various types of structures and their successful use in specific areas.

The extreme variability in climate in southwestern United States makes it difficult to isolate natural erosion and sedimentation rates from those induced by human activities. However, much of the severe erosion and sedimentation observed in the woodlands and semidesert grasslands in southeastern Arizona has been attributed to overgrazing by livestock, mainly during the last half of the 19th century (Cox et al. 1984).

Cox et al. (1984) estimated that cattle numbers in the desert southwest exceeded 500,000 between 1830 and 1840, and increased to a peak of about 1.5 million in the late 1880s. Large areas of sacaton and grama grass existed here prior to 1870, and beaver dams often restricted water flow. But, human disturbances between 1870 and 1901 (including the plowing of sacaton bottoms, channeling of rivers to provide irrigation water, overgrazing by livestock, and extermination of beaver by trappers) dramatically changed this landscape. Most of the water sources were dried up by 1893 and about 65 percent of the cattle had died because of these changes, which were amplified by a severe drought. Although the drought ended by 1895, the added effects of overgrazing, farming, and subsequent flooding resulted in accelerated sheet and gully erosion throughout the region.

Restoration efforts in the San Simon Valley illustrate the benefits arising from the implementation of proper engineering and land management practices (Baker et al. 1995). Historically the area was a broad grassy valley that was bisected by an intermittent stream with little apparent erosion prior to the 1880s. The broad, flatter areas were covered by sacaton and tobosa grass with few trees. Willows grew in the wetter areas, and cottonwoods were found in San Simon Cienega, near the current day Arizona-New Mexico state line. Little channel erosion was present, and the bottom was well vegetated.

From 1883 to 1916, head cutting of San Simon had advanced 60 miles up the channel, and had ranged from 3 to 10 m in depth and 12 to 245 m in width. Factors contributing to this rapid erosion included overgrazing by livestock, widespread drought, subsequent flooding, and construction of a drainage ditch, a wagon road, and a railroad. By 1919, the San Simon valley was recognized (by the U.S. Government) as needing extensive restoration.

Numerous erosion control measures have been implemented on San Simon since 1934, including diversion dikes, water spreaders, detention dams, gully plugs, and rangeland seedings. After 50 years of monitoring the results of the various control measures, installation of main channel structures were judged to be most effective. Side channel structures have been largely ineffective in regrading steep channels slopes although these structures have stopped further headcutting of the side channels, and have reduced water velocities.

Watershed rehabilitation

Management practices used to rehabilitate watersheds include: controlling gullies and mass wasting with properly constructed check dams (Heede 1970); establishment of a protective tree, shrub, or herbaceous plant covers on degraded sites (Cox et al. 1984); and (when necessary) curtailment of livestock grazing and other exploitative practices (Lopes and Ffolliott 1992).

Artificial seeding of rangeland plants has been studied for nearly a century in the Southwest. The results of these studies provide information necessary for rehabilitating severely degraded watershed. For example, Cox, et al. (1984) found several grass species that can be successfully established in the Chihuahuan and Sonoran deserts. Unfortunately, frequent drought and continual abuse by man has caused the deterioration of semi-desert grasslands through accelerated erosion, brush invasion, and reduced forage production. However, even though revegetation is difficult and costly, it is possible.

CONCLUDING REMARKS

The ecosystems in the Southwest represent a wide assemblage of hydrologic conditions within the context of a arid and semi-arid environment. These ecosystems sustain themselves in a delicate balance within an environment having limited water and a highly variable climate. This balance has frequently been overwhelmed by past land abuse, resulting in severe and widespread watershed degradation. Careful implementation of existing watershed and hydrologic information has been demonstrated by the successful restoration of some highly degraded sites. However, widespread application of existing technology is dependent upon a more thorough understanding of the fundamental hydrologic processes operating in the unique environment of the semi-arid grasslands.

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Using RUSLE for Erosion Control and Grassland Management

Kenneth G. Renard[2]

ABSTRACT

Overgrazing over the years has contributed to soil erosion in many areas. The method described in this paper was developed to calculate the rate and type of soil loss and environmental degradation. The Revised Universal Soil Loss Equation (RUSLE) provides a very useful tool for land managers.

Alan Paton (1948) in Cry, the Beloved Country states:

"Where you stand the grass is rich and matted you cannot see the soil. But the rich green hills break down. They fall to the valley below, and falling, change their nature. For they grow red and bare; they cannot hold the rain and mist, and the streams are dry in the kloofs. Too many cattle feed upon the grass, and too many fires have burned it. Stand shod upon it, for it is coarse and sharp, and the stones cut under the feet. It is not kept, guarded, or cared for, it no longer keeps men, guards men, cares for men. The tithoya does not cry here any more."

Although this passage describes conditions in southern Africa, it might well have been about grasslands in the United States.

Some of the earliest water erosion research started in the Western U.S. (e.g. the work by Sampson and Weyl (1912) on the overgrazed rangelands in Central Utah). Such research languished until the latter part of the 1970's (Renard, 1985). Thus, current technology for controlling water erosion on rangelands has evolved primarily from research performed on cultivated croplands and transferred with minimal validation to rangeland and grasslands (especially on the drier climate that dominate the western U.S.).

The National Research Council, Board of Agriculture's Committee on Long-Range Soil and Water Conservation (1993) published an assessment of Soil and Water Quality: An Agenda for Agriculture which enumerated the nation's resource problems on agricultural land. A considerable portion of this major undertaking involved a discussion of "soil degradation" and the physical-chemical-biological facets of the problem. Soil degradation and the associated phenomenon of compaction, fertility depletion, soil organic matter decline, loss of moisture holding capacity (through profile depth decreases), and loss of seedbed attributes, all result in environmental deterioration as well as the downstream consequences of water erosion.

The Universal Soil Loss Equation (USLE)(Wischmeier and Smith, 1978) and its predecessor versions has been widely used for conservation planning. The technology as presented in the 1978

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handbook includes many limitations for problems encountered in the later part of the 20th century. At a 1985 workshop of researchers and users of the USLE technology, it was decided that erosion prediction technology needed to be revised and new technology developed to eventually replace the regression based USLE. The results are RUSLE, the Revised Universal Soil Loss Equation (Renard et al., 1991; 1994; 1996) and the WEPP model (Laflen et al., 1991).

One of the most significant decisions associated with RUSLE development was to computerize the technology. The software produced is available from the Soil & Water Conservation Society in Ankeny, Iowa. The software package includes data bases for application to conditions encountered in the USA and a User's Manual. The society also has a video which assists with training new users.

RUSLE: THE REVISED UNIVERSAL SOIL LOSS EQUATION

RUSLE is based on the same regression equation as the USLE (Wischmeier and Smith, 1978). The USLE and RUSLE (compute sheet and rill erosion using terms representing the major factors affecting erosion) are given as:

$$A = R\,K\,L\,S\,C\,P$$

where A is the computed soil loss, R is the rainfall-runoff erosivity factor, K is a soil erodibility factor, L is the slope length factor, S is the slope steepness factor, C is a cover management factor, and P is a supporting practices factor. The empirically based equation, is derived from a large mass of field data.

DATABASES

A major difference between the USLE and RUSLE is the development of databases that permit easy and repetitive solutions with RUSLE. Three databases are included: CITY, CROP, and OPERATIONS.

The CITY DATABASE includes the basic climate information necessary for a soil loss estimate. In addition to an estimate of the annual rainfall erosivity ® = $\sum$ KE*I where KE is the rainfall kinetic energy and I is the maximum 30 minute intensity), the data base includes monthly precipitation, temperature, frost free period, % of the annual erosivity occurring by the first and fifteenth of each month, and 10-year frequency maximum daily EI. These data are available for many locations in the USA and a procedure has been developed for estimating R and the 10-year EI from precipitation data where it is available (Renard and Freimund, 1994).

The CROP DATABASE, as the name implies, includes fundamental information about those features of the crop that might affect erosion. Features include residue at harvest time, residue decomposition rate (both above and below ground are requested although lack of data may lead to a single value for both), and the amount of residue cover (weight per unit area) at 30, 60, and 90% cover. In addition, the amount of root mass in the top 100 mm (4 inches), the canopy cover (%), and the fall height of raindrops intercepted by the canopy are needed at 15 day intervals throughout the growing season. The computer software includes estimates of these data files for most major crops along with a procedure for estimating the values for various crop yields.

The OPERATION DATABASE reflects soil disturbing activities resulting from land use operations. Again the software contains examples of most operations used in the USA. The information needed includes up to five effects with each effect drawn from a list of nine possible scenarios. The information for each effect includes the percent of the surface area disturbed, the initial and final

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Water Supply Issues in Grasslands

Barbara Tellman, Panel Moderator[3]

INTRODUCTION TO THE SESSION

Water supply is crucial to grassland health. In arid regions, any depletion of water supply can make the difference between a thriving grassland and an unhealthy system tending towards dessication. In this session we will look at two studies of water supply in a healthy grassland system in southern Arizona, the Patagonia-Elgin-Sonoita area. The area is southeast of Tucson, Arizona, just north of the border with Sonora. The Audubon-Whittell Research Ranch is located in this area, as are many other private thriving ranches. The area has been relatively stable for the past one hundred years since Anglo settlement in the area took root. The area has had fewer problems from overgrazing than most other parts of Arizona.

Over the past ten years urbanization has been creeping into the area. Since 1990, the impacts of this urbanization have been a major concern for many ranchers. Impacts include change in fire management regimes, changes in grassland composition as large ranches are broken up into subdivisions, with ranchettes of 4 acres or less, and changes in the ability of wildlife to use the area for corridors. Vineyards and other types of agriculture have increased greatly in recent years also.

One of the greatest concerns to managers of the Research Ranch and many others, is a threat to the local water supply. Ranching uses relatively little water, compared to more urban uses.

Today we will look at two studies of water supplies in the area, as examples of how people in rural areas can examine water supply problems and threats to determine what the impacts of population growth will be in regard to water supply. But before looking at these studies, I will briefly describe a water supply problem that occurred more than twenty years ago in the area and was solved through the use of water supply data.

The areas where the BLM Empire-Cienega Conservation Area is today was once slated for a major development of at least 50,000 people. The area had been owned by a mining company who decided to sell to a land speculator for the purpose of established a planned community within easy commuting distance of Tucson. A rezoning was necessary, complicated by the fact that the land extends into two very different counties - Pima County and Santa Cruz County. The area is in the upper reaches of the watershed from which Tucson (in Pima County) derives some of its surface water supply.

Opposition to the rezoning was fierce in both counties, but the most heated battles were waged before the Pima County Board of Supervisors. Among many arguments, opponents challenged the availability of water for such a large community. There was no provision in Arizona water law that would deny the rezoning, so the counties had to be convinced to deal with the issue through the zoning process.

To make a very long story short, the rezoning was approved on a scaled down basis, with the provision that construction could only proceed in phases, dependent on the developer proving the availability of water. The burden was on the developer to do the necessary studies to prove long-term availability. A first phase was approved allowing for as many homes as could be supported on the known water supply. If the developer could prove the existence of more water, he could then

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proceed with phase two, and later other phases until full build-out. The developer did not find this financially feasible and dropped the project. Thus, the land became available at a later date for a publicly owned Conservation Area.

The two studies which follow discuss water supply for an area south of the one just described They are instructive in terms of knowing what are the right questions to ask. Neither study was very costly, but both are extremely useful to current residents.

Arid Grasslands And Water Resources

Charles W. Stockton, David Meko, and Mary F. Glueck[1]

ABSTRACT

The grasslands of the Sonoita-Elgin area are among the best preserved in the state. These grasslands have been occupied for years, but the rate of occupation has increased rapidly in the past ten years. Whether or not there is enough water to maintain the grasslands and their riparian areas is the subject of this paper that examines water supplies and projected uses.

GRASSLANDS ARE ATTRACTIVE FOR DEVELOPMENT

The old saying "lush green valley" has a pleasant ring to most people, and grasslands have traditionally been attractive to human settlement. In the past, when grassland valleys were relatively remote, the pressure of development was slight. Grassland valleys near Sonoita and Elgin were homesteaded relatively late, in the period 1910-1920. Much of the land was already occupied by large ranches such as the Empire, Babocomari, and San Rafael and only a few 160 acre parcels were available. For some reason, perhaps because the grassland area appeared similar to the Great Plains region, many of the homesteaders thought the land could be tilled and began farming operations in the area. Most commonly, the crops were rain-fed, and consisted of cereals, such as wheat and barley. The soil in the grassland area is relatively fertile, and because of an anomalous wet period extending from roughly 1905-1925, many small farming operations flourished. From the end of this wet period to the present, however, the primary use for water has been for livestock.

Because of the abundance of wind in the Sonoita-Elgin region, a common early source of water was ground water from either drilled or hand-dug wells pumped by windmills. These water sources were of course subject to the vagaries of the wind, and an additional source of stock water was needed. The rancher was quick to realize that grassland produces a high percentage of runoff, and many stock ponds -- most with less than 5 acre-feet capacity -- were built during the period 1920-1950. Contracting companies developed the expertise to construct stock ponds on draws and washes capable of providing water to livestock on an annual basis and yet able to withstand large runoff events. These stock ponds, built with minimal engineering design, have been remarkably durable and many have survived and are in use today. The total amount of water retained by stock ponds and produced from wells pumped by windmills has resulted in only minimal use of the water resources and little stress on local water supplies. But this scenario seems to be changing, and the point of this paper is to address some of the possible ramifications of the changing patterns of water use on the valley grasslands.

[1] All at the Laboratory of Tree-Ring Research, University of Arizona, Tucson AZ.

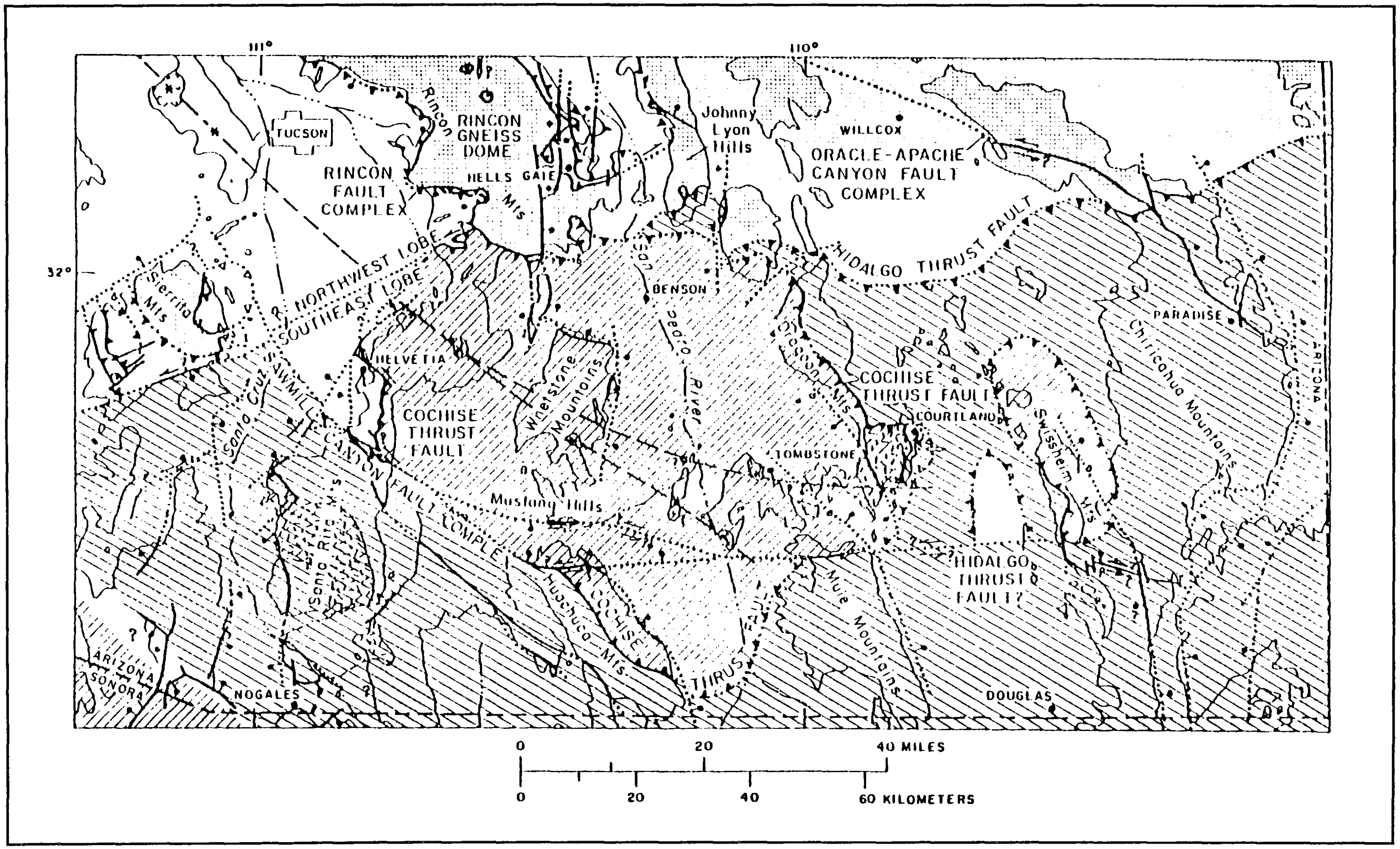

Figure 1. Map showing major thrust faults such as the Lone Mountain-Sawmill Canyon fault complex and the Babocomari Fault as well as other geologic features in a region of southeastern Arizona. (From Drewes, 1976)

BASIN AND RANGE PROVINCE: VALLEYS ARE PRESUMED TO BE LARGE SOURCES OF GROUND WATER

As cities in southeastern Arizona have grown, they have tended to look at nearby valleys as potential sources for expansion of municipal supplies of water. This is an understandable approach, because in the Basin and Range Province it is not uncommon for the valleys to be large gravel filled grabens with abundant ground water. Examples are the Tucson Valley and Avra Valley west of Tucson. Both valleys are classic in that they are occupied by pervious valley fill thousands of feet in thickness with large quantities of stored water. Not all valleys in the Basin and Range Province, however, are of this type. Two that are not are the San Rafael and the Sonoita-Elgin Valleys, both classic grassland valleys in which geologic structural events have produced valleys with fill conducive to neither storage nor transmission of large quantities of water. In the San Rafael Valley, there appears to be only a relatively thin layer of surface alluvium capable of storing and transmitting water to wells. This layer is underlain by older volcanic and well indurated sedimentary rocks. The tectonic map of the Lochiel quadrangle (Simons, 1974), which includes the San Rafael Valley, confirms that, with isolated exceptions, faults and folds have not had an important impact on the occurrence of ground water in this valley. In general, the thinness of the alluvium and the character of the underlying volcanic and sedimentary rocks make large quantities of ground water rare in this Valley and wells yield only moderate quantities of water.

In the Sonoita - Elgin Valley, the geologic framework is totally different, and structural features along with rock types play an important role in the occurrence of ground water. Two faults, the Lone Mountain-Sawmill Canyon fault complex along the western edge of the valley and the Babocomari fault running approximately along the channel of the Babocomari River along the eastern edge of the Valley have tremendous influence on the availability of ground water (Figure 1). There is disagreement among geologists as to the types and ages of these two faults (see for example Drewes, 1976) but their influence on the occurrence of ground water in this Valley is proved by the numbers of dry holes. Nearby and immediately to the east of Elgin, the Pantano Formation, a siltstone capable of storing and transmitting only small quantities of water, is exposed at the surface and only small quantities of water are available to wells. This is the up thrown block of the Babocomari fault, according to Drewes (1976). Towards the center of the valley, the alluvium is thicker and moderate quantities of water are available to wells at moderate depths. This portion of the valley is the down-thrown block, if in fact the faults are high angle faults -- segments of the Lone Mountain-Sawmill Canyon and the Babocomari faults. Apparently, the resulting trough is not deep and the valley fill is not very thick. Consequently, the water is available to wells in only small to moderate quantities. These two faults merge, according to Drewes, 1976, near the head waters of Gardner Canyon. Toward the northern end of the valley, wells have been drilled with production ranges of 100's to 1000's of gallons per minute, but ground water appears to be available only in moderate amounts (100 spin or less) over most of the valley.

CLIMATIC VARIABILITY AND MISCONCEPTIONS ABOUT WATER AVAILABILITY

Water resources management is often based on a period of record rainfall, runoff, or ground water recharge -- in general, a period of supply -- presumed to be average or "normal." This average of past values is considered to be the best estimate of the future supply. A problem arises in identifying the most representative period of record to be used to compute the average. This is because climatic variations are not random in time and the average computed from climate records can vary considerably depending on length of record and the time period involved. Examples of water resource development in the western United States can be cited in which the period of record used to estimate the future supply has been anything but average. Is the present state of the water resources in the Sonoita-Elgin and San Rafael Valleys the result of average rainfall?

To examine this issue, we have analyzed some of the longest term precipitation records available in the Sonoita-Elgin and San Rafael Valleys along with a 296 year tree ring record collected in the Huachuca Mountains in October of 1995. The precipitation series include records from Tombstone, Ft. Huachuca, Elgin and Canelo. The Tombstone record is the longest and most complete, 1899-1996.

The Canelo record is also complete but covers the shorter period 1918-1996. The Fort Huachuca record is very sparse and missing values have been estimated based on records from nearby stations. The Sierra Vista record was used to extend this record from 1982 to the present. The Elgin record contains a period of 5 years, 1986-90 with no data. These values were estimated from the monthly regional averages.

We have chosen to group the monthly distribution of rainfall into annual values composed of the sum of monthly total rainfall for November through October. This monthly grouping facilitates splitting the annual total into a cool-season and warm-season component. We define the cool

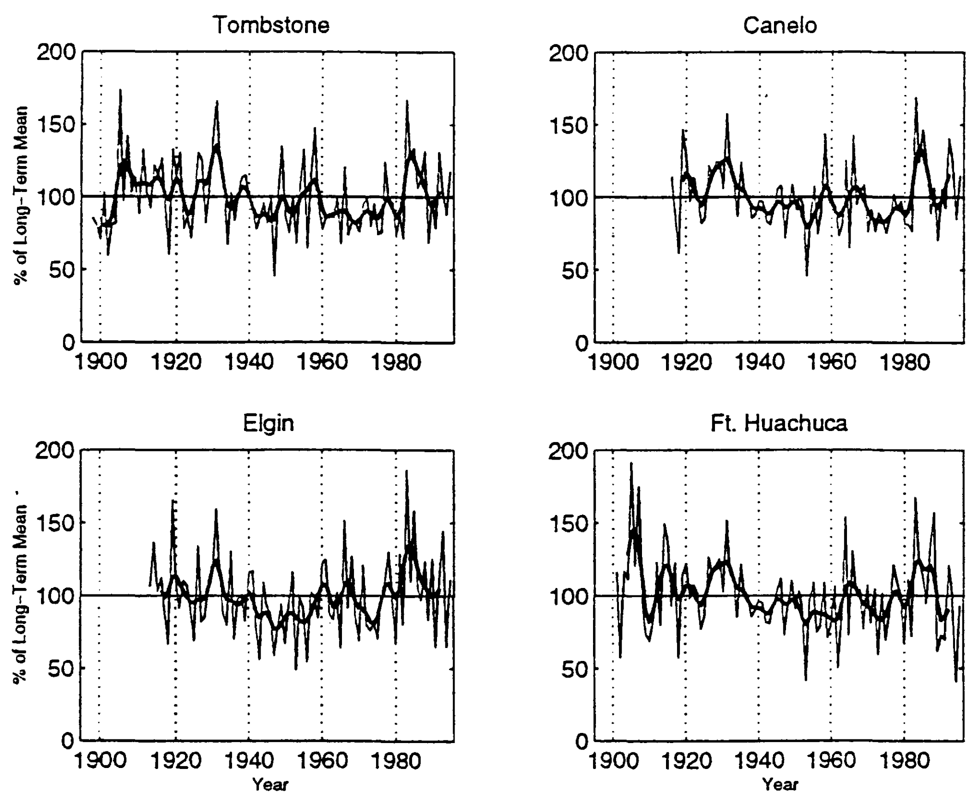

Figure 2. Annual precipitation time series expressed as a percentage of the long term mean for the period of record for Tombstone, Canelo, Elgin, and Ft. Huachuca. Annual period defined as November-October. (See text). A seven weight binomial filter was used to obatin the low frequency overlay curves.

season as November through April, a period corresponding to predominantly winter-type atmospheric circulation patterns, and convenient for comparison with winter runoff and soil moisture recharge for use by cool season grasses. We define the warm season as May through October, a period encompassing summer rains and occasional tropical storm rainfall.

Plots of the annual time series expressed as percentages of the long term mean for the period of record for all four stations are shown in Figure 2. Similar plots of the cool season values are shown in Figure 3, and of the warm season, in Figure 4. On each time series plot of the individual station values, we show an overlay of the series filtered by a 7 weight binomial filter. This allows comparison of the low frequency component of the series. Examination of the annual low frequency series reveals an important aspect of climate in southwestern United States. During the early 1900's, from about 1905 though 1930, the precipitation tended to be above normal; in some years as much as 170% of normal, but on average about 115% of normal. This is especially evident in the Tombstone record but is, in general, corroborated by the other records. This wet period is followed by an extended period of generally below normal precipitation extending from about 1931 through 1982. This dry period again shows in all four records with individual-year severity varying from one record to the other. Rainfall during this period averaged about 90% of the

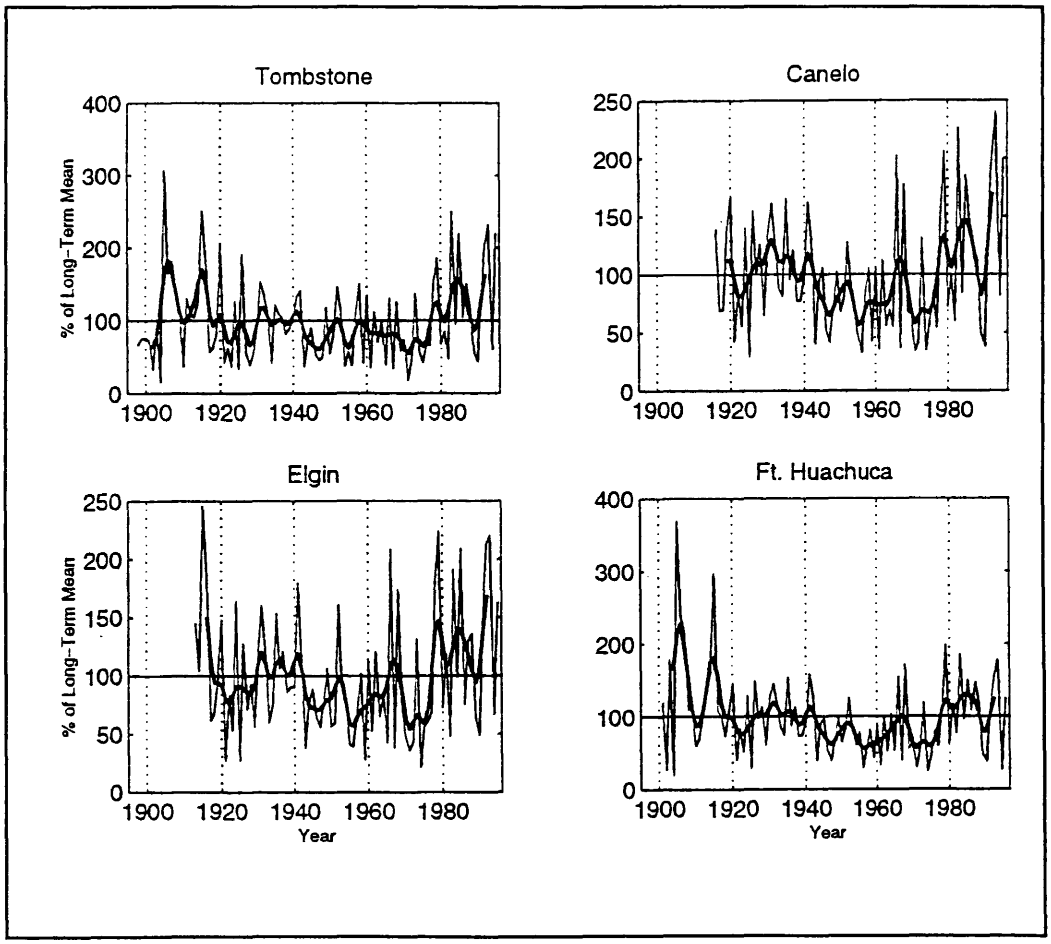

Figure 3. Cold Season (November-April) Precipitation time series as a percentage of the long term mean for the period of record for Tombstone, Canelo, Elgin, and Ft. Huachuca. A seven weight binomial filter was used to obatin the low frequency overlay curves.

long term mean. This extended dry period has been followed by another wet period extending from 1983 to the present. Again the mean for this period may be as much as 110-115% of the long term mean. The large swings in annual precipitation point out an important characteristic of precipitation in this area: precipitation occurrence is non-random in time and above /below mean occurrences predominate for extended periods of time.

The time series variations in precipitation for the cool season are broadly similar to those for the annual series, though the peaks and troughs differ slightly in location (Figure 3). The wet period of the early 1900's appears to extend only about to 1920, the extended dry period ends in the late 1970's and in at least the Canelo record, the wet period beginning in 1978 has a magnitude nearly equal to that of the early 1900's.

Station-to-station consistency in precipitation variations deteriorates for the warm-season totals (Figure 4). Each station, although showing some synchrony from year to year and over short periods with the other stations, does not exhibit the same regional synchrony in low frequency variance as the annual and cool season records. All four records, however, show the last few years as being predominantly below normal during the warm season.

In Arizona, the seasonal origin of storms changes from the warm season, monsoon and tropical

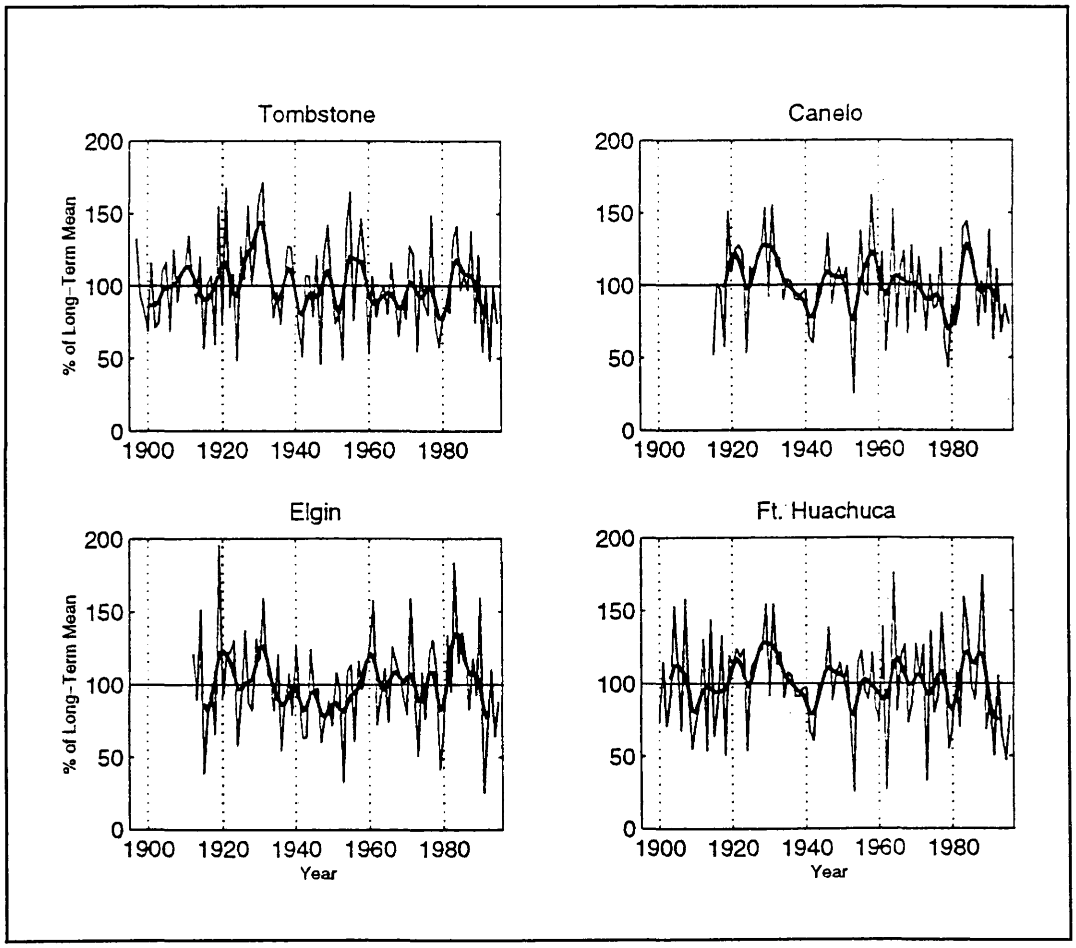

Figure 4. Warm season (May-October) precipitation time series expressed as a percentage of the long term mean for the period of record for Tombstone, Canelo, Elgin, and Ft. Huachuca. A seven weight binomial filter was used to obatin the low frequency overlay curves.

storm, to the cool season, frontal type storms from the west and northwest. The atmospheric circulation changes associated with the seasonal storm type changes are roughly the same as warm and cool season distinctions. These distinctions are also important from the hydrologic viewpoint because cool season precipitation is associated with runoff from higher elevations resulting in reservoir storage replenishment and recharge to the ground water basins.

Comparison of the plots for the warm season shows some high frequency agreement, especially in dry years but little low frequency agreement. This is most likely because most warm season storms are extremely local whereas the dry periods (droughts) are caused by more regional atmospheric phenomena. The cool season plots, however, show a greater uniformity in low frequency variance. In the Tombstone record, the longest and most complete of the four, the 1905-25 period shows rainfall as high as 200-300% of the long term mean (i.e. the mean for the entire period of record), for the period 1979-95, the wet years are 200-250% of the long term mean. The other three records are incomplete but show evidence of similar wet periods in the early 1900's, Ft. Huachuca and Elgin, or the period 1979-95, Cane lo. The two wet periods are separated by an extended period of below average rainfall, reaching a downward trending low around 1972 around 25% of the record mean. These same trends are seen in the variance in the annual records even though the cool season amount is only about 30% of the annual total at these 4 stations.

It is apparent that the variance of the cool season precipitation is greater than that of the warm season. These extended periods of wetness in the cool season precipitation are associated with the extended, southward displacement of mid latitude storm tracks. The cause of this displacement is currently unknown.

A natural follow-up question is "How rare are these anomalous wet \dry periods in the annual and cool season precipitation when viewed in the extremely long term context"? To answer this question, we use a Douglas-fir tree-ring chronology collected in September 1995 in Scheelite Canyon, on the north side of the Huachuca Mountains. This series appears to give a good representation of cool season precipitation at least back to the year A.D. 1700. Correlation coefficients with the four precipitation stations plotted in Figures 24 are about 0.40 for the annual series, 0.63 for the cool season and near zero for the warm season.

The Scheelite Canyon tree ring record has also been filtered with the 7-term binomial filter used on the precipitation records. The original annual tree-ring series and its filtered version are plotted in Figure 5. These data show that the long term variance so evident in the station precipitation data are not unusual. In fact, there appear to have been at least 4 extended, anomalously wet periods during the past 296 years The first centered around 1770 was rather short when compared to the others and showed moisture in the range of 170% of normal, the second, centered around 1835, was extended and shows moisture around the 180% of normal, the third centered around 1914, also was extended and also was around the 180% of normal, the last apparently centered around 1988 and whose duration is continuing, also shows moisture in the 180% of normal. Apparently, the extended wet periods are not too uncommon, occurring about every 74 years, but the dry spell, extending from 1925 - 1972 has no analog in the long-term record. In the worst year, 1954, moisture is only about 25% of normal. The cool season of 1995-96, not shown here, could easily have been as severe as that for 1954.

RAMIFICATIONS FOR GRASSLANDS OF SONOITA-ELGIN AND SAN RAFAEL VALLEYS

The climatic record clearly shows large swings in precipitation over periods of decades. The health and appearance of the grasslands would be expected to vary with these climatic swings. With recent variations (except for the exceptionally dry 1995-96), it is mostly the cool season grasses that have benefitted. Such grasses as plains love grass, alkali sacaton, and vine mesquite are most directly affected by the increase in cool season precipitation, though warm season grasses may also benefit from the high soil-moisture reserves in the dormant season. It is important that the recent anomalously wet period not lead to a misconception that the land is less arid than it really is, and to ill-conceived changes in land use, such as increased farming operations similar to those of the early 1900's. The limited ground water reserves in the region are unlikely to be able to support extended increased ground water development for such ventures. The immediate impacts would be lowered ground water tables, with increased pumping costs, and possibly dry wells. A possible related detrimental effect of lowered ground water tables would be harm to the vegetation in the cienegas of the Sonoita-Elgin region.

Regardless of the known limitation on supplies of water, these arid grassland valleys are likely to remain targets for future expansion. Besides stressing ground water supplies, additional development could be detrimental in altering patterns of runoff. The problem of changing land use

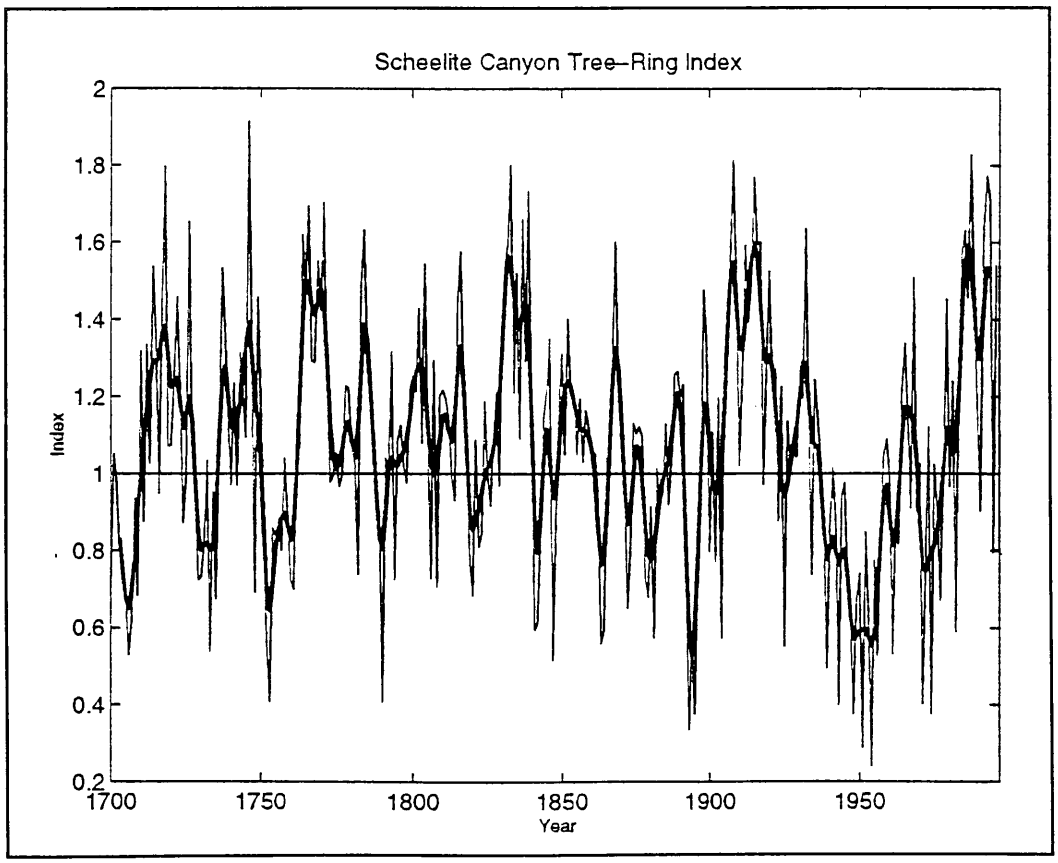

Figure 5. Douglas Fir tree-ring chronology collected in September 1995 from Scheelite Canyon on the north side of the Huachuca Mountains. As in the precipitation analyses a seven weight binomial filter was used to obatin the low frequency overlay curves.

in grassland areas and increasing percentages of runoff per unit of rainfall, especially in upland valleys like the Sonoita-Elgin area, upper drainage's for the Pantano Wash and the San Pedro River and the San Rafael Valley, upper drainage area for the Santa Cruz River can have deleterious effects on downstream communities. It has been noted that the magnitude of peak flows on the Santa Cruz at Tucson (and probably the Pantano Wash at Tucson) have increased dramatically in the past 30+ years (Saarinen et al. 1984). These increased flow magnitudes are attributed to large flows resulting from tropical storms and increased runoff associated with upstream changes in land use. When storms of the magnitude and intensity of tropical storms dump

SUMMARY

Grassland valleys in southeastern Arizona present unique challenges to water development. A trend toward wetter cool season conditions in recent years might lead to misconceptions about the available water. Considerations in water development include limited aquifer storage, health of cienegas, and possible problems with increased erosion, and runoff.

ACKNOWLEDGMENTS

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Water Use and the Future of the Sonoita Valley[1]

Robert Naeser and Anne St. John[2]

INTRODUCTION[3]

Many arid grasslands and native wildlife will continue to be degraded as increasing groundwater extraction reduces surface flows, natural waterholes, and seeps. In addition, increased human settlement will fragment the open range, also degrading the area's historic open-space character and reducing its native wildlife. These issues are evident but not widely understood. The Sonoita Valley of southeastern Arizona is an example.

The Sonoita Valley has limited groundwater storage capacity, yet its great beauty as well as its location between Mexico and I-10, are stimulating new growth that further places its water resources at risk. There is no economically feasible replacement for rural groundwater. Our best hope is that local citizens will cooperatively formulate an area-wide plan to safeguard groundwater, the open range environment, native wildlife and riparian areas, as well as a sustainable, robust economy. Our central, most recognizable issue is water. Failure to act would ultimately undermine our water resources, create adverse economic and public health consequences, and fragment the open range.

National Audubon Society's Appleton-Whittell Research Ranch seeks and provides information to assist individuals and groups to formulate and test area-wide mechanisms that will safeguard water resources.

In the summer of 1996, the Research Ranch hosted two water resource economics graduate students from Yale University's School of Forestry and Environmental Studies -- Rob Naeser and Anne St. John -- for ten weeks as they prepared the attached report.

Their report, which has been very favorably accepted locally, has helped citizens realize the disparity between a general rural zoning regulation that allows one house per five acres, and a groundwater recharge capacity that would probably support only one house per 25 acres. Getting the public to recognize the local groundwater supply limitations has been difficult.

We believe that such studies should be valuable in other areas whose population growth threatens its water resources and open range character.

THE SONOITA VALLEY - BACKGROUND

The Sonoita valley receives no outside water, relying entirely on rainfall; precipitation averages 17 inches per year (Bota, 1996). Of this, only six to seven percent (approximately 11,000 acre

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[1] This study was funded by the Appleton-Whittell Research Ranch of the National Audubon Society and the Yale School of Forestry and Environmental Studies. Contents of this paper do not necessarily reflect the views and policies of the National Audubon Society or the Yale School of Forestry and Environmental Studies.

[2] Both from the Yale School of Forestry and Environmental Studies, New Haven, CT.

[3] The Introduction to this report is by Bill Branan manager of the National Audubon Society Appleton-Whittell Research Ranch, Elgin, AZ, who presented the study at the conference.

feet per year) of the rain falling on the upland areas contributes to aquifer recharge. The remainder is lost through evaporation, evapotranspiration and stream flow. Depletion of stored water and lowering the water table will occur if groundwater withdrawals exceed annual recharge. Over time, streams will dry up, riparian plant community composition will change and residents will be forced to seek alternative sources of water (Glennon et al., 1994).

While the Sonoita valley has not yet reached a critical point in its water use, other communities in southeastern Arizona are experiencing the results of excessive groundwater use. In the Kansas Settlement area (Cochise County) for example, over-use of water for irrigation has resulted in a significant decline of the water table and increased pumping costs to $80 per acre-ft, up from $25 (Towne, 1987). San Pedro River flows, upon which the Bureau of Land Management's San Pedro National Riparian Conservation Area depends, are threatened by groundwater withdrawals in the Sierra Vista area (Glennon et al., 1994). The Tucson area is experiencing land subsidence and environmental damage as a consequence of many decades of excessive pumping (Schumann et al., 1985). The aim of this study is to provide Sonoita valley residents with a water management tool to help avoid similar problems in their community.

With the above in mind we set out to answer two questions: First, how much water is currently being used in the Sonoita valley? Second, what is a safe yield development density that will keep the area from growing beyond the capacity of the water supply?

Increased groundwater withdrawals for domestic and irrigation purposes have changed the Sonoita valley's natural environment over the last 100 years (Bahre, 1977; Glennon et al., 1994). The area was once home to extensive riparian systems that included perennial streams. The first wells were hand dug by settlers moving into the valley. Within the last fifty years, technology has enabled deeper wells to be drilled with increasingly more powerful pumps (Glennon et al., 1994). More and more people settled in the Sonoita valley as water became a less limiting factor.

Residential developments have sprung up throughout the area on land historically used for cattle ranching. Houses are being constructed as vacation homes, retirement homes, and primary residences for the residents who commute to jobs in Tucson, Nogales and Sierra Vista. Attracted by the rural lifestyle, people are relocating to the Sonoita valley in increasing numbers. By 1994 the population of the valley reached 2,351 people, and conservative growth estimates put the population at 2,980 people by 2002 (Bota, 1996) and 9,142 residents by 2040 (Mann et al., 1994). In addition to residential development, the area has emerged as a viticultural center. Home to five vineyards, the Sonoita/Elgin area is promoted as the wine capital of Arizona.

Subdivisions and vineyards use significantly more water than cattle ranches, where wells are widely spaced around the property to provide water for the stock. Residential and viticultural land uses impose significant water withdrawals on small areas. The degree to which local withdrawals will impact the groundwater supply vary depending on annual precipitation and proximity of wells to one another. Wells too closely spaced will interfere with one another (hydrologists call this capture), resulting in less water available to pump.

METHODOLOGY

We undertook four major steps to determine a safe yield density for the Sonoita/Elgin area. First, we conducted an extensive literature search. Second, we interviewed local residents in an attempt to ascertain water consumption by various user types. Third, we combined the findings from the initial two steps to develop a water budget for the Sonoita valley. The water budget contains inputs to the system (annual recharge) and demands on the system (well pumping and natural requirements) based on the *best available* information. Finally, we calculated a safe yield[4] development density - the *maximum* population that the area can support without exceeding average annual recharge.

STUDY AREA

The Sonoita valley study area covers 206 square miles in northeastern Santa Cruz County, Arizona (Map 1). The study area measures approximately 17 miles east to west and 12 miles north to south. The northern and eastern boundaries are the Pima and Cochise county lines, respectively. The southern boundary is an east-west line running approximately through the town of Canelo, and a line running north-south approximately one mile east of the town of Patagonia delineates the western edge. The study area was chosen because a significant amount of future development is likely to take place in the Sonoita valley.

Surface flow in the Sonoita valley flows toward one of three groundwater basins: Cienega Creek, Sonoita Creek, or the Babocomari River (Map 2). Precipitation falling southeast of the town of Sonoita will flow toward Sonoita Creek; precipitation on the north side flows toward Cienega Creek. Because hydrologists are unclear whether Cienega and Sonoita Creeks are in separate groundwater basins, we have included the northeastern part of the Sonoita Creek basin in our analysis of the Upper Cienega Creek Basin. *Area 1* covers 109 mi^2 with most of the population centered around the town of Sonoita. *Area 2* covers 97 mi^2 and includes the town of Elgin at the headwaters of the Babocomari River.

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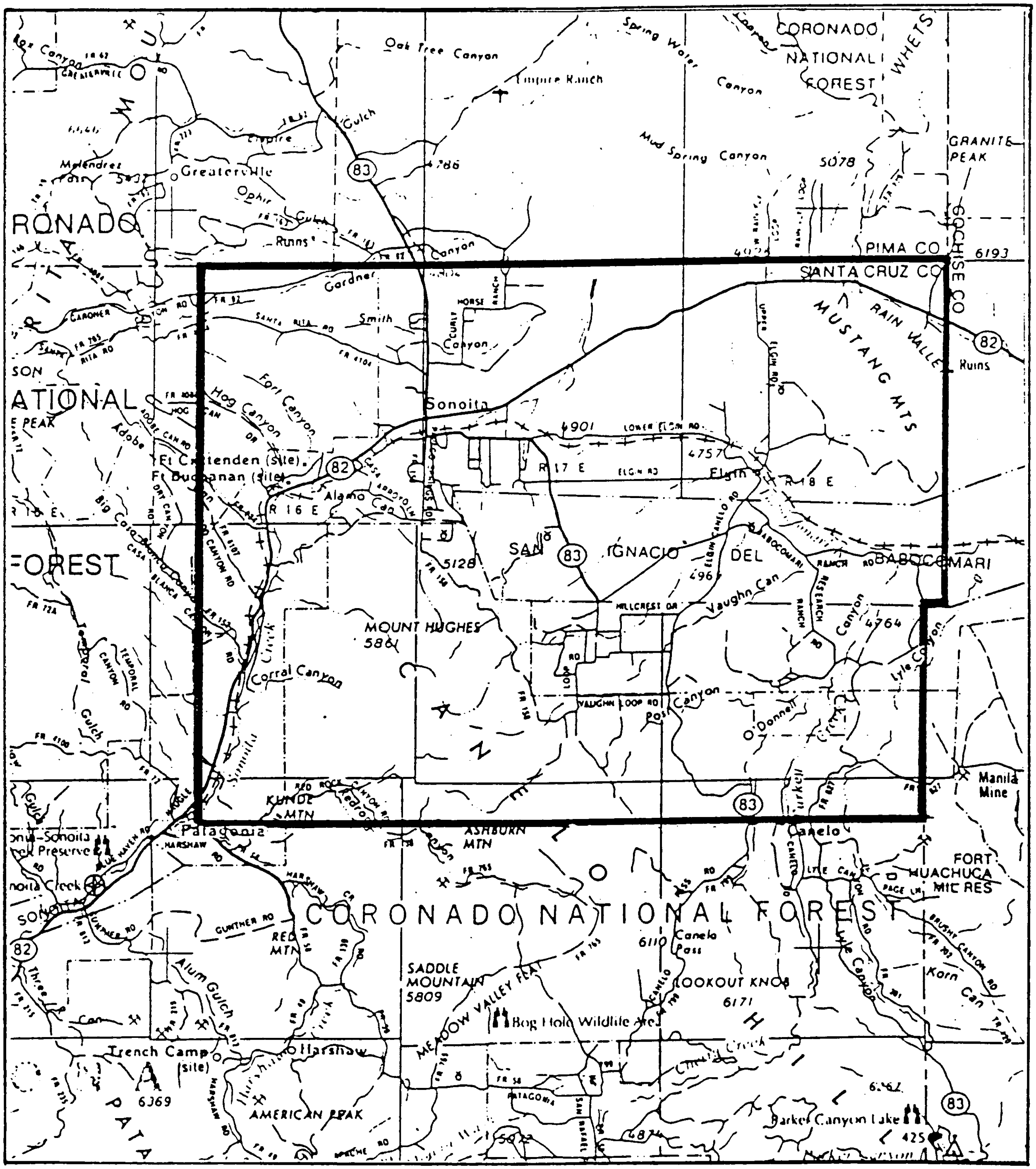
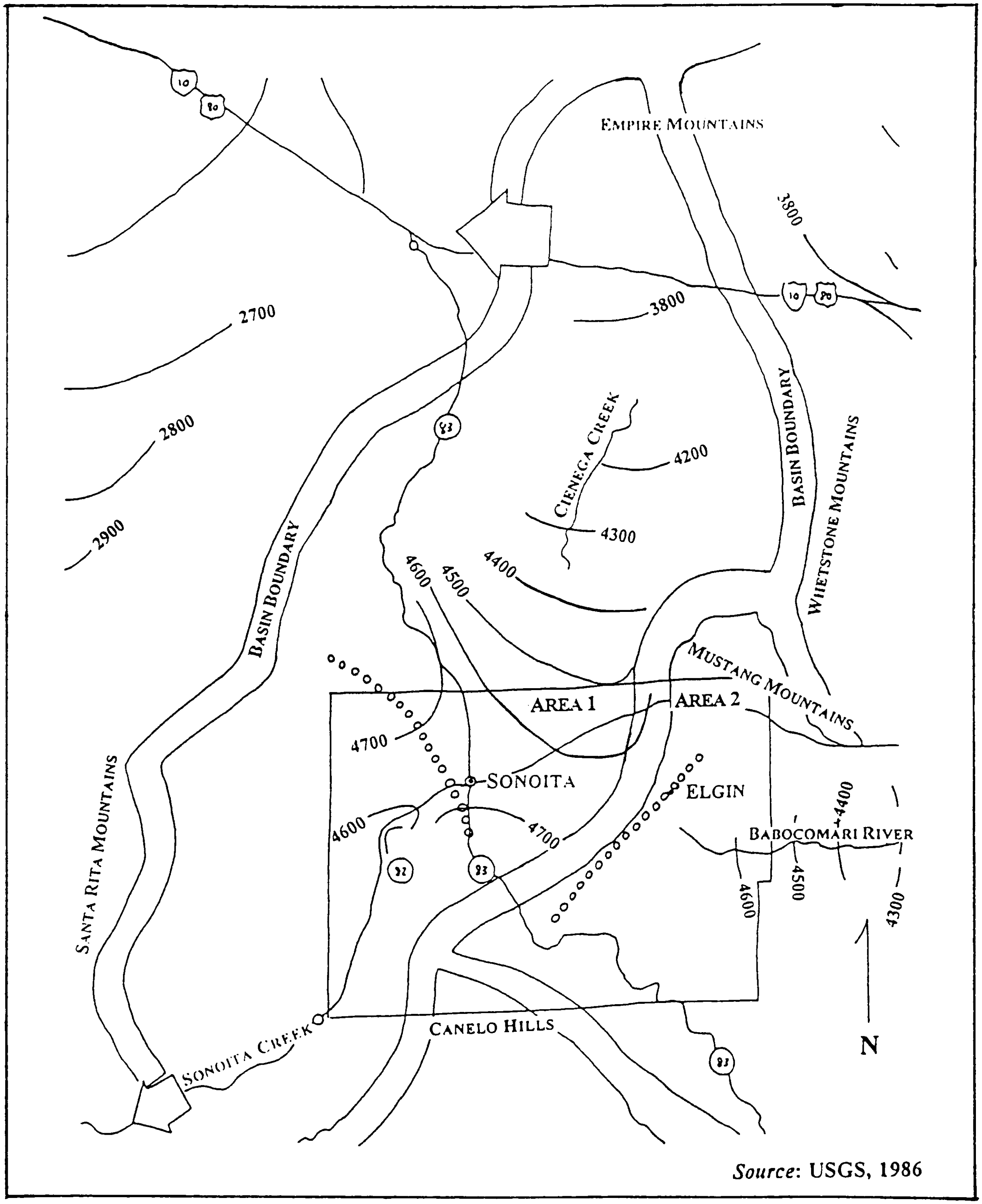
[4] Geologists call the amount of water an aquifer will yield without depletion "safe yield." The term has also been used by economists, courts and legislatures to describe rates of depletion not in excess of recharge (Getches, 1990).



Map 1
Location of the Sonoita Valley Study Area



Map 2
Hydrologic Map of the Sonoita Valley Study Area

SONOITA VALLEY WATER BUDGET

The water budget for the Sonoita valley contains ten categories. Table 1 contains estimated water budgets for *Area 1* and *Area 2*.

	Area 1 (Sonoita)	Area 2 (Elgin)
Recharge	3,980	not available
Ranching	(14)	(13)
Vineyards	0	(100)
Residential	(337)	(106)
Municipal	0	0
Industrial/Commercial	(60)	0
Cienega Creek	(346)	0
Evapotranspiration	(759)	0
Underflow to Sonoita Basin	(1,147)	not applicable
Babocomari River	not applicable	not available
TOTAL USE	**(2,663)**	**(219)**
SURPLUS WATER	**1,317**	**?**

Table 1: Annual Water Budgets for the Sonoita valley (acre-ft)

Recharge

The Upper Cienega Creek Basin (UCCB), which underlies *Area 1*, has been the focus of at least six hydrologic investigations attempting to quantify recharge.[5] By comparison, the Babocomari drainage, which underlies *Area 2* (47% of the study area) has never been studied. Because of this, our evaluation of recharge is limited to *Area 1*.

The UCCB is surrounded on three sides by mountain ranges: Empire and Santa Rita Mountains to the west, Whetstone and Mustang Mountains to the east, and Canelo Hills to the south. The aquifers beneath the valley floor are recharged by mountain front precipitation and from flood flows in the creeks and washes. Precipitation that falls on the valley floor probably does not percolate into the aquifer because the soils are deep (60 inches) and most of the water is lost to evaporation and plants before it has an opportunity to seep through to the groundwater. In the arid Southwest, all precipitation falling on soils deeper than eight inches is lost to evapotranspiration (Kafri et al., 1976).

The U. S. Geological Survey (1986) estimates that annual recharge to the UCCB is 11,000

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[5] There are two common methods for estimating recharge: one is based on the identification of recharge areas in the watershed and estimation of their properties. The second method estimates recharge as the difference between annual precipitation and losses: evapotranspiration, runoff, etc. (Ben-Asher et al., 1980).

Recharge Area	Percentage of Annual Recharge to UCCB (Boggs, 1980)	Average Annual Recharge (acre-ft) to UCCB (USGS, 1986)	Percentage of Annual Recharge to *Area 1*	Annual Recharge Available to *Area 1* (acre-ft)
Whetstone Mountains	40%	4,439	0%	0
Empire Mountains	23%	2,581	0%	0
Mustang Mountains	22%	2,406	100%	2,406
Santa Rita Mountains	8%	841	100%	841
Canelo Hills	7%	733	100%	733
TOTAL	**100%**	**11,000**		**3,980**

Table 2: Distribution of Upper Cienega Creek Basin Recharge

acre-feet (acre-ft)[6] per year, and the total recoverable groundwater[7] is 5.1 million acre-ft (maf), which is divided between the Sonoita and Cienega Creek basins. Only 24 percent of the 457 mi^2 UCCB lies within the study area, so groundwater storage beneath *Area 1* is no more than 1.2 maf.[8] Table 2 contains estimates of the percentage of annual recharge originating in each mountain range.

Because UCCB groundwater flows northward, usable recharge in *Area 1* is limited to water flowing from the Santa Rita and Mustang mountains, and Canelo Hills (36% or 3,980 acre-ft/year). Map 2 shows the average elevation of the water table to be approximately 4,700 ft in the Sonoita area or roughly 200 feet below the land surface. Going north from the town of Sonoita the elevation of the water table declines steadily to its lowest elevation (3,800 ft) where Cienega Creek enters the lower Cienega Creek basin, north of the study area. The elevation of the water table declines steadily between Sonoita and Patagonia, however, the actual values are not available (USGS, 1986).

Ranching

The Sonoita valley was historically a ranching community, and it remains the single largest land use in the area. Cattle are grazed on upwards of 64,000 acres within *Area 1* and *Area 2*. The

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[6] One acre foot of water is equal to 325,850 gallons. An acre foot can also be thought of as the amount of water required to cover one acre a foot deep in water, or the amount of water consumed annually by an average family of four in the United States.

[7] The USGS defines recoverable groundwater as the estimated amount of water in the basin-fill material to a depth of 1,200 feet below the land surface (USGS, 1986).

[8] In the absence of a better methodology, we assume homogeneity of groundwater storage beneath *Area 1*.

average cow/calf unit requires 40 acres of forage each year, and consumes approximately 15 gallons per day on hot, dry days (Jacobs, 1991; Rouda et al., 1994). We estimate that local ranches maintain 1,600 cow/calf units, consuming approximately 27 acre-ft of water each year.[9] Wildlife water consumption for deer, pronghorn and javelina is included in the estimate for ranching usage because wildlife utilize the same water resources as cattle (stock tanks, seeps, springs, etc.).

Vineyards

Local vineyard owners are promoting the Sonoita valley as the "wine capital of Arizona." It is currently home to five vineyards covering approximately 200 acres. All of the vineyards are presently located in the upper Babocomari basin.

Even though vineyards use an efficient drip irrigation system, they are being established on land that was traditionally used for raising cattle. Annual vineyard groundwater withdrawal varies inversely with precipitation. Generally, each acre of grapes is irrigated with three to six inches of water per year (Private conversation *A*, 1996). The area currently has about 200 acres of grapes, such that annual water consumption approaches 100 acre-ft per year.

Residential (Domestic)

The increasing subdivision of ranches into ranchettes is an often expressed concern by local residents. By 1989, Sonoita had approximately 400 homes and Elgin had about 200 homes. This number increased to 707 in Sonoita and 223 in Elgin by 1995 (Bota, 1996). This is a 76 percent increase in Sonoita and 11 percent in Elgin. The average occupancy is 2.8 residents per house (Bota, 1996).

It is difficult to estimate domestic water consumption because very few homes have water meters. The Casas Arroyo and Papago Springs subdivisions are metered, as these subdivisions are served by private water companies. Casas Arroyo residents each use an average of 150 gallons per day (0.17 acre-ft/yr/person).[10] Water consumption in Papago Springs averages less than 125 gallons per person per day (0.14 acre-ft/yr/person) (Private conversation *C*, 1996). These figures likely under-represent actual use in the Sonoita valley since they are based upon water use in subdivisions that encourage water conservation - Casas Arroyo residents are not permitted to maintain lawns or extensive gardens. Papago Springs residents are uncertain of their water supply after a severe shortage in 1994 forced them to truck in water from Tucson. During that time residents were asked to limit their consumption to 7,500 gallons per month. Despite a new deep well, residents are still unsure about the reliability of their system and continue to voluntarily restrict water use (Private conversation *C*, 1996).

Some past studies have assumed that septic systems reduce consumptive use in residential homes. The argument is that water flows out through the septic system and slowly percolates down, recharging the aquifer (Geraghty & Miller, 1970). However, soils in the Sonoita valley are classified as "severe"[11] for septic percolation by the U. S. Department of Agriculture. The Santa

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[9] Cow/calf units in the Valley estimated by dividing 64,000 acres by 40 acres per cow/calf unit.

[10] This number was calculated using biannual Casas Arroyo meter data from 6/84 - 6/96 for 17 houses. The average Casas Arroyo residence has 1.7 people. Annual per person consumption ranged from 0.01 acre-ft to 0.66 acre-ft, with an average of 0.17 acre-ft.

[11] A severe rating means soil properties are so unfavorable and so difficult to correct or overcome as to require major soil reclamation, special designs, or intensive maintenance

Cruz County Health Department likewise believes that groundwater recharge from septic systems is minimal (Private conversation *B*, 1996). While there may be some recharge from septic systems, without any data we assume it to be zero.

A conservative estimate, using Casas Arroyo consumption numbers, of annual domestic water use in the Sonoita valley is 443 acre-ft per year (930 homes * 2.8 residents/home * 0.17 acre-ft/person/year). Of this, 337 acre-ft is in *Area 1* (Sonoita), while 106 acre-ft is used in *Area 2* (Elgin).

Municipal

The Sonoita valley currently has no municipal water providers. All demands are served by individual wells or private water companies.

Industrial/Commercial

No industrial developments are currently located in the Sonoita valley. In the 1970s, the Anamax Corporation considered using local water to operate a copper mine northwest of Sonoita, centered on the Rosemont Ranch. When the market price of copper fell, Anamax determined that such an operation was uneconomical and sold the property. More recently, the ASARCO corporation purchased the same land for future mining. ASARCO is currently negotiating a large (13,000 acre) land exchange with the U. S. Forest Service but does not foresee opening the mine for at least 20 years.

Operation of an open pit copper mine requires approximately 200 gallons of water per ton of raw ore (Private conversation 1996). ASARCO plans to extract 30,000 tons of ore daily from the Rosemont mine, for a daily water consumption of 18.4 acre-ft. The company acknowledges that the groundwater resources in the area are not sufficient to cover their water use. ASARCO's current plan is to construct a pipeline to import water from its Mission Mine (Green Valley) or to bring in Central Arizona Project (CAP) water from the Tucson area.

Although the mine will not withdraw any water from the UCCB, it may employ as many as 600 workers, which will result in a population increase of about 2,000 people to the surrounding area (Private conversation *F*, 1996). A portion of these people will probably move into the Sonoita valley and will add greatly to domestic water consumption.

The water budget includes 60 acre-ft per year of commercial use; restaurants, gas stations and other small businesses. The businesses considered here occur entirely in *Area 1*.

Cienega Creek

Cienega Creek contains some of the last cienega communities[12] in southeastern Arizona. Sections of the Creek are bordered by giant cottonwoods, mesquite, willows and deep grasses. Cienega Creek is also home to several endangered and threatened fish species: the Gila topminnow, the Gila chub, and the Longfin dace. The Creek also provides important riparian habitat for numerous other species, including the Mexican garter snake, yellow-billed cuckoo, lowland

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[12] "Cienega" is a term applied to mid-elevation wetlands characterized by permanently saturated, highly organic soils. Until the late 1800's cienega communities were common to southwestern riparian systems. The number of cienega communities has dwindled in the 1900s due to declining water tables, channel erosion, and conversion to agriculture.

leopard frog, and the belted kingfisher (Bota, 1996).

Cienega Creek is a perennial stream that flows along a seven mile reach in the northern part of the UCCB. Except during seasonal precipitation events, the flow of the Creek is fed entirely by groundwater. The average baseflow between 1975 and 1983 was calculated to be 1,440 acre-ft/yr (Montgomery & Associates, 1985). The highest flows occur in the winter, with lower summer flows attributed to a lower water table and increased phreatophyte (water loving plant) use. We estimate that *Area 1* contributes 346 acre-ft per year to Cienega Creek baseflows.[13]

Underflow to the Sonoita Creek Basin

The groundwater divide southeast of Sonoita (Map 2) serves to partially separate the UCCB from the Sonoita Creek basin. Approximately 4,000 acre-ft of groundwater flows into the Sonoita Creek basin from the surrounding basins each year (Ben-Asher et al., 1980). The groundwater divide is 29 percent of the Sonoita basin perimeter. Thus underflow from the UCCB to the Sonoita Basin is 1,147 acre-ft per year (0.29 * 4,000 acre-ft).

Babocomari River

The Babocomari River is largely unstudied at this time. Thus, a safe yield density for *Area 2* (Elgin) cannot be calculated until additional data becomes available. Future hydrologic studies are imperative to answer such important water supply questions for Elgin.

Evapotranspiration

Evapotranspiration (ET) by riparian plants in the UCCB averages 3,300 acre-ft/yr (Kafri et al., 1976). Most of the ET occurs along the perennial section of Cienega Creek, although many of the intermittent streams in the study area also support riparian habitats. The 759 acre-ft of ET included in the water budget represents 24 percent of the total ET in the basin, but this number may over represent ET in the study area. It is included because maintaining the current level of the water table is crucial to sustaining much of the plant life in the basin as a whole.

SONOITA VALLEY SAFE YIELD DEVELOPMENT DENSITY

The average annual recharge in *Area 1* is 3,980 acre-ft per year based on the water budget presented in the previous section. Of this, 2,663 acre-ft of water is accounted for, leaving approximately 1,317 acre-ft available for future use. *Area 1* encompasses 109 mi^2 (69,875 acres).

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[13] Twenty-four percent of the UCCB is within the Sonoita valley study area (109 mi^2 / 457 mi^2). Thus, we calculated 24% of Cienega Creek baseflows to estimate the contribution from *Area 1*. Again this assumes homogeneity in aquifer characteristics, but it is the best method available until specific data becomes available.

	Current Zoning		Scenario I		Scenario 2		Scenario 3	
Lot Size (acres)	**Number of Lots**	**Total Acreage**	**Number of Lots**	**Total Acreage**	**Number of Lots**	**Total Acreage**	**Number of Lots**	**Total Acreage**
4.13 12.26 20 30 40	8,213 0 0 0 0	33,920 0 0 0 0	0 2,767 0 0 0	0 33,920 0 0 0	534 1,660 568 0 0	2,205 20,352 11,363 0 0	1,232 692 390 215 153	5,088 8,480 7,802 6,445 6,106
Total Average Lot Size Water Use (acre-ft)	8,213	33,920 4.13 3,909	2,767	33,920 12,26 1,317	2,762	33,920 12.28 1,315	2,681	33,910 12.65 1,276

Table 3. Residential Build-out Scenarios for Area 1 (Sonoita)

Approximately 53 mi² (33,920 acres)[14] of this is privately owned, and developed or eligible for future development. The remainder is public and administered by state and federal agencies; this study assumes that public lands will remain undeveloped. The privately owned land consists of ranch land, developed land and speculative acreage.

The safe yield development density in *Area 1* is one residence per 12.26 acres. This assumes 2.8 residents per household and a consumption rate of 151 gallons per person/day (average water use in Casas Arroyo). A safe yield withdrawal rate of 0.04 acre-ft/year is obtained by dividing 1,317 acre-ft (the unused portion of annual recharge) by 33,920 acres (total private land).

Santa Cruz County zoning ordinances classify much of the developable acreage in Sonoita valley as General Rural (GR); minimum lot size of 4.13 acres (180,000 square feet). Under current zoning the Sonoita valley can accommodate 17,000 homes at build-out (8,200 in *Area 1* and 8,800 in *Area 2*), assuming a total developable private acreage of approximately 70,400 acres. This level of density would result in annual groundwater withdrawals of 8,092 acre-ft/year (17,000 homes * 2.8 residents/home * 0.17 acre-ft/person/year).

Using the calculated safe-yield development density (one home per 12.26 acres), *Area 1* will have a total of 2,767 homes at build-out - three times the current level of 930 homes. The annual water withdrawal for residential use will be 1,317 acre-ft (2,767 homes * 2.8 residents per home * 0.17 acre-ft/person/year). This level of development allows the area to use most of the recharge water each year without mining the stored groundwater, which then remains available to carry the population through severe droughts and prevents damage to the ecosystem. While these numbers may also be useful for planning in *Area 2*, the actual safe yield density cannot be estimated without a determination of annual recharge.

A different variation of the safe yield density could accommodate those people interested in buying smaller lots. This scenario would involve segmenting the basin into zones of varying lot size. The periphery of the basin would be restricted to large lot subdivisions. Since the aquifer is recharged by the surrounding mountains, and all water flows toward the north, limiting development in the recharge zones would minimize capture of groundwater as it flows toward Cienega Creek. As

[14] This number was estimated from the BLM map *Surface Management Status: Fort Huachuca, Arizona*.

long as the average lot size is greater than or equal to 12.26 acres, water withdrawal should proceed at a sustainable rate (Table 3).

Current zoning was included in Table 3 to provide a basis for comparing the presented scenarios with the current Santa Cruz County zoning. Scenario 1 assumes build-out at the recommended safe yield density of one residence per 12.26 acres. Scenarios 2 and 3 are mixes of different lot sizes that achieve an average lot size larger than the suggested minimum. Table 3 illustrates that there are many possible combinations that will ensure an average safe yield development density while still enabling some future residents to purchase smaller lots (4.13 acres).

CONCLUSION

Available information (both scientific and anecdotal) on the local water resources allows us to draw four basic conclusions. First, groundwater is the only available source of water for both environmental and human needs. While the basin may contain a significant amount of stored water, the annual recharge amounts to less than one percent of the total storage (USGS, 1986). Second, groundwater is not found uniformly or predictably throughout the Sonoita valley. For example, in Elgin, residents of one house were forced to drill to a depth of 330 feet for a three gallon per minute well, while their neighbor's well produces 15 gallons per minute from a depth of 100 feet (Private conversation *E*, 1996). Third, siting developments without a careful hydrologic assessment can result in water scarcity for individual property owners, as well as interfere with the recharge of the basin. Fourth, periods of drought may result in a lowering of local water tables, which will exacerbate any overdraft that has already occurred.

The results of our safe yield density study indicate the need to establish minimum lot sizes for future development in the Sonoita valley. Under current zoning, *Area 1* will have 8,213 homes at build-out withdrawing 3,909 acre-ft of groundwater annually. That withdrawal rate is three times greater than the surplus of water available for future development (1,317 acre-ft). Using the safe yield development density presented in this paper, the minimum lot size in *Area 1* is 12.26 acres. At that density, *Area 1* will contain 2,767 homes at build-out with annual groundwater withdrawals of 1,317 acre-ft.

While our results are based on the *best available* data, the current literature leaves more questions than answers. Additional research is needed to enhance the available information. For example, metering wells could help tremendously in quantifying the amount of water withdrawn for different uses. Another needed study would measure the water level in wells across the Sonoita valley. A database of biannual, or quarterly, water levels would help residents determine if the water table is declining.

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Chapter III
Managing Grasslands

Large scale management issues were presented by Wes Jackson who put grassland management in a philosophical framework and Hector Arias who described management of the Matape Watershed in Sonora. A series of panels and posters dealt with other important management techniques. Monitoring and information gathering are the focus of the first section. Peter Warshall and Tony Burgess describe the results of a monitoring workshop in which individuals shared experiences in monitoring the state of their grasslands. How grasslands are managed by non-profit groups and private landowners was discussed by a panel led by Peter Warren, consisting of representatives of the Nature Conservancy, the Animas Foundation and private ranchers. Public grassland management was discussed by representatives of the Bureau of Land Management and the U.S. Forest Service in sessions led by Jeanne Wade and Karen Sims. Grasslands management on tribal lands was discussed by representatives of the San Carlos Apache and Tohono O'odham nations in a session chaired by Gary Nabhan.

Non-profit and Private Grassland Management

Public Grassland Management

Grassland Management on Tribal Lands

Agricultural and Human Communities When Nature's Prairie is the Standard

Wes Jackson[1]

I'm wearing this necktie for symbolic purposes. Increasingly, the abstraction is too distant from the particularity. The abstraction, of course, is in the head and the particularity has to do often with what the rest of the body is able to do. It is part of the dualism of western civilization. Males, we are told, are more prone to dualism so it must be because neckties have cut the flow between the head and the rest of the body.

Were I involved in the presidential debates, here's what I would say. "My fellow Americans, grass-fed beef is growing on the tall grass prairies of central Kansas. There's probably no more ecologically correct way to raise a pound of red meat protein anywhere on the land surface of the planet." And then I would say, "as soon as a critter goes to the feed lot there is probably no more ecologically incorrect way to add the pound." I would pause and then say, "when that critter is on the grass it is part of a renewable economy and as soon as it goes to the feed lot it's an extractive economy. Furthermore, the subsidies from our government to the rancher who owns the grass are close to zero but the subsidies going into that pound of red meat protein from the extractive economy are huge. Why is it that we now have a system that rewards, through subsidy, the nonrenewables and does not reward the renewables? My fellow Americans, this is a metaphor for the way we do things in this country. From this point on let's measure our progress by how independent of the extractive economy our society can become." I'd win the debate for neither Dole nor Clinton would know what to say. They apparently have no way of thinking about that question. Why is it that most of us here understand that problem and they understand it not at all? Count that as a sidebar for what I want to talk about.

Agricultural and Human Communities when Nature is the Standard is my chosen title. I will begin with a paragraph from Aldo Leopold written for a university committee report in 1944:

> "There are two kinds of conservationists and two systems of thought on the subject. One kind feels a primary interest in some one aspect of land such as soil, forestry, game or fish, with an incidental interest in the land as a whole. The other feels a primary interest in the land as a whole and an incidental interest in its component resource. The two approaches lead to quite different conclusions as to what constitutes conservative land use and how such use is to be achieved."

This is our battle. A culture which looks at a forest and thinks board feet instead of foresthood, will destroy forest. If we look at a stream and think acre feet, that stream is doomed. If we don't have foresthood and streamhood as primary in our minds then forests and streams become chattel. The source goes. Leopold noted what we all have observed, that the first approach is the most common. Almost everyone feels some primary interest in part of the land.

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[1] The Land Institute, Salina, Kansas

Leopold was forever drawing contrasts. Here's some more of his thinking. These thoughts came while he was sitting in a hotel room one evening in Berlin in the mid 1930s. He jotted down some notes to himself under the heading, "Wilderness";

> "One of the anomalies of modern ecology is that it is the creation of two groups, one of which seems barely aware of the existence of the other. The one studies the human community almost as if it were a separate entity and calls its findings sociology, economics and history. The other studies the plant and animal community and comfortably relegates the hodgepodge of politics to the liberal arts. The inevitable fusion of these two lines of thought will perhaps constitute the outstanding advance of the present century."

That was 1935—and of course it didn't happen. More than half a century has passed since Leopold wrote those words about those who will look at an ecosystem with some particular interest versus those who will look at it whole, with maybe a minor interest in one aspect, and this idea of the fusion of nature's economy with the human economy. Think of the possibilities if we could get serious about that thought for after all, nature's economy features material recycling and it runs on sunlight.

John Goudy, an economist at Rensselaer University in Troy, New York, and Karl McDaniel, a biologist in the same university—an economist and a biologist—have written in an abstract that appeared in a 1995 issue of Ecological Economics:

> "The self-organizing principles of markets that have emerged in human cultures over the past 10,000 years are inherently in conflict with the self-organizing principles of ecosystems that have evolved over the past three and a half billion years. The rules governing the dynamics of ecosystems, within which all human activity takes place, are ultimately a function of biological laws, not a function of human-created economic systems. The conflict between these systems is illustrated by the fact that economic indicators have shown vigorous growth during the last century while a variety of environmental indicators have exhibited negative trends."

Nature's economy is in direct conflict with the human economy! How is it that this came to be? We'll talk about that. There are two kinds of conservationists, two systems of thought, an anomaly of modern ecology featuring two groups (the human community and the plant and animal community), and there are the self-organizing principles of markets versus the self-organizing principles of ecosystems. Are we talking about something unique to humans when we're talking about a split with nature? And is it so fundamental it cannot be healed? Alfred North Whitehead, the mathematician and philosopher, said "The essence of dramatic tragedy lies not in unhappiness but in the remorseless, inevitable working of things." It is, however, through people that it's experienced as unhappiness. In other words, if you go to a Shakespeare play like Othello and you go out before the last act to go to the rest room, one is apt to say something like "It's piling up in there. There's going to be bodies all over the stage before this is over." You return for the last act and sure enough bodies end up all over the stage. There's a certain inevitableness. So the question becomes, are we talking about a certain inevitableness in human economies about a fundamental conflict?

Now let's consider for a moment who we are. If we don't talk about our nature and what needs controlled through culture, we'll just keep acting out some horrible side of ourselves. Before the invention of agriculture, 10,000 years ago, only 400 generations, (1) we could "take without thought for the morrow" and get away with it. (2) Any technological device we invented likely increased our adaptive value. (3) There is an aspect of our nature described by Wallace Stegner in Wolf Willow which notes the reality of "the things once possessed that can't be done without." He was speaking to the creation of necessity. We often say that necessity is the mother of invention. Less often said is that invention is the mother of necessity. Here are some major components of the human condition with which we must deal. They come with the meat, so to speak.

There are also some philosophical roots of our problem but they come out of the Enlightenment. Frances Bacon, around 1600, writes to King James and says something like, "We must bend nature to our will, O King. We must torture her, O King, even as you tortured witches, O King, in order to get truth out of them." Rene Descartes sitting over in France apparently agrees that we must bend nature and the way one does it most effectively is to place priority on the parts of things over the whole—without acknowledging that whole influences part even as part influences whole, that there is an interpenetration between part and whole. Descartes says that we should break a problem down to the point where there is no ambiguity. Of course, when one gets to that point it's totally irrelevant. These two men became the architects of the modern, scientific technological revolution and their spirit is now so all pervasive in the culture that it "comes with the milk." We believe this even when we fight against it. It somehow sticks.

There is more and it is even worse: Descartes said in his Discourse on Method that the more he thought to inform himself, the more he realized how ignorant he was. But rather than regard that as an apt description of the human condition and the very proper result of a good education, Descartes thought our ignorance correctable. And so we now have a knowledge-based world view. And yet we all know that we're billions of times more ignorant than knowledgeable and always will be. Why not an ignorance-based world view? Why not go with our long suit? Being billions of times more ignorant than knowledgeable doesn't mean that we avoid knowledge, but rather we start with the assumption that we're mostly ignorant. I think it is prudent to start with the idea that we're stupid and bumbling and wicked besides and always will be.

What do we do about it? How do we take care of that reality? It should force us to remember things, keep the scale small and become students of exits. What are the chances of backing out before we go into something? When it comes to managing our landscapes it is more prudent to be mindful of the ecosystem concept rather than lower levels of organization. This will cause us to keep our boundaries of consideration larger. Dick Levins at Harvard, a theoretical ecologist, has written about the cholera pandemic. He points out that when one looks around to see where cholera is—inland waters and estuaries mostly around third world countries—there is an algal growth which serves as a host for cholera. The surrounding hillsides reveal bad agricultural practices. There is soil erosion and fertilizer run off into the water sponsoring that algal growth which in turn serves as a host. The World Health Organization officially says that the cause of cholera is a bacterium. The cause of cholera, more accurately stated, is bad agricultural practices, among other variables. The bacterium is an agent. When the boundary of consideration is closer to the boundary of causation we have assistance in dealing with our ignorance.

Why all of this philosophy about our nature, what does any of this have to do with grasslands? First of all, the ecosystem concept still has little standing in our minds. It's beginning to and I want to tell you why it should have even more standing and how that ultimately helps our management of grasslands. But first, some history. In 1967 Arnold Schultz, an ecologist at University of California, Berkeley wrote a paper entitled "The Ecosystem as a Conceptual Tool for the Management of Our Resources", and in that paper Arnold Schultz cited a previous paper by J. Stan Rowe, an ecologist at the University of Saskatchewan. J. Stan Rowe was referring to a paper written in 1959 by Feibleman and his paper was called, "Theory of Integrative Levels." In the hierarchy of structure starting with atoms and going on to molecules, cells, tissues, organs, organ systems, and then to organisms, there are certain laws associated with these integrative levels, twelve altogether. There are also emergent properties. Biologists naturally asked "What comes next after organisms?" Some said species. Some said populations. Stan Rowe asked "What do these other levels of organization have in common?" Molecules, cells, tissues, organs, organisms. Rowe noted that they all have contiguous volume. Species don't have volume. Populations don't have volume but ecosystems do. By establishing the volumetric criterion for "thinghood", the laws of Feibleman also fit the ecosystem.

P.W. Anderson wrote a paper published in Science in 1972 entitled "More is Different." Anderson noted that up the hierarchy of structure, stopping at each level, we can discover principles even but as fundamental as the fundamentals of physics. This assumes that there is no basement, of course. At the ecosystem level then are principles yet to be discovered that are just as fundamental as the principles of physics. If we acknowledge the "thinghood" of an ecosystem, is it not likely that some of the principles yet to be explored will be associated with the efficiencies inherent within the natural integrities of ecosystems? A cell biologist is certain to think about cell biology differently than an organismic biologist. Ecosystemologists (not a pleasant sounding term) seem certain to eventually develop principles for the ecosystem level too.

What lies before us then is the opportunity to learn about those natural integrities and their attendant efficiencies, many of which we have yet to acknowledge. One such efficiency that is particularly dramatic was revealed to us at The Land Institute. Illinois bundle flower can suffer from a splash-borne bacterium under some conditions. Raindrops bombard the ground, bounce up on the underside of the leaf where that waxy cuticle is thin and the plant begins to lose its leaves from the bottom up. Those of us who have a "human cleverness" penchant, some geneticist-type like myself, might say "I'm going to build in resistance to that pathogen and then I will have a 'release' that's resistant to that pathogen." But the ecologist in us, and we all have some of that too, says "let's walk over to the native prairie and see what's happening there." On the prairie it's free of the disease probably because the grassy mat absorbs the shock of the bombarding rain. Rather than pay a plant breeder for seven years to build in resistance to the splash-borne bacterium the strategy better employed would be to provide a context to take advantage of the efficiencies inherent within the natural integrity. Strategic thinking of an ecosystemologist is certain to be different than that of your usual brand of plant breeder.

Nearly twenty years ago I wrote a paper in which I began to explore what I call the "problem of agriculture." I'm going to tell you part of that story to help illustrate how the ecosystem concept has informed my thinking in taking on this problem. What I mean by the "problem of agriculture" is simply this: Essentially everywhere till agriculture has been practiced over the planet our disturbance of the land has caused an erosion of ecological capital, primarily soil. Whether we're talking about ancient Babylon, Mesopotamia, or China, the way we humans grow most of our high-yielding crops is to tear the ground up, almost every year, and on sloping ground leave it to the forces of wind and rain. When I looked at the 1977 study done by the General Accounting Office it seemed to me that soil erosion was as bad in 1977 as it was in 1935. How could this be? We've had thousands of miles of terraces and grass waterways, billions of dollars spent, and the Mississippi Delta continues to receive a high level of nutrients for burial in a 300 foot watery grave every year. Looking back into the history of earth abuse through agriculture, I wondered if maybe the past lacked people who were eloquent, enlightened, impassioned. Such people are there. They're there all the way back to the biblical Job—numerous people. I call that the failure of history and prophecy. Second, there's the failure of organizations, the Soil Conservation Service, for example. I do hate to think what our country would be without it but soil erosion is still rampant. Thirdly, the failure of stewardship. I've even seen soil erosion beyond replacement levels on Amish and Mennonite farms. Fourth, the failure of success—200 bushel per acre corn. "We must be doing something right," we say. The agricultural-economist would say so. But you all know what makes a good economist? Somebody who can narrow the boundaries of consideration to satisfy a "rigorous" economists model, a hard-headed realist. As Wendell Berry once said in a phone conversation, "A hard-headed realist is somebody who uses a lot less information than is available."

Looking out at our never-plowed native prairie in Central Kansas, in an area of around 30 inches of annual precipitation, we see a system running on sunlight, with no soil erosion beyond replacement levels, a system sponsoring its own nitrogen fixation and, because of species diversity, a system with such a high degree of chemical diversity that it would take a tremendous enzyme system on the part of an insect or a pathogen to mow it back down. The questions came: Is it possible to build an agriculture based on the prairie as model and still produce an abundance of grain. Stated otherwise, can we sufficiently mimic that prairie's workings to work for us even as we tweak individual species enough to produce sufficiently high seed yield? Can we feed people without having to plow every year?

Of course, such a question raises more questions, four of them particularly basic. Several of my friends, mostly formerly fellow students, said such things as, "well Wes, we always knew you were crazy and now you're completely nuts! Everybody knows that perennialism and high seed yield don't go together, or if they did, there's such a high trade-off cost it would not be worth it. Their comments didn't come out of ignorance, for when we divide a plant up into root, stems, leaves and seeds we discover that roots and seeds are resource-rich, stems and leaves resource poor. Therefore by selecting for high-seed yield we would be taking it out of the root and driving the plant toward annualism. There's a famous r and K selection model which implies an R selected plant will allocate its resources to seed while a K selected plant will allocate its resources to "hanging in there." It is a teeter-totter idea in that one can not expect to maximize both variables. It is an equilibrium model, intellectually satisfying and accommodating rigor. There's an elegance to it.

We challenged a fundamental assumption when we took on the question as to whether herbaceous perennialism and high seed yield could go together and at no trade-off cost to the plant. We needed to know whether it was in the cards for flowering plants to have seed increase at a substantial level without experiencing some liability. My daughter Laura's Ph.D. work at Cornell, now published in Ecology, destroyed that as an absolute in a elegant experiment. Jon Piper's work at The Land Institute with sorghum supports the no trade-off idea. The second question is whether a polyculture or a mixture of perennials can out-yield a monoculture of the same? In other words, can you put plants together and yield as much? The answer is yes. In fact, more. The third question is, can that system adequately manage insects, pathogens and weeds? We have good data and publications to support that. The fourth question, can the system sponsor enough of its own nitrogen? We don't know. We have suggestive evidence.

I hope I have not overly dramatized these results gathered over the past 18 years for our results are modest in one sense but we are able to say that we've had our Kitty Hawk. We're where the Wright Brothers were on December 17, 1903. We don't have anything that will carry 250 people across the Atlantic, but we've demonstrated the analog of lift and drag. But it is now time for the "wind tunnel phase" and we must ask how do we get an agricultural research culture to lift their thinking from the idea that nature is to be subdued or ignored to looking at nature as the standard against which one judges our agricultural practices? That requires a shift in world view. How do we move toward looking at the way the nature's systems have worked over the millions of years? Humans may learn faster than nature but nature's been at it longer. The highest form of good judgment will require knowing when to exercise human cleverness while drawing primarily on nature's wisdom.

I have a chart which outlines a 25-year research agenda that I submitted to the Department of Agriculture. It lists some twenty researchers at the top, all Ph.D. level professionals. Eight plant breeders, four ecologists, three biotechnologists, two computer modelers, an environmental historian, a data manager, and a director. The ecologists, however, are the ones sitting in the dominant seat. What's the cost of this? For one site only at $5 million a year times twenty-five years? About $125 million. It may sound like a lot of money but consider that soil erosion is now costing the US $44 billion per year! Those numbers are from Dave Pimental and his group at Cornell. Let's say that they're wrong by half. Let's say it's only $22 billion per year. Or let's say only a quarter, $11 billion per year. We're talking about $125 million over 25 years. Peanuts. We should have ten of these centers around the country but we would settle for only one in the short run.

Jack Ewell, from the University of Florida and now in Hawaii, has worked in the tropics in Costa Rica in an area of 300 inches of annual precipitation. Jack and his colleagues set out to mimic forest succession. He substituted vine for vine, tree for tree, shrub for shrub to follow the succession and have an analog to what was going on in nature. The only rule of his team was that any substitute could not have arrived on its own. Their conclusion was that where they imitated the structure they were almost always granted the function. That's good news. Why can we not begin to get such talk about that at the national level between the likes of Clinton and Dole? This would begin the consideration as to how nature's economy could lead the way toward a transformation of the human economy. Another part of the good news is that these principles should hold everywhere and unite people. Rather than us taking agricultural technologies out of fossil-fuel intensive infrastructures and parachuting them into Chad or India or wherever, we would have common principles that would unite us. They are predicated upon universal evolutionary/ecological precepts.

What I have just described is not enough. It's no use trying to build a satellite of agricultural sustainability and expect it to safely orbit the extractive economy. My friend Professor Charles Washburn of California State University in Sacramento said recently that "if we don't get sustainability in agriculture first it will never happen." We'll just put the blow torch to the planet.

I believe that we can carry such thinking to human communities and opportunity is there, too, for there are thousands of small towns and rural communities that are going down and out as people flock to cities. Many of these emptied places provide opportunity to reverse a trend which finds families ending up in the likes of Silicon Valley where kids grow up shopping malls and Little League.

I will now describe a project of The Land Institute which addresses this problem. Eighty percent of Chase County, Kansas has never been plowed. The area receives 33 inches of annual precipitation and supports tall grass prairie. During the grazing season, up to 2.4 pounds of meat per day is being added to each critter in this area of 3.5 acres per animal unit. It's very good grazing country and yet Chase county is still losing population. It's gone from 8,500 in the late 1800s to 3,000 now. Matfield Green, population 50, is in that county. I went to a tax sale a few years ago and came home with five properties totaling about $2,000. Five of us bought the 10,000 square foot school for $5,000. A lot of these schools throughout the region have been bought for a dollar where they continue to deteriorate. My nephew bought the bank in Matfield Green for $500. I bought the lumber yard for $1,000. And so it goes. We've picked this as a place where we can begin to think about developing a human economy that is isomorphic with the economy of nature. This is the kind of thing that's going to require a lot of thought.

Our first effort at intellectual rigor was to discover and elucidate the environmental history led by our Education Director, an environmental historian, Dr. Brian Donahue. He asked such questions as, what were the regimes that were here? First the environmental history and then what we call "setting up the books" for ecological community accounting. How does one set up the books to measure the carrying capacity given various assumptions? This is complicated of course and in a certain sense, we don't care what numbers go where the columns and rows intersect. What we want to get a sense of is how many people can be supported here at what level of throughput so that this can go on for 10,000 years and more. Being attentive to what's going on the surrounding native prairie should help inform us. I will leave it at that.

As I finish, let's review some of the ground we've covered. "There are two kinds of conservationists," Aldo Leopold said, "there are those who look primarily at one thing versus those who look at the land overall." There is the human community and then the plant and animal communities. Those two disciplines have not come together. The self-organizing principles of markets are in conflict with the self-organizing principles of ecosystems. Our work must be to bring the human economy in line with nature's economy? I see the ecosystem concept to be the primary source of thinking how to manage such a transition. The ecologist will need elevated from the bottom of the pecking order to the top. Physicists occupy that spot now. If we can begin to invert this pecking order and then bring in a different breed of economists, we might begin to put together a real economy.

There are lots of people working on the pieces of all this, but now we need to begin to get the synthesizers to start pulling all this together. It won't be easy and it certainly won't be finished in my lifetime and probably won't be finished in the lifetime of most of us here. But if we're working on something that can be finished in our lifetime, chances are we're not thinking big enough.

Bacon and Descartes date from 1600. Charles Darwin's Origin of Species dates from 1859. We are still more the intellectual descendants of Bacon and Descartes than we are Darwin and his ecological world view. It is understandable when we consider that Bacon and Descartes had a 250 year running start on Darwin. Therein lies the story, I think. Reductionism, the belief that the world is like the powerful method, lies so deep within us and carries along with it the legacy of the period of its origin the idea that nature is to be dominated.

But there is hope, for there was a time when the church organized our thinking. Then came the Enlightenment and the nation-state organized our thinking. The nation state peaked at W.W.II and then economics came to dominate our thinking. We built cathedrals to the glory of the church. We built capitols to the glory of the nation state. With economics, we built shopping malls to the gods of secular materialism. There's where we go on Sunday now. If ecology can come on after the economic era has passed, what will be the symbol? Not a cathedral, not a capitol, not a shopping mall, but wilderness that is not made by human hands! That becomes our standard. The wilderness, whether it is of the desert or whether it is of the alpine meadow, becomes the standard for both the behavior and management of our agriculture as well as our human communities.

Natural Resources Management in the Matape Watershed

Hector M. Arias, Christopher Watts, David Peña, Gonzalo Luna, Maria L. Fernandez, Martin Reyes[1]

ABSTRACT

The Matape Mission, in the Upper Matape Watershed, has the oldest record in ranching in the Arizona Sonora Desert, that covers northwestern Mexico and southwestern United States (there are historic records from 1670 showing that this area supplied animal food to central Mexico).

The project has four stages: (1) resource inventory, (2) information analysis, (3) experimentation of solutions that would provide sustainable development, and (4) application of a regional program. This paper only includes the first two stages, although the third stage is in the preliminary phases.

The initial stage of the project involves the resource inventory using available map information to build databases on Geographic Information Systems. As a result, the watershed was divided in two parts, the upper part is mainly rangeland, and the lower part is mainly agricultural lands combined with rangelands. In the second phase of the project, land degradation phenomena were analyzed, and erosion was found to be one of the main problems in the upper Matape Watershed, while salinity and saline intrusion were related to low productivity of the lower part.

Erosion control measures along with techniques to improve the range productivity is the challenge for the following stage of the project. To do that, communication with farmers is required to obtain a sustainable development.

INTRODUCTION

The state of Sonora in northwestern Mexico is traditionally considered a cattle raising state. It was established as an important economic activity since 1670 when father Daniel Angelo Marras, Rector of the Matape Mission, set the basis for this activity in Sonora. According to records from 1680-1682, the mission sent 5 000 cows/yr to central Mexico (Atondo et al, 1985). Since then, livestock is the largest economic activity, in terms of area. Navarro et al (1986) mentioned that about 78.44% of Sonora has cattle on a temporal (6.3%) or continuous basis (71.11), plus areas with introduced species (1.04%), mainly buffel and Lehman love grasses. According to a land use

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map developed by Arias et al (1996) for an ecological planning project (Proyecto de Ordenamiento Ecologico del Estado de Sonora), livestock could be practiced in about 57.14%, that includes 38.07% of Sonora covered by desert shrubs, grasslands in 13.06%, and about 6.01% of desert shrubs conditioned on rainfall availability. What seems more interesting is the fact that livestock is the most important activity in terms of aerial coverage in Sonora.

Economic figures from 1985 to 1994 shows that the economic impact of this activity has been steadily decreasing from 4.1 to 3.25%. Also, agriculture displaced livestock as the main primary activity in the state after the green revolution when large areas of the plains were incorporated to agriculture due to reservoir and irrigation structures construction. Less rural population is involved in livestock, and although the numbers does not decrease significantly, the percentage of population and the percentage of participation in the Internal Revenue Product is decreasing, in part due to the grow of the industry and tertiary sectors (Arias et al, 1996a).

Natural resources mismanagement has been strongly correlated with land degradation processes. COTECOCA (Technical Commission for the Estimation of Carrying Capacity), the authority for assessing range management, claims that in 1994, the estimated average range occupation was 10.51 ha/au, while the recommended average carrying capacity for Sonora is 22.2 ha/au (unpublished data), and as a result, they consider that erosion is increasing. This is why it is important to know what degradation processes are responsible for land degradation; and if it is so, at what extent is affecting the land, and where are the areas most affected. It would not only provide information of the problem but where to apply corrective measures.

This project addresses the question: is there a way to reduce land degradation processes, like erosion or salinity, to increase the land productivity, which will eventually improve the economic condition of ranchers?. Sustainable development claims for the reduction of land degradation processes and increase the land productivity in an anthropocentric fashion; that is, improve man's socioeconomic conditions. However, it involves natural resource management. Since natural resource management is made by land owners, programs focused to induce sustainable development must deal directly with the land owners, especially low income farmers who might be most affected by land degradation processes and declining land productivity.

What is described here is a natural resource management program in a watershed level in northwestern Mexico. The main objective is sustainable development, as was above presented, by increasing land productivity, reduce land deterioration, to improve the land owner's conditions. The short term goal is the generation of a "Master Plan" for the Matape watershed, which could have been the "cradle" of livestock in northwestern Mexico and southwestern United States.

MATERIALS AND METHODS

Watershed description. The Matape watershed is a 7,249.87 km^2 drainage area of the Matape River, a 200 km ephemeral stream that drains into the Gulf of California, or Sea of Cortez, East of Guaymas. There are two cities, Guaymas and Empalme, both in the coastline, representing the two municipal heads of the Lower Matape; other communities are La Misa, Ortiz, and San Marcial. In the upper watershed there are three municipal heads, La Colorada, Matape (Villa Pesqueira) and Mazatan, representing the largest rural communities, along with Cobachi.

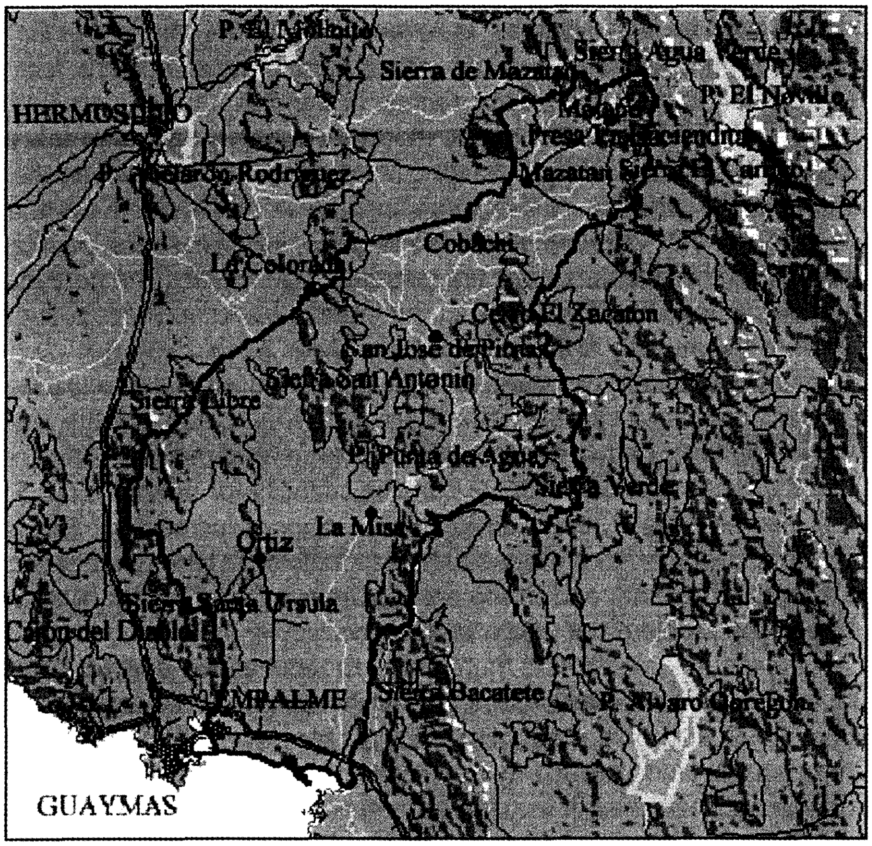

Figure 1. Map of the Matape watershed in Sonora, Mexico. Large cities are in capital letters. Small letters are for sierras, reservoirs (P.), and towns.

Resource inventory.

The resource inventory was performed by digitizing map information of soils (INEGI, 1982), land use and vegetation (INEGI, 1984), at a 1:250,000 scale maps using ERDAS version 7.5 and ILWIS version 4.0. The topography map was produced using Digital Elevation Models (DEM) available from INEGI at 1:250,000 scale. DEM's were also used to generate a slope range map for erosion calculations.

Degradation Processes.

The degradation processes analyzed were salinity and erosion because they are related to agricultural and/or livestock activities.

The Salinity map was obtained from soil maps (INEGI, 1982), since soil chemical data was included in terms of electrical conductivity, EC (dS m^{-1}), and Sodium Adsorption Ratio, SAR (%), based on the US Salinity Laboratory Staff (1954) report. This information was updated using maps from the National Water Commission (Comision Nacional del Agua, 1992) for the Irrigation District of Guaymas.

The erosion map was obtained using the Universal Soil Loss Equation as described by Arias et al (1996b). The equation has six factors: (1) erosivity, obtained from an erosivity map provided by

Colegio de Postgraduados (1991), (2) soil erodibility, obtained from soil maps according to the methodology cited by Colegio de Postgraduados (1991), (3 and 4) slope and length factors, estimated from Digital Elevation Models converted to slope gradients and equations provided by Wischmeier and Smith (1994), (5) cover management factor, calculated according to Wischmeier and Smith (1978) for crop and rangeland, and Dissmeyer and Foster (1980) for forest lands, and (6) the mechanical practice factor was set to 1.0, because it was not possible to detect areas with erosion control works at the scale we worked.

RESULTS AND DISCUSSION

Since the watershed is very large (7,249.87 km^2), it was divided into Upper (3,141.85 km^2) and Lower Matape (4,108.02 km^2) by the Reservoir Punta de Agua (Ignacio Alatorre).

Climate.

Climate is hot and dry. There are 4 meteorological stations in the watershed in an elevation gradient: Matape (745 m), La Colorada (390 m), Punta de Agua (245 m), and Empalme (10 m). There is a rainfall gradient from the coast, since total annual rainfall is 742 mm for Matape, 350.9 mm for La Colorada, 411.3 mm in Punta de Agua, and 166.4 mm in Empalme, related to the elevation gradient. Figure 2 shows the monthly rainfall and the marked differences in rainfall along the watershed for the two main rainy seasons, summer (Jun-Oct), and winter (Dec-Mar). Although the summer rainfall is larger, a substantial amount is provided in the winter, too.

What is really interesting is the fact that the rainfall regime in the upper part is favorable for livestock, and sets the basis for a reclamation program, in terms of cattle raising, once the other factors are present; that is, a germplasm of native vegetation that can increase the carrying capacity.

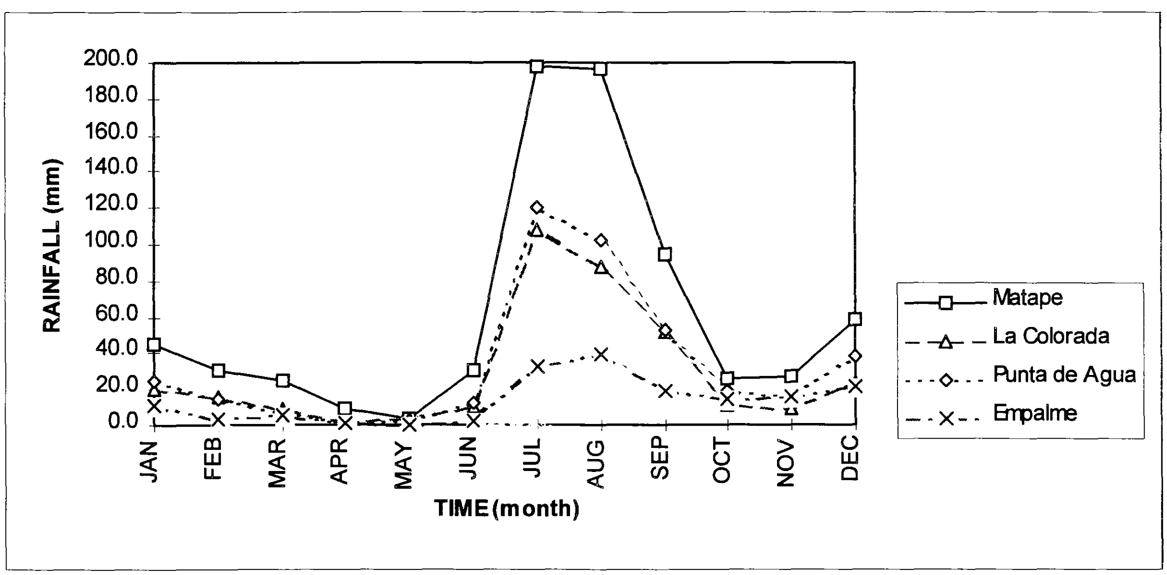

Figure 2. Monthly rainfall in four stations in the Matape Watershed.

Temperature.

The temperatures can be considered high and decreasing with elevation. The average monthly maximum temperatures ranges from 40's in Empalme to 30's in Matape. The average monthly minimum temperatures ranges from 10 to 15 °C in Empalme, while in the upper part the minimum temperatures ranges from 0 to 15 °C (Figure 3).

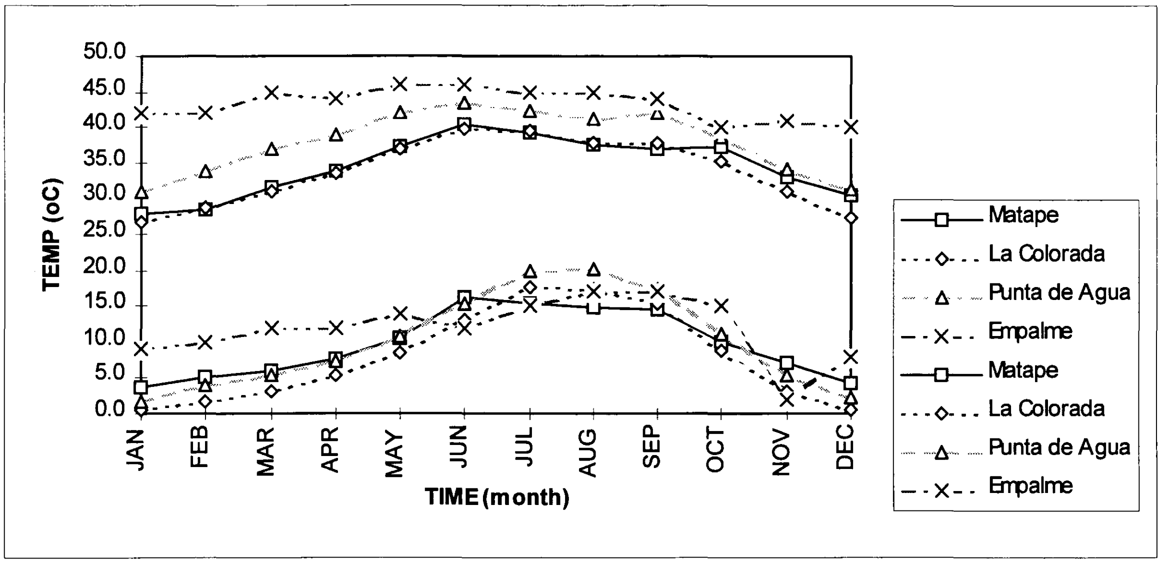

Figure 3. Maximum and minimum temperature in the meteorological stations of the Matape watershed.

Evaporation.

Pan evaporation is very high in La Colorada (2,430.4 mm/yr) and Punta de Agua (2,610.7 mm/yr), as can be seen from Figure 4. That is very important in terms of planning for the efficient use of water in the area. For instance, water harvesting techniques need to account for this disadvantage.

Hydrology.

The main stream starts in Sierra Agua Verde, the highest peak (1680 m), filling La Haciendita Reservoir, after passing Matape. It travels southwest, passing Cobachi, up to San Jose de Pimas, where it turns south. In San Marcial, the stream turns southwest again and fills Punta de Agua reservoir. Although the river continues in the same direction, most of the water is diverted to irrigation channels at La Misa. In Ortiz, it is a dry stream, and most of runoff is collected in what is called Bordo de Ortiz, a water retention structure used to grow forage crops. This structure has its origin on colonial times, but the technique apparently was also used by native Mexicans in pre-Columbian times. From Ortiz, the river goes south to Empalme, where it drains in Estero el Rancho. Several other small streams drain into San Carlos, Guaymas, and along the coast (Figures 1 and 5).

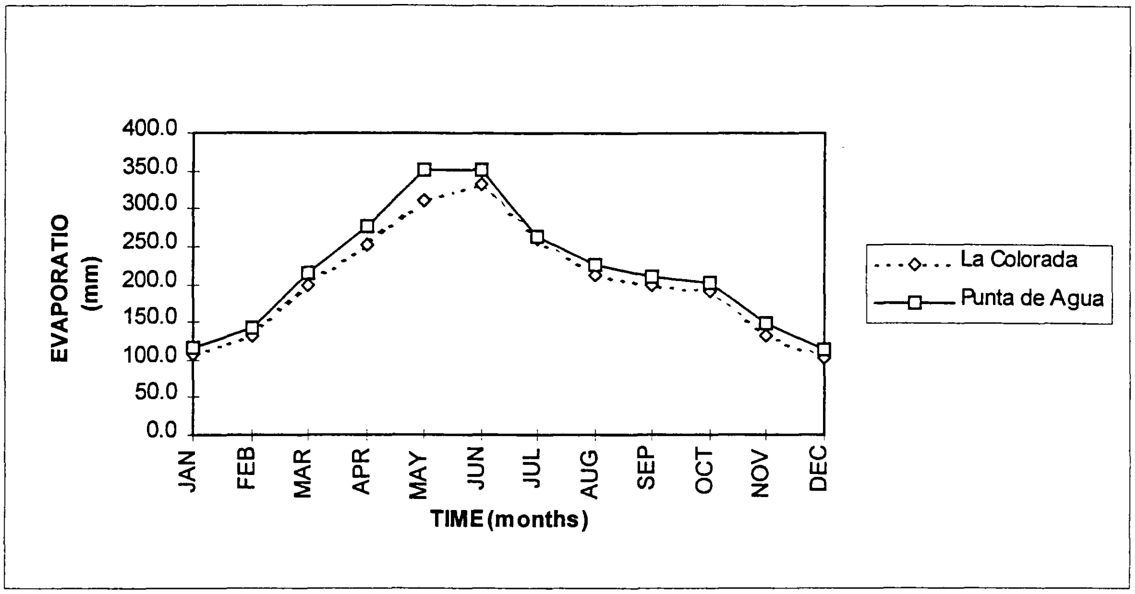

Figure 4. Average monthly pan evaporation in the Upper Matape Watershed.

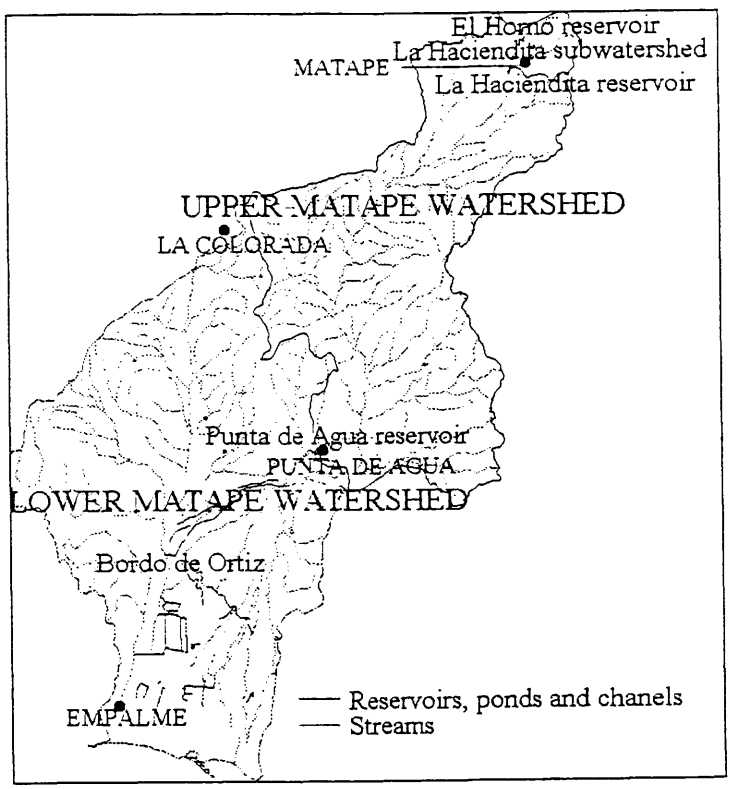

Figure 5. Stream network and location of streams, major reservoirs, ponds and channels. Four meteorological stations: Matape, La Colorada, Punta de Agua and Empalme are shown. Punta de Agua is also a gaging station.

Runoff.

The only gaging station in the watershed is Punta de Agua, located in San Marcial, and runoff data is available from Jun. 1957 until Dec. 1969 when it was changed to the new location nearby, named Punta de Agua II in Jul. 76 - Dec. 78, and Jan. 82 - Dec. 85. It is a staff gage, calibrated with a flow meter. Annual runoff were 11.99 and 9.01 mm/yr in Punta de Agua I, and Punta de Agua II, respectively. Figure 6 shows the runoff season, and again, the summer rains are the ones that contribute the most runoff

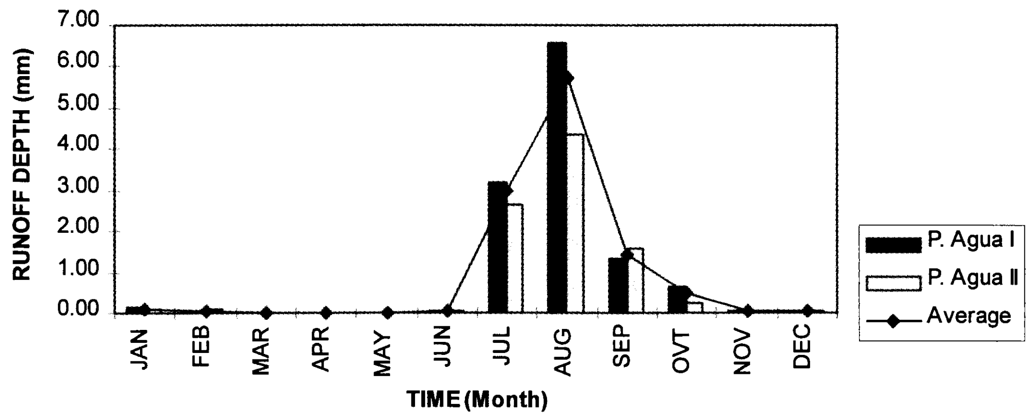

Figure 6. Monthly runoff depth (mm) distribution in Punta de Agua I (Jun. 57-Dec. 69), and Punta de Agua II (Jul. 76 - Dec. 78, Jan. 82 - Dec. 85). Average is shown as a line.

The highest discharge rate was 636 m^3/s. In general, the runoff distribution follows the same pattern as the rainfall data, since the most intense runoff events happen in the summer (Jun.-Oct.), as can be see from Figure 7.

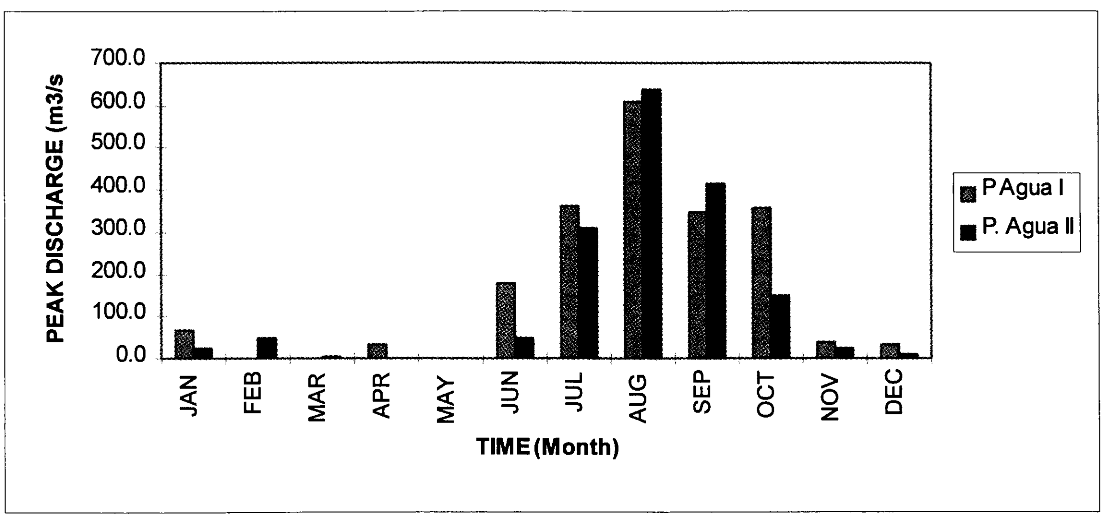

Figure 7. Maximum peak discharge rates (m^3/s) at Punta de Agua I (Jun. 57-Dec. 69), and Punta de Agua II (Jul. 76 - Dec. 78, Jan. 82 - Dec. 85).

Sediments.

Sediment concentration is related to the intensity of runoff and most of the sediment transporting events occur during the summer (Jul.-Sept.), as can be seen in Figure 8. Annual sediment yield are 389,700 m^3, and 210,600 m^3, for Punta de Agua I and II, respectively, with an average of 322,200 m^3.

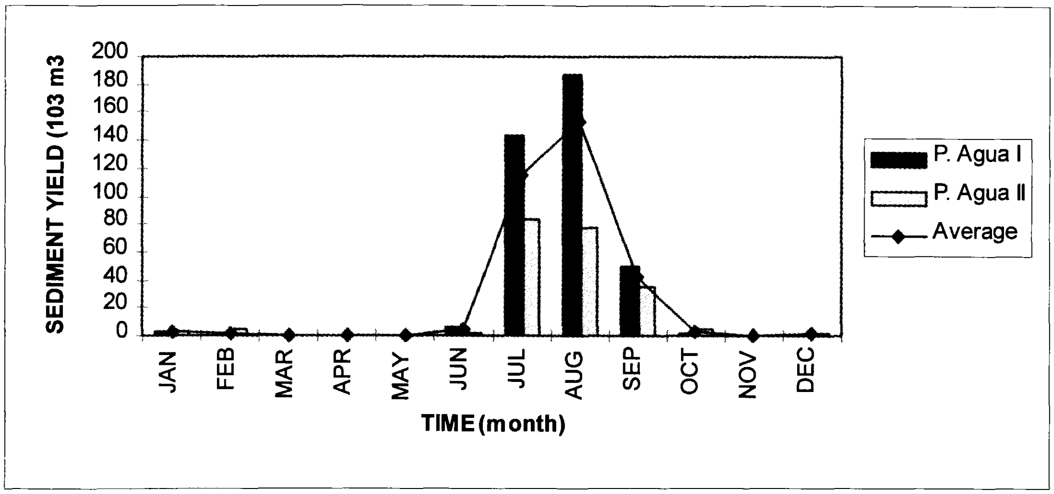

Figure 8. Monthly sediment volumes (thousands of m^3) at Punta de Agua I (1961-1969) and Punta de Agua II (1982-1985), as well as the average for the two stations.

Reservoirs.

In the watershed there are 4 major reservoirs: Punta de Agua with a capacity of 27.9 hm^3 occupying an area of 426 ha, which irrigates 25,467 ha in the Irrigation District 84 Valle de Guaymas. A unique feature is "Bordo de Ortiz", which is a runoff detention structure used to grow forages and is considered the largest water harvesting structure in the state with a capacity of 2.75 hm^3, in an area of 269 ha. La Haciendita has a capacity of 3.4 hm^3, an area of 125 ha, and Hornos with a capacity of 1.0 hm^3, an area of 100 ha, both of them to grow forage crops in small areas. Figure 5 shows the reservoirs. There are many small ponds to supply water for cattle, but they are difficult to identify in the map because of the size.

Soils.

Most soils of the region are limited by arid conditions (Xerosols and Yermosols), others are very shallow soils (Regosol and Leptosol, formerly Litosol). The soils that have possibilities for agriculture are Phaeozems (3.25%) and Vertisols (13.28%). Those soils are occupied by agriculture or intensive ranching. The desert soils, once water is available either by pumping or surface irrigation, can be used for either agriculture or livestock.

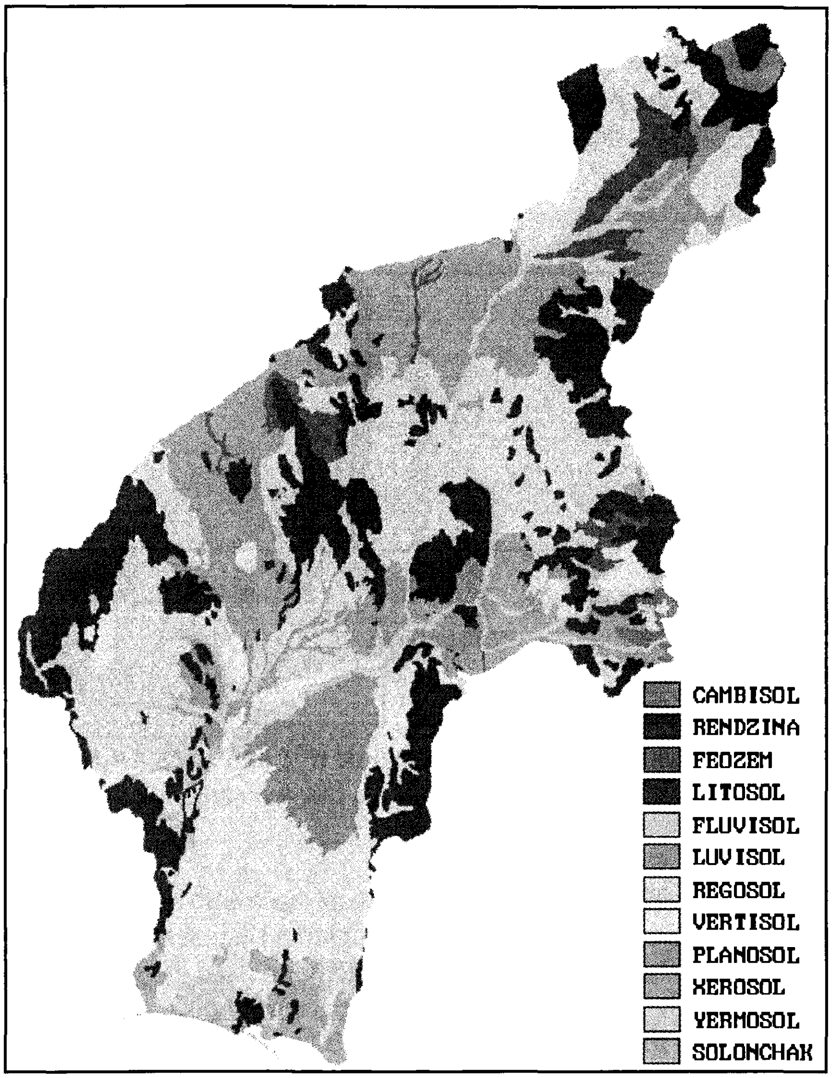

Figure 9. Soil map of the Matape watershed according to FAO classification

SOILS (FAO CLASSIFICATION)	AREA (HA)	(%)
Regosol	175282	24.20
Leptosol	174063	24.03
Xerosol	145737	20.12
Vertisol	96212	13.28
Planosol	29559	4.08
Fluvisol	28568	3.94
Yermosol	27095	3.74
Phaeozem	24481	3.38
Solonchak	13560	1.87
Luvisol	4033	0.56
Rendzina	2404	0.33
Cambisol	3461	0.48

Land use and vegetation.

Most of the vegetation belongs to desert life forms, shrubs and mesquite lands are the most important vegetation classes, in terms of area (about 83%). Introduced species are represented by irrigated agriculture in the alluvial fans by the coast, and improved grasslands, mainly with buffel grass, and they both add to 9.77%. Transition vegetation are represented by Low jungle, from arid zone to the tropical zone, as well as oak vegetation (forest) to the Sierra Madre Occidental (temperate zone). It is important to mention that most of the dryland agriculture is practiced in the river stream bed for forages (Figure 10).

Land degradation processes and degradation phenomena, erosion and salinity, were mapped using mathematical models, digitized maps, and Geographic Information Systems. Salinity. Most of the irrigated croplands in the lower Matape watershed have salinity problems as well as the coastal areas (Figure 11). Saline-sodic soils are the most abundant (8.10%), in terms of salinity problems, followed by saline soils (4.08%), and strongly saline-sodic soils (3.04%). The irrigated agriculture has been practiced pumping groundwater and, as a result, most of the salinity problems in croplands are related to saline intrusion. A reclamation program needs to know the type of problem and the area to reclaim. The map (Figure 11) helps in establishing a salinity reclamation program by overlapping the cropland map and the type of salinity problem.

Erosion.

GIS studies showed that erosion is a very important degradation process in the Matape watershed (Arias et al, 1996b) by using the Universal Soil Loss Equation to estimate average annual soil losses. The average annual soil losses for the entire watershed are 11.76 Mg/ha/yr. The upper Matape watershed, with steeper slopes and livestock as the main activity, have average annual soil losses of 16.85 Mg/ha/yr, and the lower watershed, with less steep lands and irrigated agriculture and some rangeland are the main economic activities, have average annual soil losses of 7.87 Mg/ha/yr. Field observations and rainfall simulation studies carried along with the USDA-ARS allowed us to check two sites and the average soil losses were the same, 4 Mg/ha/yr, as those estimated with the USLE (Lane, Nichols, and Arias, 1994).Tolerable soil losses vary depending on the parent material, soil class and depth, as some of the most important factors; however, any rate larger than 8 Mg/ha/yr is above the natural soil-forming rate, an equilibrium condition.

About 88% of the land has soil losses below 8 Mg/ha/yr; it means that the problem are the hillslope areas. Therefore, we can say that the erosion is a major problem in the upper Matape watershed lands, since the soil losses are higher than the permissible values.

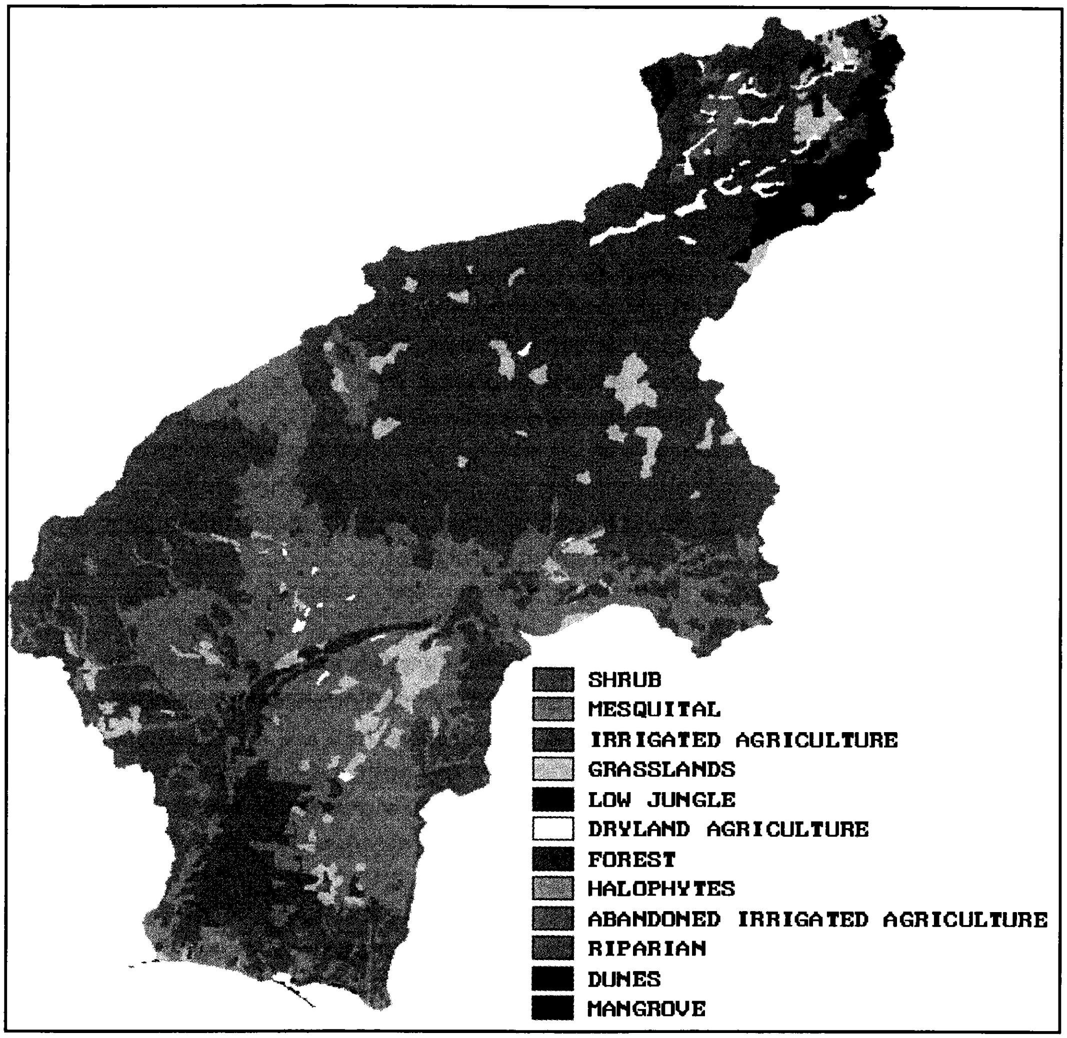

Figure 10. Land use and vegetation of the Matape watershed.

LAND USE/VEGETATION	AREA (ha)	PERCENT (%)
Shrub	413548	57.03
Mezquital	198987	2744
Irrigated agriculture	36191	499
Grasslands	35057	4.83
Low jungle	18659	2.57
Dryland agriculture	6422	0.89
Halophytes	5814	0.80
Forest	5659	0.78
Abandoned irrigated agriculture	3828	0.53
Riparian	502	0.07
Mangrove	163	0.02
Dunes	267	0.04

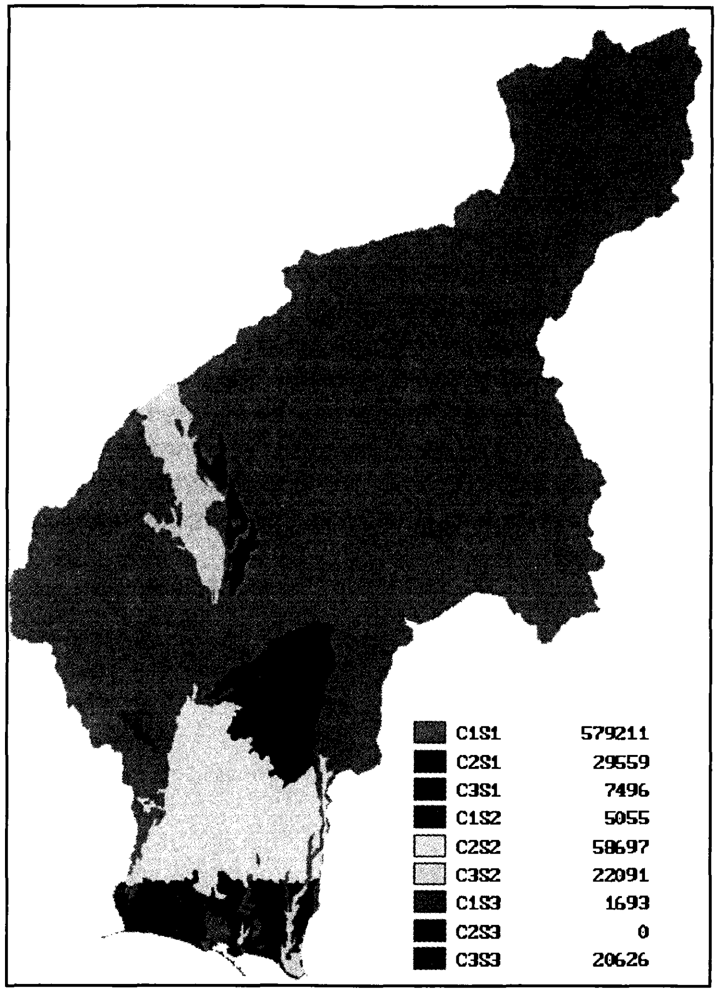

Figure 11. Salinity map of the Matape Watershed. The map was obtained from INEGI soil maps.

CLASS	KEY	EC (dS m^{-1})	SAR (%)	Area (ha)	PERCENTAGE (%)
Normal	C1S1	< 4	< 15	578922	79.85
Saline	C2S1	4-16	< 15	29559	4.08
Strongly saline	C3S1	>16	< 15	7496	1.03
Sodic	C1S2	< 4	15-40	5055	0.70
Saline-sodic	C2S2	4-16	15-40	58710	8.10
Strongly saline-sodic	C3S2	>16	15-40	22046	3.04
Strongly sodic	C1S3	< 4	>40	1693	0.23
Saline- Strongly sodic	C2S3	4-16	>40	0	0.00
Strongly saline- Strongly sodic	C3S3	>16	>40	21495	2.96

CONCLUSIONS

The climatic conditions of the watershed are not very promising for livestock, especially in the lower part because of high temperature, high evaporation rate, and low rainfall regime. The upper watershed has better climatic conditions for cattle raising. Since the rainfall amount in the watershed varies, runoff and/or groundwater represent possibilities for economic activities in the area. Runoff is widely used in the lower Matape watershed by water retention structures, but in the upper watershed, with better rainfall regime, programs of water conservation are needed. The two reservoirs in the area can be used more efficiently providing infrastructure to irrigate larger areas or supply water to other users. Even though there are not many wells in the upper Matape, it is possible to pump groundwater, especially in the area of Cobachi-San Jose de Pimas; however, a more detailed study is required in order to avoid problems like that in the coastal areas, where seawater intrusion has affected large areas that used to be irrigated.

Although there are not large areas with good soils, it is very important to consider those areas as a priority for agricultural o livestock activities since the natural fertility of those soils can have a more rapid impact in the region. It is also important to know that vertisols, although difficult to work, have a good potential for crop production.

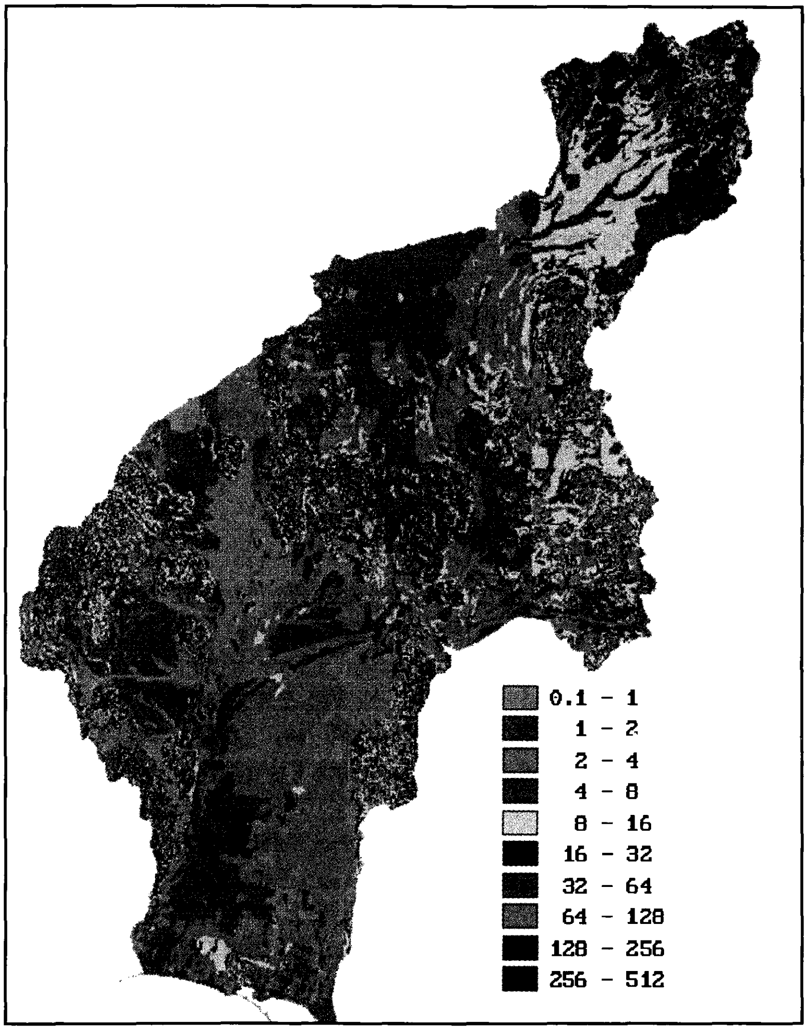

Figure 12. Actual erosion map of the Matape watershed.

SOIL LOSS RANGE	UPPER MATAPE		LOWER MATAPE		WATERSHED	
(Mg/ha/yr)	AREA (ha)	(%)	AREA (ha)	(%)	AREA (ha)	(%)
0.1-1.0	4170	0.58	56312	7.77	60482	8.35
1.0 - 2.0	20991	2.90	80045	11.05	101036	13.95
2.0 - 4.0	52902	7.30	126641	17.48	179543	24.78
4.0 - 8.0	105790	14.60	66184	9.14	171974	23.74
8.0 - 16.0	62015	8.56	32038	4.42	94053	12.98
16.0 - 32.0	28869	3.99	26794	3.70	55663	7.68
32.0 - 64.0	23122	3.19	18311	2.53	41433	5.72
64.0 - 128.0	13558	1.87	3630	0.50	17188	2.37
128.0 - 256.0	2407	0.33	237	0.03	2644	0.36
256.0 - 512.0	408	0.06	4	0.00	412	0.06
	314232	43.38	410196	56.62	724428	100.00

Most of the vegetation in the area is considered as desert vegetation, shrubs and other species; however, there are still areas with important biological value. Sierra de Mazatan has been proposed as a state reserve, also in Sierra El Carrizo we have observed native grasses not present in the lowlands. It is very important to have a more detailed vegetation study to provide other alternatives in terms of natural resource management in the area.

Salinity was clearly located in the lower watershed, different levels of salinity are present, some of them are signs of the impact of human activities, but others are due to natural conditions. In the vegetation map, 3828 ha are shown as abandoned due to salinity. It is also convenient to analyze the risk of reclamation programs for salinity.

Erosion is a major problem in the upper watershed in general. That is due to steeper slopes (mainly) and low vegetation cover. Historic references, and climate information, could lead us to think that grasslands have deteriorated, changing to desert scrubs, and a program to restore environmental conditions and reduce land degradation is a must for the economic development of this region.

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The Apacherian Savanna: The State and Future of Long-term Monitoring

Peter Warshall[1] and Tony Burgess[2]
with the generous help and assistance of workshop participants (Table 1)

ABSTRACT

This conference has brought together, for the first time, most of the groups monitoring the vegetation and biological diversity of the Apacherian savanna (Burgess, this volume). Until recently, the bioregion has largely gone unnoticed or undefined (McClaran, 1995). There is only the most elementary understanding of how Apacherian savanna ecology differs from adjacent grasslands such as the tall and short grass prairies of Midwestern United States, and how human economics (largely cattle grazing, subdivisions and infrastructure) impact the Apacherian savanna.

To better assess the state of our knowledge, the authors sent out a questionnaire prior to the conference, summarized the questionnaire, and then held a two and one-half hour workshop to air issues. All attendees agreed that the workshop was just a beginning. The questionnaire itself needed revisions to better reflect the concerns of ranchers, agencies, scientists, conservation groups, and the military personnel that have been and will be monitoring the Apacherian savanna. Nevertheless, this paper reflects the first coming together of information for long-term monitoring for those concerned with forage production, biological diversity, watershed stability, driving forces that shape the savanna's species composition and vegetation structure, biogeography, and future conditions. This paper includes many additions and clarification by participants and is truly a cooperative effort of more than thirty people.

GROUPS MONITORING VEGETATION IN THE APACHERIAN SAVANNA

Fifteen groups responded to our search for long term monitors (Table 1). Fourteen were in the United States which includes maybe one-third of the bioregion. Only the Centro de Ecologia represented Mexico and its focus was on the smaller extent of Apacherian savanna on the western side of the Sierra Madres. Two groups came from military reservations; two from federal wildlife

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[2] Biosphere II, Oracle AZ.

refuges; one from a Native American reservation (Tohono O'odham); three were non-governmental organizations (Nature Conservancy, Audubon, and the Malpais Group), and two represented research areas in the San Simon Valley (James Brown and Robert Chew). Three are funded by federal funds (NRCS, Jornada, Forest Service), and one by federal/state funds (Santa Rita Experimental Range). The NRCS had two programs: a range trend program and a large scale Natural Resources Inventory program.

Other groups in the Apacherian savanna may have long-term studies. We could not contact them or they did not respond to the questionnaire. They include the Walnut Gulch Experimental Range, Chiricahua National Monument, Ft. Hood and Ft. Bliss (Texas), Chihuahuan Desert Research Station, unidentified groups in the Trans-Pecos, Sevilleta Long-term Ecological Research Site (LTER) in New Mexico, San Carlos Apache and Hualapai tribal lands (Arizona), the Borderlands Project of the Rocky Mt. Experiment Station (just beginning), and numerous individuals in Mexico. The only official LTER site is the Jornada. The oldest range experimental station, the Santa Rita Range (93 years in existence), has not been designated a LTER. The most obvious gap was the two-thirds of the Apacherian savanna in Mexico.

Buenos Aires Nat. Wild. Ref.	BANWR	Bill Kuvlesky, Jr. and *Bill Flesh, Ulam
Portal, AZ (RM Chew)	SSRC	Robert M. Chew
Gray Ranch	GR	Peter Sundt, Peter Warren
Centro de Ecologia	CE	Alberto Burquez *
Muleshoe Ranch, Nature Cons.	MNC	David Gori, *Peter Warren
San Bernadino Nat. Wild. Ref.	SBNWR	Tony Velasco, *Myles Traphagen
Ft. Huachuca Military Reserv	FHM	Sheridan Stone, *Miles Tandy
San Rafael Grassland	SRG	Bill Wilcox, Sierra Vista Ranger District
Natural Resources Cons. Serv.	NRCS	Dan Robinett, NRCS-Tucson
San Rita Experimental Range	SRER	Mitch McClaran, University of Arizona
Jornada Experimental Range *	JER	Kris Havstad
Audubon Research Ranch	ARR	Bill Branan, *Carl Bock and Jane Bock
San Simon Valley	SSJB	James H. Brown,*Kevin Rich
Tohono O'odham Nation	TON	Kristin Egen, * Tom Davis (BIA)
White Sands Missile Range	WSM	†David Lee Anderson

* Attendee at Conference, if different from person filling out questionnaire. † Not at workshop

Table 1:
Contributors to the Monitoring Workshop and Questionnaire

QUESTIONNAIRE RESPONSES

The response of the long-term monitoring group (Table 2) shows three goals, admirably summarized by Kris Havstad of the Jornada: livestock production (9 groups), biological diversity (10 groups), and soil protection (5 groups). Livestock production includes forage value and shrub invasions, impacts of disturbances, and livestock managing methods. Biological diversity includes species and plant associations of special concern, foodweb linkages, barriers to dispersal, wildlife corridors between sites, wildlife production, competition, exotic plant invasions, and other aspects of natural history. Soil maintenance includes soil descriptions, watershed conservation, soil moisture, soil biogeochemistry, seed banks, soil crusts, and definition of landscape units.

Objective	**Group**
Improvement of forage for livestock	TON, NRCS, JER, SRG, GR, SRER
Natural history of biotic community	TON, SSJB, BANWR, ARR, JER, FHM, SSRC, GR, SRER
Comparison of grazed/disturbed grassland with a control	ARR, JER, SSRC, GR, CE, SRER
Understanding mass/energy and biogeochemistry relationships	SSRC, CE, SRER

Table 2
What have been the objectives of monitoring in the Apacherian Savanna?

The objectives of most permanent plot sampling (Table 3) focused on grass species frequency and vegetative cover. In addition, three groups monitored density, three groups monitored forage trends, and three groups monitored species composition trends. The Santa Rita and Audubon paid special attention to exotic grasses and four groups focused studies on special floral species of concern. One study (Robert Chew) has monitored the changes in size of creosote bush.

In the Apacherian savanna, continuity of permanent plot monitoring programs has been erratic. Four groups had less than five years of data (Gray Ranch, Centro de Ecologia, San Bernadino Wildlife Refuge, Fort Huachuca). Four groups have been monitoring for five to ten years (Buenos Aires, Muleshoe, Tohono O'odham, White Sands). James Brown's program is 20 years old; the Audubon Research Ranch is 28 years old, while Robert Chew's monitoring site has been monitored for 38 years. The Natural Resource Inventory started in 1957. The oldest monitoring sites at Jornada and Santa Rita both exceed 50 years. Like most long-term sites, the monitoring has been dependent on research interest and funding. The Santa Rita program was revived in 1986 and now, once again, appears to lack funding. The Forest Service monitored the San Rafael grasslands in 1958 and never returned until 1993. Unstable funding and priorities makes the Forest Service program inconsistent.

Sampling Objective	Groups
Frequency	MNC, GR, TON, NRCS
Cover	MNC, GR, SSJB, TON, NRCS, SRER
Density	MNC, SRER
Exotics	SRER, ARR
Species composition	MNC, GR, SBWR
Special Status Species	GR, FHM, BANWR (extensive),ARR
Forage trends	MNC, GR, SRG
Other	SSRC (creosote bush size)
Repeat photography	JER, WSM, GR, SSJB, SRER, FHM, ARR. SBWR, NRCS, TON, BANWR, MNC , CE
Aerial images	JER (fixed wing), SSJB, ARR, SRER, FHM, SBWR
Satellite images	JER, SSJB, ARR, SRER, FHM, SBWR
Leaf-Area Index	JER (special),
Phenology of a single species	JER, ARR (trees, shrubs), SSJB
Phenology of a group of species	Blooming of forbs (SSRC), select (FHM), JER, SSJB
Energy provided by grassland	JER (BOER grassland), CE
Nutritional analysis	JER
Biogeochemical cycling	JER

Table 3
Vegetation Attributes of Longterm Monitoring by Various Groups

The monitoring techniques varied widely depending on the goals and the date the monitoring started. Some methods (e.g., the Parker Three Step method) which had been the current choice of range scientists at the time are now are no longer utilized. Frames with transects, line intercepts, point-line intercepts, and step point methods were the most common for vegetative studies and trends. All groups have repeat photography programs included in their permanent plot monitoring. Six groups have less frequent but continuing aerial and satellite monitoring in which the permanent plots help in ground-truthing. Unfortunately, the questionnaire was ambiguously worded and more precision about the number of transects and quadrants utilized and how they relate to the goals of the monitoring program cannot be attained at this time.

Production and biomass	SSRC (N = 1), TON (dry weight rank), CE; comparative yield (MNC); SRG; NPP 3 times/year at 3 sites in 5 communities (JER), clipping (ARR); SRER
Soil loss	NRCS (Natural Resource Inventory)
Special studies	JER (remediation techniques),GR (fire), MSNC (improvement of watershed), ARR (biodiversity maintenance); ARR (exotics); SRER (mesquite control/herbicides), SRER (revege/reseed/fertilization)SRER (watershed);
Disturbance regimes: grazing	ARR, SRER, CE, TON, SSJB, JER, SSRC, GR
Disturbance regimes: fire	ARR, SRER, CE, TON, SSJB, BANWR, FHM, GR
Disturbance regime: extreme weather events, drought, air pollution	ARR, TON, SSJB, BANWR, JER, FHM
Disturbance regimes: mechanical injury to watershed	ARR, BANWR, FHM
Disturbance regimes: plant disease	GR (notes)
Disturbance regimes: folivore, faunal, pathogen outbreaks	SSJB (granivore), BANWR (disease outbreak), GR (notes)
Remediation manipulation	SRER, JER
Exotic invasion and competition	ARR

Table 4
Special Soil/Plant Studies that Accompanied Longterm Vegetation Monitoring

Faunal, including endangered, threatened, rare and faunal species of special concern.	SSRC (ants, grasshoppers); JER (avian, small mammals, select inverts); ARR[1]; BANWR[2]; SSJB(harvester ants, granivore rodents); SRER (ants, termites, rodents, jackrabbits, coyote)
Soil biota	JER, SRER (ants), SSRC, SSJB, FHM (rare)

1. Grasshoppers, butterflies, small mammals; coyote, rock squirrel, cassins sparrow, acorn woodpecker, botteris sparrow, grassland sparrows, javelina, bunchgrass lizards, montezuma quail
2. Quail, mule deer, breeding birds, pronghorns, herps.

Table 5
Longterm and Special Non-Cattle Faunal Studies

The return interval for permanent plot vegetation monitoring varied from pure research studies such as Jim Brown's with monthly sampling to trend analysis (especially frequency and cover trends) with annual to three year return intervals; and to longer term intervals for groups focused on species composition, biodiversity, soil conditions, and shrub/tree growth (five to ten years). The return intervals are not cast in stone. For instance, the Gray Ranch increased frequency of sampling from once every five years to every year after a wildfire. Similarly, Ft. Huachuca will increase frequency of sampling if a monitoring site signals a possible change in trend. The workshop did not have time to fully discuss the implications of varied return intervals. Within the context of permanent plot sampling, eight or nine of the groups conducted special studies (Table 4). Eight groups have specific programs to monitor production and biomass connected to the permanent plot programs. The Jornada is unique with studies related to their permanent plots on biogeochemical cycling, nutritional analysis, energy flows, autoecology, phenology of single species and leaf-area indices. The NRCS monitors for soil loss in its Natural Resource Inventory program.

The monitoring of groups of plants with similar life-styles (aggregates of life forms) or vegetative trophic levels has not occurred. Four groups monitored the phenology of a group of species.

Context	**Groups**
Topography (latitude, elevation, slope, aspect, physical barriers, etc.)	ARR, SRER, CE, TON, SSJB, GR, BANWR (select), JER, FHM, SSRC.
Geomorphology (alluvial fan, fossil sand dune, etc.)	SRER, CE, TON, SSJB, JER, FHM, SSRC, GR
Soil moisture regime (previous rainfall, water holding capacity, inter-storm drought, run-on or run-off, ET, etc.)	Rainfall only: TON, GR (scattered)Rainfall/temp only: ARR Not specified: SSJB, JER, SSRC
Soil profiles and erosion conditions	TON, SSJB (?), JER, FHM (rare), GR (select 50cm), NRCS
Soil biogeochemistry	SSJB, JER
Ecostructure (canopy, edge effects)	CE, SSJB, FHM, GR (notes)
Land use history (ethnoecology, grazing, feral horses/burros)	
Human structures (fences, waterholes, salt blocks, roads)	GR
Unknown or no response	NRCS, WSM, SBWR

Table 6
Context Data Needed for Long-term Trend Analysis

The baseline data, inventory, or "context" information for long-term studies is summarized in Table 6. Almost all groups located their permanent plots after considering topography and geomorphology (landscape forms). But, less than half the groups studied soil profiles or ecostructures before implementing the monitoring program. No group documented the land use history of the site from informants, census records, water and homestead filings, and newspapers. The questionnaire unintentionally omitted an inquiry about human structures and infrastructure but most of the range trend monitoring programs designed their permanent plots away from fences, watering holes, and structures that might skew the overall range trend. Two groups performed soil chemistry studies after setting up permanent plots. The completeness of plant surveys that serve as a baseline for biological diversity monitoring was not explored in detail.

Faunal Monitoring and Studies

Only the two San Simon Valley studies, Audubon and Jornada have long-term monitoring of the Apacherian savanna fauna (Table 4). Very little work has been done on foodweb linkages. Buenos Aires has begun five studies within the last five years and the Santa Rita has numerous scattered studies associated with vegetation change. No one reported work on soil microbiology studies associated with these arid grasslands and shrublands.

SUMMARY OF QUESTIONNAIRE AND WORKSHOP

Changes in the Apacherian savanna have multiple, staggered causes. Major driving forces are inter-storm drought, intense (gray ash) fire, exotic invasions, and intensive grazing. Brown would add granivore/herbivore consumption. Jornada scientists would add nitrogen and phosphorus distribution and concentration. "Wildcards" include hard freezes, founder effects, seed banks, and winds (exasperating evapotranspiration, pollination, or fire). The timing and sequence of these events drive the ecosystem as much as the intensity of the events themselves. The Apacherian savanna is a classic "pulse-reserve" soil moisture ecosystem (Noy-Meir, 1973). In addition, the Apacherian savanna harbors many different geomorphological landscape units, soil profiles, erosive conditions, and soil chemistries. Within the Apacherian savannas, the periodic or total removal of livestock from grazed lands can show ambiguous dynamics. "Recovery" of grazed areas may not occur. In some locales, a new "stable" equilibrium has been established. In well-studied locales such as Audubon Research Ranch, the removal of cattle both increases the number of faunal species and, more importantly, skews the species list in a new direction. From this overview, the following conclusions can be made:

- Context or landscape inventory data for soils and landscape units are crucial.
- Weather pattern recorders near locations of the permanent plots are crucial.
- Good observational notes that accompany the permanent plot data and describe seasonal or annual events such as hard freezes, insect outbreaks, plant disease, hot winds are essential.
- Determining the location of the permanent plot and sampling method is not a trivial problem.
- Remediation or rehabilitation or recovery of grazed landscape units will not necessarily be able to accommodate all three purposes of monitoring: animal production, biodiversity, and watershed stability. Remediation techniques (e.g., fertilizer applications, reseeding, prescribed burns, fencing) must be custom-designed to the future desired condition and monitored long-term to see if the technique is actually driving the landscape toward the desired goal.

The questionnaire revealed that soil conditions and the network of weather stations needed the most attention in all studies. Some of the NRCS range units (now called ecological units) need to be re-surveyed. More important, many of the study plots did not have adequate soil profiles to provide credible replicate transects for comparisons. There were very few "reference stands" or controls for range trend monitoring. The best situations occurred at locales such as the Audubon Research Ranch which is adjacent to a private rancher. Audubon essentially serves as the reference stand for the rancher and, by mutual agreement, monitoring occurs on both sides of the fence. The question of fire frequency and intensity on the reference stands (what is "natural"?) was broached and remains unresolved.

Although some groups such as the Gray Ranch have the flexibility to change the interval of sampling, others do not. Follow ups on "natural experiments" by increasing sampling frequency after droughts, fires, erosive floods or folivore outbreaks can yield more information than rigid monitoring with set-in-stone return intervals.

The questionnaire revealed very few "retrospective studies" such as packrat midden, tree ring, and pollen studies that provide a longer temporal context to the monitoring studies. Similarly, there were no land use histories that could provide data on the longterm (more than a century) changes in soils, grazing intensity, fires and drought which have shaped today's vegetation patterns.

A revised questionnaire is shown at the end of this paper. This questionnaire results from our first iteration within the workshop. It may help others coordinate monitoring studies within their bioregion. Gaps that have been corrected include: stating the size of the landscape unit that the permanent plot represents; indicating the shape of the quadrants (circle, squares, points, rectangles); better defining the vegetation attributes being sampled; adding land use histories and special studies; including observational notes; etc.

DISCUSSION

Range Trend and Research Differences

Mitch McClaran and Peter Warren emphasized the differences between the long-term research vs. long-term range sampling methods and return intervals. To determine a cause-and-effect relationship credible to academic researchers a 95% confidence level may be required. Academic standards may also require a shorter-term manipulative study with a treated vs. control plot to more precisely define cause and effects. To determine a change in range trend so that a livestock raiser can adjust cattle numbers or pasturage time may require an 80% confidence level.

While research requires an explicit hypothesis and complete consideration of all possible variables, range trends analysis is based on "indicator" prescriptions (e.g., "If snakeweed has expanded, the range needs fire and/or rest.") or indices (e.g., cover substituting for biomass). It is the job of research to determine how accurate the indices and indicators are.

Mitch McClaran pointed out that serendipity plays an important role in the monitoring and research programs of the Apacherian savanna. Monitoring can provide indications of subjects that need more intensive research. The influence of acid rain or climate change are, perhaps, two examples in which long-term studies provided the background for research topics.

Technical Issues

Table 7 is a summary of technical issues. Not all could be dealt with within the workshop. Range trend monitoring could profit from the research-oriented autecology studies (i.e., studies on individual grass and shrub species to define their resilience to soil water moisture, geochemistry, and fire extremes). The Jornada was the only research group providing this information. Long-term

• What plot size to reflect a larger landscape unit? What is the linkage between plot and landscape scale? Do your key areas reflect a larger landscape? Are your reference plots typical of a larger scale? How do you choose your plots to represent larger landscape units?

• What pattern of placement of macroplots, baselines, and transects is the most meaningful for response patterns to disturbances or biodiversity? What do you do when the study area has patchy soils, rugged topography, run-on and run-off patterns, and varied aspects? How do you handle ecotones and other gradients? When do you need a pilot study and when can you rely on subjective judgment in placing permanent plots?

• What parameters should be measured? How to reconcile the spatial scales required for resource management vs. biodiversity?

• What shape should the quadrants be? Circles? Squares? Rectangles? Points? Embedded for biodiversity studies?

• How many transects to provide a credible generalization?

• How many quadrants or points along transects? How many random sampling hits?

• How frequently should the monitoring occur for resource management or biodiversity management? What is confidence level used when comparing means of plots or transects for range trends vs. research?

After Monitoring Has Started

• What do you do to accommodate for the unpredictable nature of external disturbances on your study? Do you have enough replicates? Do you change reference stand or control?

• How have you dealt with varying responses of what appeared to be similar plots or transects?

• How do you cope with unique events or discovery of unique landscape histories that may limit abilities to generalize?

Table 7
Technical Issues Involved in Longterm Monitoring

range monitoring would also profit from research that includes short-term experiments to determine more precisely cause and effect (before/after impacts); specific functions of plants or fauna; and the resilience and resistance of ecological units to multiple stressors. These short-term experiments include exclosures, deliberate burns, fertilizing or reseeding pastures. The Jornada, James Browns's studies and the Santa Rita have provided some of these short-term experimental studies.

Mitch McClaran and others brought up the question: How long do we have to monitor to understand trends? McClaran showed slides of nearly a century of range "trends" on the Santa Rita and felt that observing the past photographically cannot lead to predicting the future condition of the arid grasslands. "Trends," in fact, may not become clear during the period of one professional's lifespan. The time scale implied by the term "trend" should be made explicit. The term is also used by agencies and ranchers for grazing adjustments over very short time scales. Dan Robinett pointed out that the soil constraints to potential shrub and tree invasions may be most useful in predicting future possibilities (McAuliffe 1985).

Peter Sundt showed the result of his "running mean" data and said that, if the accuracy required for percent cover is +/- 2%, then his point-intercept transects gave representative data after eight samples. He felt if the area were reliably homogeneous then even seven transects may suffice. The lower the number of transects, the greater the cost savings.

Peter Warren and Peter Sundt recommended the point intercept method for ranchers and range trend analysis. Kris Havstad agreed that this was a method that provided reliable data on cover and frequency. McClaran and others pointed out that the point intercept method did not pick up uncommon or rare species and was not the best method for monitoring concerned with changes in biological diversity and species composition. Peter Warren said that Nature Conservancy uses a very focused approach for monitoring rare species. The issue of tracking the frequency of uncommon but not rare species and the best monitoring method remains unresolved. All agreed that the "rare species" emphasis requires a careful and complete inventory of the range or savanna which many agencies and ranchers cannot afford.

Inter-site Comparisons

At the moment, comparisons between sites within the Apacherian savanna are difficult because of varying methodologies, contexts, and goals. It appears that the NRCS has the best over-arching framework for inter-site studies because its land units closely match soils. The Natural Resource Inventory could also be modified to provide a bioregional overview. How to coordinate monitoring programs and provide NRCS the funding to become the organizational structure for the region remains unresolved. Similarly, how to include Mexico and parts of Texas into the bioregional monitoring program was not resolved. Finally, the NRI program occurs on state, Indian, and private lands. The NRI sites on public lands are supposed to be monitored by the public land agency. This has not occurred.

The questionnaire revealed a need to define plant associations in a more biologically meaningful manner (i.e., in a way that better revealed to other monitors the differences between sites). Gloss categories such as arid grasslands, savannas, desert or semi-desert grasslands, Chihuahuan desert or shrub-steppe were too broad. The Gray Ranch (1994), Fort Huachuca and Robert Chew used the formation/series/association levels of Brown and Lowe (l9XX). For instance, Ft. Huachuca had nine plots in the *Eragrostis lehmanniana* Association but none in the Shrub-scrub Disclimax series. At least as a first iteration, the Brown/Lowe system would help monitors in comparing sites and responses of sites to disturbance.

THE FUTURE

The future of meaningful monitoring is constrained by funding, organizational stability and interest, methodologies, trained monitors, archiving, and public/private information flows and their credibility (Table 8). Although funding gets the most attention, all the other constraints can be equally important. Dan Robinett pointed out that NRCS, for instance, plays a delicate role as an

A. Funding (start-up costs, long-term cashflow, archiving)
B. Organizational structure and stability (including policy changes)
C. Absence of baseline information and replicates
D. Field sampling needs (equipment, methods, trained skills)
E. Methods (e.g., pseudoreplication and sampling procedures)
F. Archiving (data and identification vouchers)
G. Public/private information flows and the issues of credibility

Table 8
Constraints on Longterm Monitoring and
Biological and Resource Management Meaningfulness

extension agent on private lands. The information collected cannot be made public without landowner permission. The long-term monitoring program can be terminated be a simple refusal of the landowner. This privacy can provoke skepticism among other interest groups who assume, rightly or wrongly, that something is being hidden. There are those who believe that monitoring just creates more data and rarely changes policy. So why spend the money? In many instances, the connection between monitoring, the interchange of public and private information and policy needs trust and clarification.

Similarly, organizational interest and continuity should not be minimized. Besides the overriding need for funding, many participants were concerned that long-term data tend to get lost and, with the data, the prime usefulness of the monitoring program. Except at the Jornada, there is no mandate to maintain archives. McClaran is working on an electronic archive for the Santa Rita with the Forest Service, University of Arizona, and others.

Dreams and Suggestions

Havstad, Sundt, Warren, Bill Willcox, Robinett and others discussed rancher-based or NGO-based (non-government organization) monitoring. Havstad set out the following criteria: rapid, simple, repeatable, quantitative, inexpensive and interpretable. Citizen-based monitoring requires funding for educating both citizens and extension agents. The difficulties of grass and insect identification, and how to certify a monitor could both be addressed with a "Apacherian savanna monitor certification program." Citizen-based monitoring programs have become more pressing with budget cuts to the Forest Service, NRCS, and Bureau of Land Management.

Peter Warshall suggested that the ultimate goal would be a yearly network in which various monitors could report and hear about the responses of local plant associations to the specific year timing and intensity of storm patterns. The information, as indicated by Sundt, could best be reported using NRCS "ecological units."

Tony Burgess suggested an atlas of major grasses and shrubs of the Apacherian savanna similar to the atlas recently completed for the Sonoran desert (Turner, et al.19955). There is little information available on the biogeography of Apacherian savanna species. An atlas could bring the understanding of range and ecosystem management to a more detailed level and bring Mexico and Texas into the discussion.

CONCLUSIONS

Almost everyone agreed that we are all neophytes. With all the work done, the publications printed, and the data recorded, we still need a lot more understanding on how to graze, how to prescribe fire, how to manage both exotics and shrubs, and how different sites respond to similar stresses.

Ranchers, extension agents and scientists all love living and working on the Apacherian savannas. Although their goals and methods may differ, they are the "seed stocks" whose combined efforts will provide both local knowledge and natural history information to public policy and private management decisions. Given the erratic nature of the weather, the patchy framework of the hills and soils, and the increasing land conversions to housing and exotic grasses, local citizens, extension agents, and committed scientists involved with long-term monitoring are the ideal forum to provide perspective and advice on the future direction of livestock production, biological diversity and watershed health.

QUESTIONNAIRE FOR APACHERIAN SAVANNA MONITORS

Name of site:
Contact name:
Best address:
Best phone: Best e-mail and/or fax number:

Monitoring Techniques for Vegetation Attributes Only
Permanent Plots (details requested below):
Repeat ground-based photography (with dates)
Aerial images (kind/ dates)
Satellite imagery (kind, dates):
Other:

Permanent Plot Description
Using the Brown, Lowe and Pase (l979) system provide the Formation, Series and Association for each site with a permanent plot.
Using the NRCS ecological site classification, list all the sites with permanent plots.

Context or Background Inventory (indicate if background data was used in choosing plot locations by underlining item)
Topography (latitude, longitude, slope, aspect)
Geomorphology (alluvial fan, fossil sand dune)
Soil profile (texture, structure, depth, classification, crusts, hardpans)
Soil characteristics (water holding capacity, infiltration, percolation)
Weather station (nearest location, rainfall, evapotranspiration, wind, temperature, humidity)
Soil geochemistry (pH, nutrients, metals)
Ecostructure (hard surfaces for run-on or run-off, tree shade, landscape shade)
Human structures (watering holes, roads, fencelines, buildings)
Water tables (seasonal, height, permanent)

Basic Info
When did the study start?
Is the study continuing?
Do you have a reference stand which serves as a control with minimal human influence?
Did you perform a pilot study to determine either the location or methods or sampling procedures for the permanent plots?
What kind of judgments went into determining the location of the plots?
What kind of judgments went into determining the method or intensity of sampling? Was the sample stratified or random?
Has an inventory for the flora been completed?

What would you say that your overall goals have been?
- Improvement of forage for livestock
- Natural history of the biotic community
- Comparison of disturbed grassland with a control
- Understanding energy/mass relationships
- Special status species and their ecology
- Soil and watershed processes
- Other

What monitoring method do you employ?

(If more than one, indicate which method for which sampling goal)
Frequency
Line Intercept
Step point
Point intercept
Density
Double-weight sampling
Dry-weight ranking
Harvest
Comparative yield
Other(s):

Spatial Scale Considerations:
Size of "macroplots" (bounded area of permanent plots):
The size of landscape unit that the macroplot represents:
Length of monitoring baselines:
Number of transects per baseline:
Length of transects off baseline:
Width of transects off baseline (if applicable):

Temporal Scale Monitoring
What is the return interval for each permanent plot?

What do you sample for?
Frequency
Cover
Density
Production
Biomass
Forage trends
Species composition

How intensive was sampling? Did you include:
Forage species only
All grass species
Subshrub species
Forbs
Succulent species
Woody species (shrubs and trees)
Exotic flora
Others (special taxonomic groups?):

Special Vegetation Attributes
Leaf-area index:
Phenology of single species (name):
Phenology of groups of species:
Energy turnover in permanent plot or experimental plot:
Biomass or productivity (described) in plot or experimental plot:
Plant nutritional analysis:
Biogeochemical cycling and soil nutrients:
Other:

Vegetation Attribute Analysis
Were data grouped by a particular compartment or trophic level (describe)?
Were data grouped by growth form category?

Savanna Fauna and Soil Biota
Terrestrial species monitored:
For each species:
- Life cycle
- Seasonal demography (pop size, density)
- Yearly demography (inter-annual trends)
- Foodweb (predators, prey, pathogens, competitors)
- Habitat requirements

Soil macrobiota sampling:
Soil microbiota sampling:

Special Studies That Related to Permanent Plot Monitoring
For each study, list start and end of study; general scale and return interval for sampling.

Special status (plant or animal) species:
Purpose of monitoring (pop size and trend, habitat area and trend, reproductive effective pop, extinction probability, carrying capacity, dispersal ability, dispersal corridors, pollinators, other)

Disturbance studies (deliberate "treatment" vs. "control" studies):
- Grazing
- Fire
- Drought
- Mechanical injury
- Plant disease
- Folivore or other faunal outbreaks

Autecology studies (list species):

Post-Startup Considerations
Have you altered the plots or return intervals or methods after startup? Why?
How do you accommodate unpredictable events and disturbances to the permanent monitoring plots?
Did you increase replicates?
How have you dealt with the varied responses of permanent plots that you, at first, thought were similar?
How have you changed methods or sampling after discovering unique landscape histories that might limit generalizations? Or after increasing your information about the plot's context (e.g., soil profile or water table location)?

Reporting Monitoring Results
Do you report results as averages (means)? What confidence interval do you use?
Do you use a regression analysis?
What computer simulation models do you use?

Summary of Knowledge and Information
What have you learned about management of the biotic community?
What do you consider the most important driving forces on your permanent plots?
Please attach publications related to your monitoring project.
THANKS AGAIN!

Building an Electronic Knowledge Center for Rangeland Management: The Arizona AgNIC Project[1]

Mitchell P. McClaran[2]; Michael Haseltine and Barbara Hutchinson[3]; and Jeanne Pfander[4]

The National Agricultural Library (NAL) is sponsoring an interdisciplinary team at the University of Arizona to develop a prototype Rangeland Management World Wide Web (WWW) site. This site will be a component of the national Agricultural Network Information Center (AgNIC).

The Arizona AgNIC team is made up of members from The University of Arizona Library and three divisions of the College of Agriculture (Administrative Computer Support, Arid Lands Information Center, and School of Renewable Natural Resources). This project team has created the framework for a responsive, adaptive electronic reference tool on rangeland management - a topic with application not only for Arizona, but for the entire western U.S. and similar regions throughout the world.

The Rangeland Management web site (http://ag.arizona.edu/OALS/agnic/home.html) will supply fundamental educational information on the principles of the discipline and methods for measuring resources and impacts. Users will find glossaries of terms, answers to frequently asked questions (FAQs), directories of research projects, full-text documents, primary data, hypertext links to other related resources, and search engine options. The web site will also provide a forum for discussion of issues relevant to rangeland policies via an associated listserv.

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[1] Abstract of a poster presented at the conference.

[2] School of Renewable Natural Resources, University of Arizona, Tucson AZ.

[3] Arid Lands Information Center, Office of Arid Lands Studies, University of Arizona, Tucson AZ.

[4] University of Arizona Library, Tucson AZ.

Distribution of Chihuahuan Desert and Colorado Shortgrass Prairie Species Controlled by Soil Moisture Heterogeneity In a Desert/grassland Ecotone at Sevilleta National Wildlife Refuge [1]

Charles A. Z. Buxbaum[2]

Bouteloua gracilis (blue grama), *B. eriopoda* (black grama), and *Larrea tridentata* (creosote) are the dominant plants of the McKenzie Flats area of the Sevilleta NWR in Central N.M. Much recent research of the Sevilleta LTER has focused on discerning processes that regulate the distribution of these species within a desert/grassland ecotone. In this study, I examine the hypothesis that landscape heterogeneity of soil depth and fine-textured fraction controls the relative dominance of the three major species. The area is relatively flat, grading at a 2-3% slope to the edge of a fault scarp. However, even the within the flattest parts of the landscape there are abrupt and dramatic soil changes. These correspond to the presence of buried channels that cut through a petrocalcic horizon that formed in a 500-100 ky old buried soil.

Cluster analysis of soil-moisture-related characteristics and Spearman rank correlation analysis of soil data and dominance or codominance of the three species of interest shows the following: *B. gracilis*, a Colorado Shortgrass Prairie species, dominates the buried paleochannels, where the soil profile is deepest and clay accumulation is highest; B. eriopoda, a Chihuahuan Desert grass, is most abundant where the buried petrocalcic horizon is within 40 to 60 cm of the surface; and *L. tridentata* is the dominant species where the petrocalcic horizon is exposed or near the surface. Understanding edaphic patterns in arid grasslands can help predict rates of desert expansion or retreat; and is a critical factor in grassland restoration.

This study illustrates the strong relationship between geomorphology, soils, and vegetation patterns in arid environments. While grassland soils may appear homogeneous at the surface, the climatic history of alternating wet and dry periods has caused alternating periods of soil deposition and erosion. The vegetation patterns on the recent deposition Al soils of the Sevilleta NWR grasslands follow the dissected pattern of a buried past landscape.

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[1] Abstract of a poster presented at the conference.

[2] Dept. of Biology University of New Mexico, Albuquerque NM.

A Landscape Approach to Monitoring and Assessing Ecological Condition - San Pedro Case Study[1]

William G. Kepner[2], Kurt H. Ritters[3], Christopher Watts[4], David C. Goodrich[5], Russell Scott[5], and Ghani Chehbouni[4]

The U.S. Environmental Protection Agency has initiated a national approach to assess ecological risk relative to exposure to environmental stressors. A key component of this framework enlists landscape ecology as a theoretical basis from which to assess cumulative exposure to stress at multiple spatial and temporal scales. This project has focused its research into developing a system of landscape composition and pattern indicators which can be used to estimate current status, trend, and changes in ecological and hydrological condition. Specifically, it is designed to determine ecosystem vulnerability relative to large-scale natural or man-induced disturbances (e.g. climatic change and livestock grazing, respectively) using a system of landscape pattern metrics derived from remote sensing, spatial statistics, and geographic information systems technology. The program has proposed a strategy of utilizing triplicate Landsat Multi-spectral Scanner imagery from the early 1970s, mid-1980s, and early 1990s, in addition to finer resolution imagery (i.e. Landsat-TM, SPOT, and aerial photography) to generate land cover data and establish 20-year trends in condition for selected geographic areas. This process has been tested in a small community-based watershed in southeast Arizona and northern Sonora and has been particularly related to land degradation and habitat modeling for selected wildlife species in the Upper San Pedro Watershed.

Very little quantitative information on a regional or watershed scale is available on status of land degradation for rangelands. Rangelands, such as those that occur in the San Pedro Watershed, are the most extensive land use of the world dry lands. Nearly 85 of the North American rangelands are estimated to be in degraded condition; more than any other continent in the world. Landscape composition, connectivity, and patch sizes and number were used to evaluate ecosystem resilience and changes in land cover extent and wildlife habitat suitability over a 13-year period in the San Pedro River basin. The evaluation determined that extensive grassland areas with high connectivity were the most vulnerable ecosystem to fragmentation due to encroachment of woody shrubs and cacti. For example, the number of grassland patches increased 61% and the average grassland patch size decreased 60% between 1974 and 1987. The preliminary results of this project are presented to 1) illustrate both the indicator and change detection strategy; 2) demonstrate the value of the approach to ecosystem and watershed management; and 3) demonstrate the potential application of the approach for developing a

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[1] Abstract of a poster presented at the conference.

[2] U.S. Environmental Protection Agency, National Exposure Research Laboratory, Las Vegas NV.

[3] Tennessee Valley Authority, Environmental Research Center, Norris TN.

[4] Centro de Investigacion y Desarrollo de los Recursos Naturales de Sonora, Hermosillo, Sonora.

[5] USDA Agricultural Research Service, Southwest Watershed Research Center, Tucson AZ.

national, regional, and watershed program for systematic assessment of ecological condition, especially in regard to land degradation in arid and semi-arid regions of the world.

This research is one component of a multinational long-term monitoring and modeling proposal entitled the Semi-Arid Land Surface-Atmosphere (SALSA) Program. Results of the landscape analysis listed above will be integrated with other related projects within SALSA to determine the consequences of natural and human-induced change on the water balance and ecological diversity of the Upper San Pedro Watershed at multiple temporal and spatial scales. (Also see http://www.hwr.arizona. edu/salsa/salsa_l.html and http://www/epa.gov/crdlvweb).

Climatic Causes and Biotic Consequences of Recent Shrub Increase in the San Simon Valley[1]

Thomas J. Valone[2], James H. Brown, and Charles C. Curtain[3]

Using chronosequences of aerial photographs, we document a nearly three-fold increase in woody shrubs at three sites in the San Simon valley since 1980. At the one site containing a long-term cattle exclosure fence, woody shrub increase was identical inside and outside the exclosure. The increases in woody shrubs coincided with a climate shift in southeastern Arizona; since 1977, this region has experienced significantly higher than average cool-season precipitation. Regional warm-season precipitation has not deviated consistently from long-term averages. These changes in vegetation and precipitation have coincided with major changes in many animal populations at out long-term study site near Portal, Arizona. Populations of banner-tailed kangaroo rats, silky pocket mice, burrowing owls, horned lizards and seed-harvesting ants have all declined dramatically over the past twenty years.

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[1] Abstract of a poster presented at the conference.

[2] Department of Biology, California State University, Northridge CA

[3] Department of Biology, University of New Mexico, Albuquerque NM.

The Role of Nonprofit Organizations in Grassland Management: a Panel Discussion

Peter Warren, Session Moderator[1]

INTRODUCTION

There are some qualities and conditions of southwestern grassland ecosystems, ecological qualities and current social and political conditions, that make grasslands extremely difficult to manage in a sustainable way. Some of those conditions are related to the ecology of grasslands. To be ecologically functional, grasslands must be large enough to support processes like fire. Fire must be able to burn through a pretty large area to have the effect of creating a mosaic of patchwork conditions that characterize healthy grasslands. Grasslands need to be large to sustain migratory ungulates and they must be open across large areas to function as the corridors between mountain ranges for animals like bears, deer, bighorn sheep that travel from one mountain range to another. Grasslands require large areas to sustain them ecologically and to sustain them economically, from the point of view of ranching. Here in the southwest, to be sustainable livestock operation needs large areas in which to move the stock around and make the most effective use of variation in rainfall, and productivity, across the landscape.

On top of the pattern of ecological need for large size, these grasslands are located in valley bottoms where we have a complex mosaic of land ownership with state land, many private owners, and often some federal ownership. So to consider managing these grassland landscapes in a large, ecologically meaningful scale, you have to deal with a lot of the land owners, many of whom have different ideas about what they want to do with their land. This creates combined problems of maintaining ecological function and being organized socially as a community to keep sustainable management activities going on a suitable scale.

We are faced with multiple challenges in grassland landscapes and we don't really understand how to solve the problems of ecological sustainability or long-term economic sustainability. We have tremendous need for good information, and better distribution of information, about ecological and economic aspects of grassland management. We don't really understand how to apply fire in the most cost effective and ecologically effective way. There are some information needs, and some research needs, to help us understand how to use fire. Typically if you're a commercial ranching operation you do not have the spare pastures and the spare time to do fire research. Generally the open valley-bottom grasslands do not have very much research going on to help understand how to improve grassland management, so there could be a role for non-profits in improving our understanding of ecological management of grasslands.

In most southwestern grasslands with complex ownership patterns, the history has been of landowners operating very independently from one another. We don't have a history of working together as a community to manage these landscapes on a large scale. In many cases existing

[1] Arizona Nature Conservancy, Tucson AZ.

ranches are too small to be managed sustainably for the long term due to the great unpredictability of rainfall in time and space. If neighboring ranches could be managed together in a way that allows utilization of the patchy pattern of productivity this could contribute to the economic sustainability of grasslands. Non-profits can have a role in encouraging this kind of cooperation.

The combination of ecological and social factors make grasslands extremely difficult to manage. The session today will deal with organizing ourselves into community groups and non-profit organizations that may be able to solve some of these questions. The main point that I would like to get across in the session today is that non-profit organizations can take many forms and they can serve many functions.

We have speakers here today who can talk about the tremendous variety of activities that non-profit organizations are doing in grasslands of the southwest, ranging from Ben Brown talking about the Animas Foundation what they're doing and how their activities in community cooperation contribute to grassland management, to Tom Collazo who will be talking about what The Nature Conservancy is doing, with a focus on the research end of things in many cases. Dennis Moroney from Prescott will talk about the Santa Maria Mountains group, maybe a little bit about the Central Arizona Land Trust. Bill Branan will talk about what the Audubon Society is doing with their research ranch and what they see their role is. And finally Bill McDonald will talk about what Malpai Borderlands Group is doing.

That's all I want to say for now, that non-profit organizations can play many roles both on the ecological/scientific side, and on the community organization side to help find solutions for some of these very difficult issues concerning grassland management.

Grassland Management by the Animas Foundation

Ben Brown[1]

My name is Ben Brown and I am the Program Director for the Animas Foundation. The Animas Foundation is a private operating foundation created by Drum Hadley and his family in 1993. The primary purpose of this foundation when it was created was to acquire the Gray Ranch from The Nature Conservancy and to manage it in an ecologically responsible manner within the context of a working livestock operation. A private operating foundation is a little bit of a hybrid. You have probably heard of private foundations and public foundations. A private operating foundation is a private foundation that serves a public purpose. The Internal Revenue Service treats them as though they are a public foundation in some important ways.

The Nature Conservancy was seeking a private solution to the long-term problem of managing the Gray Ranch and protecting and preserving its significant ecological features. The Gray Ranch is a 502-sq mi ranch in southwestern New Mexico. The Animas Mountains run through the center of the ranch, and its eastern boundary lies in the Playas Valley and the western boundary in the Animas Valley. It contains a large expanse of diverse, high-quality grasslands as well as some fairly unique woodland and riparian communities. The Nature Conservancy met Drum Hadley when he was given the New Mexico Chapter's Aldo Leopold Stewardship Award for his work in restoring the riparian communities in his Guadalupe Canyon Ranch. the Conservancy talked with Drum and his family about the peculiar problems of finding a satisfactory solution to ensure the integrity of the Gray Ranch over the long term. The culmination of these conversations was the creation of the Animas Foundation and its purchase of the ranch from the Conservancy in 1994.

The Animas Foundation has a seven-member board of directors, consisting of Drum Hadley, his wife Teresa, his son Seth, Mike Hadley, Leo MacDonald, Sr. (who is also our legal advisor), Bill McDonald (a neighboring rancher) and Dr. Ray Turner (a plant ecologist). Our board meets four times each year and it is very active in setting the overall management agenda for the foundation and the Gray Ranch.

Our operating programs on the ranch fall into four areas. The first is called Land Management and Conservation. Under this program we take care of the unique natural features of the Gray Ranch. We have been working steadily at grassland restoration, primarily through the restoration fire as a natural process on the landscape. We employ both natural prescribed fire and management-ignited prescribed fire to alter and restore the natural structure of the grassland communities. We have implemented some mechanical treatments, as well, to compare the relative costs and effectiveness of both methods of altering vegetation structure. We have some other research that we will touch upon in other program areas, but most of the activities under our Land Management and Conservation Program consist monitoring and managing the unique natural features entrusted to us.

The second program area is Science and Education. We operate our own monitoring program to document the effects of our management on the natural communities and their

[1] The Animas Foundation, Animas NM.

constituent plants and animals. When the foundation acquired the ranch, we established a network of 114 monitoring plots and established an ecological baseline through quantitative sampling. The monitoring regime is designed to be repeated at five-year intervals, but some of our plots have burned in natural and prescribed fires, and we have revisited those plots annually to track changes in species composition and abundance following these fires. It has been interesting to look at these results because most of the effects that we have seen following our extensive fires in 1993 and 1994 seem to be more associated with the effects of summer drought than the effects of the fires themselves. We also have a number of outside collaborators that we work with. Tom Valone, from California State University-Northridge (who is speaking at this conference) is researching the effects of fire, looking not only at the changes in species composition and structure of the vegetative communities, but documenting the effects on vertebrate and invertebrate populations, as well.

The Rocky Mountain Forest and Range Experiment Station is researching the effects of fire and mechanical treatments, both alone and in combination, on the structure of older, more established woodlands and shrub lands. One of their experimental plots is on the Gray Ranch. We also have cooperative programs with agencies such as the New Mexico Game and Fish Department, various universities, and private cooperators to monitor species which we would like to track on an annual basis. There has been a significant amount of work on the fire history of the Animas Mountains and how that affects the structure of the vegetation, both in the woodlands and the adjacent grasslands. Ray Turner and a panel of scientists are actively involved in reviewing proposals from potential cooperators who want to establish research programs. We have a formal Science Advisory Panel which assists us in evaluating and making recommendations on proposed research projects. If we get a proposal from a potential cooperator and it looks like something that fits with the mission of the foundation, we will usually try and find a way to get it done.

The third program area is called Domestic Grazing. We are committed to carrying out all of our programs within the context of a working, responsible livestock management program which preserves the ranching culture of the Boot Heel as well as the biological diversity of the area. Right now, there are two kinds of grazing management programs. The first is called "grass banking", and some of you may have heard Bill McDonald talk about his earlier in the conference. Some of the pastures on the Gray Ranch have been made available to cooperating ranchers who have conveyed a land use easement over the deeded land on their own ranches to the Malpai Borderlands Group. The value of these easements is determined by an appraisal process and the Malpai Borderlands Group enters into an agreement with the Animas Foundation to provide a number of animal unit months of grazing that is determined by the value of the easement and the value of an AUM. The "home ranches" are rested, usually for a term of approximately three years, permitting them to benefit from rest and natural reseeding. Most of these ranchers are engaged in conservation planning in conjunction with an Natural Resources Conservation Service range conservationist, planning for better management, prescribed fire and other conservation practices. The grassbank ranchers manage their own livestock while they are on the Gray, with the foundation assigning them pastures and a desired rest-rotation grazing schedule. The foundation has also begun to purchase cattle to build its own cow/calf herd and will begin producing calves for sale sometime next year. These cattle will be used both for demonstration grazing and for research into the effects of grazing as an experimental treatment in conjunction with other management activities.

The fourth program area is called "Culture and Neighbor Outreach". In this program, the foundation works with our local community to support cultural and community activities. We also work with the ranchers who are actively involved with the Malpai Borderlands Group, and were instrumental in starting this sister non-profit, providing funds for start-up activities. We support local community service groups like the volunteer fire departments and the emergency medical service. We have helped the Cochise County Historical and Archeological Society with by hosting a fundraiser and we work with the Bootheel Oldtimers Association, too. The purpose of this program is to help preserve the culture and the lifestyle which make this part of the United States and adjacent Mexico unique.

Our fifth program area deals with the administration of the everyday affairs of the foundation: personnel matters, budgeting, and other administrative tasks. However, within the umbrella of the first four programs that I have described, we concentrate our efforts primarily on the management of the Gray Ranch. As I mentioned earlier, our current emphasis is on grassland management and grassland restoration, mainly through the use of fire and grazing. We have been very fortunate so far in that we have had to use hardly any management-ignited burns. In the years in which we have had fine fuels and wanted to burn, we have been blessed with a lot of natural ignition. We haven't had to light many fires ourselves, so far.

We have also had a lot of cooperation from the agencies that have the responsibility for fire suppression: New Mexico State Forestry Department, the Bureau of Land Management and the U. S. Forest Service. These are the agencies that deal with wildfires in our part of New Mexico and they have cooperated in establishing containment lines at natural fire breaks, backfiring off of these and letting fires burn as they will until they reach the containment lines. In 1993, we burned about 38,000 acres on the Gray Ranch and in 1994 we were able to burn about 78,000 acres. With a total of approximately 322,000 acres in the ranch and a preferred fire return interval of five years, we are looking at having to burn acreages of these magnitudes in the good years to achieve our management goals. We hope to do some more research on the effects of fire, particularly on the effects of fire frequency in the grasslands.

We feel like we know when natural fires occurred in the presettlement grasslands, because Mother Nature lights the fires herself at the proper time. In 1993, we had approximately 214 natural starts on the Gray that we know about, all from lightning storms. In 1994, we probably had similar numbers. We rarely have natural starts before the middle of April nor after the middle of July. Those fires that do start outside of this April-July window usually don't burn very long nor do the burn very extensively.

I'll quit here and let someone else have the floor, but I'll be around for a bit if anyone wants to ask questions about the programs of Animas Foundation and the Gray Ranch. I'll be happy to talk with you about them. I do want to brag a bit on the Animas Foundation before I sit down. Our foundation was one of the key ingredients in starting up the Malpai Borderlands Group and this whole landscape/ecosystem planning effort. This was largely due to the vision of Drum Hadley, who thought that this magnificent piece of country that we call the Gray Ranch had the ability to leverage conservation action outside of the boundaries of what he and his foundation could afford to buy. I think that the results so far have proven that his hopes were true. I think that Bill McDonald will tell you that the Malpai Borderlands Group is finding that they have a similar (and probably more extensive) ability to leverage grassland conservation and grassland restoration efforts beyond the 900,000 or so acres that we call the primary planning area. Good ideas are contagious.

Private Ranchers Cooperating on Public Lands[1]

Dennis Moroney[2]

My name is Dennis Moroney and I'm, I think in some ways, kind of an odd duck in this situation because I ranch mostly on public land. Our ranch is 30 miles northwest of Prescott, approximately 76 square miles, 98% of which is Prescott National Forest land. We bought the ranch just under 5 years ago. We came into a situation in which the community was very much caught up in kind of a polar opposition on issues related to land management, and in particular grazing on public lands. My background teaching agriculture in public schools and working in the public school system, has kind of prepared me for dealing with conflict and inter-personal relationships inherent in dealing with public trust. What has developed in our area is a group that we call the Santa Maria Mountains Group.

The land itself is extremely diverse. We sit at the top of two water sheds. The ranch basically straddles the Santa Maria Mountains, the east side of the ranch is at the top of the Verde River Watershed, the west side is the Bill Williams Watershed. We sit, in many respects, on the urban-wilderness fringe. The country to the northwest of us, you can go from our ranch to the Grand Canyon and encounter virtually nothing. There's the small town of Ash Fork and a few small subdivisions out in the grasslands, but it's a really wild piece of country beyond us. Looking the other way toward Prescott, there's an incredible development taking place at a very rapid rate. Two ranches that are neighbors of ours have been purchased and are undergoing subdivision right now. One of those ranches has been in the same family for over 100 years and they actually wrote into the deed restrictions for prohibition of commercial agriculture of any kind. We feel that that makes for neighbors that are probably going to be pre-selected to be not particularly be favorable to the kind of work we're involved in, so we are kind of alarmed at the trend.

BACKGROUND

What we found is that in talking with different people, everybody has certain expectations of the land, and because it is public land, there already is a constituency who see it as a recreational asset or as a place to find solitude or a wilderness experience: two designated wilderness areas are within a horseback ride or a long hike from our home. I will describe some of the polar positions that have helped define the middle ground where we were. On one hand we had very strong "Earth First" contingent folks who were absolutely dedicated to the removal of all cattle grazing from public lands, and for whatever reason Prescott is home to a lot of those folks. They have been very actively involved in the permit removal process with the Forest Service, and even on our ranch prior to the time that we had bought it, there has been incidents where there was a direct confrontation between the Forest Service and Earth First folks. On the other hand the neighboring ranchers essentially are pretty traditional, pretty set in their ways,

[1] Transcribed by Nova Suenaga and Diana Imig, Arizona Nature Conservancy, Tucson AZ.

[2] The Santa Maria Mountains Group, Prescott, AZ.

extremely dedicated. I'll use these descriptors hoping not to offend anybody, but they were kind of in the anti-government movement, the property rights coalition, standing firm, holding solid, "fighting for all that's ours."

FORMATION OF THE SANTA MARIA MOUNTAINS GROUP

I guess in some respects being kind of a generalist I share some of the sympathies of both ends of the spectrum. I felt that if there's any future in ranching on public land in this particular area, we're going to have to bring these two sides together and we're going to do some talking and have some discussion. We became involved in establishing what we call a "Collaborative Management Team." We invited folks that fell across that spectrum from one end to the other. We invited the people that wrote letters to the editor, asked them to give us lists of names and address of people that they felt should be involved in the discussion We invited neighboring ranchers, we contacted folks at Prescott College, Yavapai College, agency people, sportsmen's groups, anyone and everyone that we could conceive could possibly be interested in the land. We met people out on the ranch and asked them if they had any concerns about the future of this piece of land and would they be interested in participating in the process.

We made some ground-rules. We said, first of all, that you come to the meeting representing only yourself and your personal values. You can't come and say you're a representative of a constituency, that you're with the Rocky Mountain Elk Foundation, or Earth First, the Audubon Society or whatever. It doesn't matter what groups you belong to you come representing only yourself and you own values. Secondly, we would sit in a circle, and go around the room initially, and every single person introduced themselves, shared a little bit about their expectations for the process or what they expected from the land, and by that process we began to develop some trust, we put a human face with the enemy. Instead of grouping and boxing people like, "He's damn environmentalist, he's a selfish land-raping rancher," we viewed each person as a human being. Thirdly, we said everything was a potluck. We're going to sit down and eat together, and share the process or whatever happens in the bonding when people share a meal. And lastly after every meeting, we have an ending time for the business portion of the meeting, but the social aspect can go on for hours.

Next, we went through a process to set goals for the land trying to be absolutely as inclusive as possible within a framework that would lead us to some actions on the land. We followed in a very loose, I'll say even liberal interpretation of holistic resource management, and came up with a three part goal. I'm going to go ahead and bore you with sharing the goal mostly in the hope that you can understand where we were coming from. I will tell you that in arriving at the goal it took a long time and it was very frustrating in many respects because some people were intransigent in their positions on certain things. We agreed to work on those areas of agreement first and go outward from there toward the polar positions because we build from that a core of things that all agreed upon. That helped in terms of a conflict resolution.

There are three parts of our goal. First of all is a portion related to the quality of life, to spend time working and playing in a natural setting that provides opportunities for solitude and creativity, enjoy a rural lifestyle characterized by environmental, economic, and social responsibility, diversity of plants and animals, and enough leisure to spend enjoy family activities, cultivate relationships with family and friends of all ages and diverse points of view, experience good health, clean air and water, nutritious food, and enough life energy to deal with strife. You can picture different people's values being apart of this just like a quilt. Pursue life-long learning, personal and spiritual growth, meaningful work, and contribute to our community and environment, share a community characterized by cooperation with, understanding of, and respect for our unique differences whether they be lifestyles, politics, spiritual or cultural values. This is pretty important to some folks.

The forms of production, or the outputs, or the things that the land must provide to support this quality of life are the second part of the goal. We call it management for a healthy and sustainable ecosystem characterized by biodiversity for present and future generations, producing profit from solar energy both directly and indirectly through domestic livestock, cultivated crops, native wildlife and plants, and providing educational, recreational and aesthetic opportunities, and producing abundant clean water and high quality habitat for the benefit of the community. What does the land have to look like in order to support that kind of production? We tried to describe a future landscape which would create and maintain a full range of natural diversity within the grassland, chaparral, pinon-juniper, and ponderosa pine communities, to reduce the amount of bare ground, to reduce the amount of run-off from uplands, and increase the amount of moisture so it can get into the ground. We want to see perennial streams, and a mosaic of mixed grasses, shrubs, and trees. We want to create movement corridors which enhance watershed values, utilize natural materials for buildings and improvements, and maintain large areas of open space. Once we have formulated a goal and agreed that it is something we could all support then looking at what were those areas most in need of attention that would bring us toward fulfillment of the goal.

We identified three areas in particular that would essentially begin the process. I really can't go into a lot of detail about the conditions on the ranch, but the ranch prior to our ownership had very little maintenance. We had a lot of problems that needed adjustment right away. We looked at three areas that jumped out at us right away, feed, water and predation. The feed situation on the ranch is such that the grassland community was in a pretty serious decline, with quite a bit of juniper invasion into areas of the ranch that had been initially grassland, a number of treatments that had been done in the 50s and 60s, chaining and pushing and crushing juniper and chaparral, burning juniper and chaparral. There was evidence where some things had worked, some things hadn't worked, but in many cases the energy cycle, or nutrient cycle on the ranch was bound up in woody material, a lot of bare ground, a lot of active erosion, and relatively poor performance from the cow herd, and even wildlife. We began to look at what we could do from the ranch from the private side of it. There's only a certain amount that we're going to be able to do on our own. We need to reach out and take advantage of some of the other resources that are available. The Santa Maria Mountains Group, which numbers loosely about 150 people, gets about 40 to 50 people at a good meeting. There is a wealth of tremendous creativity that has enabled us to really pull some things together.

ONGOING PROJECTS

Right now we have three major projects that are ongoing on the ranch which address three weaknesses. We have a grant proposal that will address the chaparral component and a problem that we have with shrub live oak on the ranch and its nutrient tie-up. We looked at a number of ways to deal with that problem. The old paradigm was to destroy the scrub oak; we need to remove that and create grassland. Most of those earlier projects failed. Burning, crushing, pushing, and chaining resulted in a return of chaparral after 25 or 30 or 40 years. So we said, well, it may be that in those areas that were grasslands that were invaded we can sustain grassland, but in those areas that are chaparral we're over our heads with it, so what are we going to do.

The University of Arizona, Utah State University, the Forest Service, and the Santa Maria Mountains Group, have collectively written a grant proposal that looks at expanding on some research done in Israel and at Utah State University supplementing cattle or supplementing livestock on high tannin diets with something called polyethylene glycol. Now, I don't know a lot about polyethylene glycol, but I've been told that it lies similar between an alcohol and sugar, it's a carbon chain. It's used in a full range of food products. It's approved by USDA and the Food and Drug Administration. They have what they call food-grade polyethylene glycol. I was fascinated with work done in Israel where they had been feeding sheep and goats and found that with a very tiny amount of this stuff, it was breaking the bond that holds energy and protein, and they got a tremendous amount of livestock response and apparently the polyethylene glycol goes through the animal with no particular effects. That's a little bit skeptical because we're kind of into organic food and clean and natural things, but at the same time I saw this dilemma with oak brush as a serious problem. So we got a full blown project where they're gonna have a research student on the ranch all summer, and they'll be doing this with a small group of cattle and will replicate a similar program that Utah State in a fine situation. And if indeed it works and if indeed it meets the criteria of our goal to be ecologically and environmentally sustainable and responsible, it could be a real breakthrough for people ranching in this chaparral community and we're kind of excited about it.

The second project deals with juniper in grassland, predation and nutrition, because all of these things are linked, but there is another entity in our community called the Juniper Institute. Its members are also members of the Santa Maria Mountains Group and it's goal is to look at the Juniper not as a weed, or as the enemy, but as a resource in something that we can use to create sustainable communities and economies within these communities, so we have a grant proposal and a project put together with the Juniper Institute, we've already had a Ph.D. from Germany who came and has not published a paper looking at the economic uses for juniper in a world market view. Looking at everything from chemical sources, pharmaceuticals, various wood and paper by-products, just every possibility. And that paper is now being edited for publication by the Juniper Institute, the Highland Center which is a nature education program in the Prescott area, the Forest Service, the Santa Maria Mountains Group, the Phoenix Zoo whose animal observation team has begun quarterly monitoring the mountain lion population on the ranch, the Environmental Protection Agency is concerned about some watershed aspects of Juniper woodlands and the fact that we have very active erosion in juniper monocultures and especially in areas where juniper has invaded the grassland, and Arizona Game and Fish is concerned about the habitat implications.

Initially we wanted to do a large burn and open up an area that was adjacent to some open grassland where we have not experienced live predation. It seems as though the politics of getting the burn accomplished are just unbelievable. When we burn we are putting a lot of carbon into the atmosphere rather than into the soil horizon, and so we asked what could we do that would mimic a burn or mimic some benefits of a burn that would not lose this carbon from the energy cycle. So what we proposed was to do a green fuelwood cut of juniper, or a green juniper product cut where we could remove firewood, fence posts, stays, the larger scale usable products and leave the slash on the ground. Then we're going to some seeding and leave some areas not seeded as an experiment, but bring in mulch in the form of cheap, poor quality hay, bring cattle in concentrate them on this cut area by using hay as bait. They will then tramp down the juniper slash, plant the grass seed, prepare the seed bed by pressing mulch into the area, and we've got a couple of small experiments with this on our private land, and we're very pleased with the results. Over about three years, when it rains, we get grass established pretty readily and the first wave includes annuals and weedy types of pioneer species, followed by the establishment of the perennial warm season grasses. We're hoping to see the cool season grasses come in as time goes on.

Our final project is one to establish waters, or re-develop some waters in some areas of the ranch that were being very much under-used because of lack of water, and again, pulling in cooperation from a variety of agencies and entities that, in this case, included the Rocky Mountain Elk Foundation and the Prescott Area Wildlife Habitat Community, and so on, and I guess that the essence of my message is that there is a lot to be done on the land to bring out what we all want from it, and many of the people that are stakeholders but not ranchers can play an active role in bringing about a sustainable situation in our grasslands and in our public lands by working together, cooperating, and by doing what each of us can do individually and collectively.

Grassland Management by the Nature Conservancy

Tom Collazo[1]

The Nature Conservancy, for those of you who don't know, is a national and international non-profit conservation organization whose mission is to preserve plants, animals, and natural communities that represent the diversity of life on earth, by protecting the lands and waters they need to survive. We accomplish this mission in a variety of ways, including land acquisition, cooperative partnerships with public and private land owners, and activities to strengthen the ability of local communities to manage and conserve natural elements. Just as we've heard about ranchers evolving in their perception of what their role is, or their relationship to natural systems, TNC has evolved over the years, initially as an organization that went out and bought lands and set them aside as nature preserves, and I think that as we learn our business, we take a broader ecosystem approach and we realize that we can't, nor should we, own all of the lands necessary to maintain naturally functioning systems such as grasslands.

Our programs in Arizona can be characterized as both intensive and extensive. I think an example of the extensive type of work we do in the field is the sort of thing that Peter Warren, as a Field Representative of TNC, does such as consulting with different groups such as Malpai Borderlands Group or with Forest Service, or with other public and private land owners. This kind of activity could include commenting on land use plans, making nominations for special management area designations, gathering data and providing input to the data management systems that are maintained by the Arizona Game and Fish Department and others as the basis for decision making and ecological management and research projects, again both with public and private land owners around the state.

On the intensive side is the management of areas where we have a direct land ownership interest and a direct management responsibility. We manage a system of nature preserves around the state. We have 12 preserves that include two areas which are primary grassland management areas : Aravaipa Canyon and the Muleshoe Ranch Cooperative Management Area where the Conservancy has played a role by acquiring base property that has been associated with BLM and USFS grazing leases. These are areas which have significant biological resources, where the highest quality biological assets are native fish communities. Aravaipa is distinct in having seven native fish endemic to the southwest. Muleshoe streams support 5 native fish as well as riparian habitats and breeding areas for zone tailed and black hawks and several other riparian dependant species.

We feel that protecting these rare aquatic elements includes the grasslands and watersheds that are an integral part of the systems that maintain the riparian areas. This got us into the grassland management business. I think that what these areas represent in demonstrating the role a non-profit like the Conservancy can play in grassland management is that we are able to work cooperatively with our public land management partners and, as I think you are going to hear later this morning in the case of the planning process we've just wrapped up at Muleshoe Ranch, also involving neighboring land owners and ranchers. We took an approach where the

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[1] Arizona Nature Conservancy, Tucson AZ.

highest value part of the natural system can be incorporated into a planning process and where, because the Conservancy does not have the imperative to turn a profit from livestock grazing operations, we can bring other resources in to improve ecosystem conditions.

Once the ecological conditions and functions are restored and functioning properly, we can then make available forage accessible to other land managers and livestock operators in the larger ecosystems of which these are a part, to leverage protection of the larger ecosystem or the larger watershed by cooperative involvement. This is essentially the grass banking concept pioneered at the Gray Ranch by the Animas Foundation and the Malpai Group. We took a look at it and thought it was a pretty good model. Interestingly enough, while these areas had very high biological values, they also had some pretty heavily impacted rangelands where shrub encroachment was a serious concern.

What we brought to the planning process was our approach which is to try to find ways for the natural ecological process to be used to restore natural grassland community structure. We developed ecological models which try to predict how the different processes of grazing and fire can move the grassland communities from the current condition with a lot of shrub encroachment into the desired future condition where amount and species composition of perennial grasses would be improved and shrub canopy would be reduced. The benefit would be in terms of returning the land to more productive use as well as creating a functioning watershed that would benefit, in the long run, the restoration and long-term maintenance of the riparian communities.

I think our time is getting kind of short, so a couple of other things that I would like to mention, on the extensive side we have a number of voluntary private conservation programs going with different land owners around the state where through conservation easements we can help ranchers achieve their goals of staying on the land, ensuring that grassland landscapes are not subdivided in the future and in some cases providing some necessary cash flow to get rangeland improvement programs going. We also do a lot of work in the area of education and outreach. We work cooperatively with the Arizona-Sonora Desert Museum to produce the Desert Speaks television program where we are able to communicate what's going on -- all the exciting projects you have been hearing about in terms of partnerships and working together to restore fire landscapes. Communicating stories about the need for, and achievements of , a cooperative approach to ecosystem conservation out to a much broader audience around the country so people can understand the issues is another role that we play.

Use of Volunteers In Land Management

Bill Branan[1]

Volunteers can be an important part of a land management strategy. Following is a single example, but there are many I could mention for The Research Ranch and no doubt there are countless other examples on other areas.

The Research Ranch was criss-crossed by about twenty-five miles of fencing just three years ago. In addition, its seventeen-mile perimeter fence was not wildlife friendly -- a fact that became clear one day as my wife and I watched a herd of thirty pronghorns attempt to enter the Research Ranch. Unfortunately, back then our perimeter fence's lowest strand was about six inches above the ground and strung so that the pronghorn had great difficulty getting under or through -- pronghorn are very poor jumpers, thus going over the fence is not really an option for them. Anyway, four antelope got through onto the Research Ranch. The other twenty-six couldn't make it. Then the four couldn't get back out to rejoin the herd. Ultimately the herd split up for the night. We realized that something had to be done.

We contacted the Arizona Antelope Foundation for advice. To make a long story short, we enlisted volunteers to remove most of our interior fences and to upgrade most of our perimeter fences to wildlife standards -- removing the bottom two strands of barbed wire and then adding a new, barbless lower strand twenty inches above the ground. We had ranchers, retirees, attorneys, and the whole spectrum of folks working together to remove and upgrade fences. In fact, volunteers donated over ten miles of the barbless wire. The budget savings has been enormous -- probably more than $20,000. The good will we earned was enormous for the Research Ranch, but also for grasslands in general as so many from so many backgrounds worked together. Currently, we are replacing any wooden perimeter posts with steel posts recycled from interior fences, which will also provide us the ability to institute a burn plan on the Ranch -- burning can be problematic with wooden fence posts. Incidentally, nothing has gone to waste -- the steel interior posts are being moved to the perimeter. The wooden posts are heating several of our buildings -- we measure firewood in miles, not in cords. The old wire was given to a small company that fashions it into decorations, including cowboy hats, boots, pistols, cacti, etc. -- to date the Research Ranch's old wire has been exported to over 30 countries, which makes us about the most international ranch on earth.

Volunteers assist in research -- probably 25 people will participate in our upcoming sparrow round-up, but there are many other opportunities to learn by working with some very knowledgeable and patient scientists. Volunteers also maintain our buildings by creating straw-bale exterior insulation, rewiring, replumbing, repainting, and on and on.

We recruit volunteers mostly by providing guided tours of the Research Ranch, in fact, it's difficult to get onto the Ranch and not receive a tour from my wife. We've learned that the Research Ranch sells itself once folks discover what s happening there.

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[1] National Audubon Society , Appleton-Whittell Research Ranch, Elgin, AZ.

Cascabel Management Committee: A Report to the Grasslands Conference

Dave Harris[1]

BACKGROUND

The Nature Conservancy and the Bureau of Land Management purchased approximately 750 acres of riparian lands along the San Pedro River near the unincorporated community of Cascabel during the years 1991 to 1993. Since 1993 Conservation Easements have been purchased on other tracts bringing the total of protected lands to about 900 acres within the riparian corridor.

Concerns about future uses of the property and the need for a management plan have been raised by TNC, members of the community and cooperators of the Redington Natural Resource Conservation District since at least 1994. In 1995 the Redington NRCD board agreed to convene a committee of interested parties to work with the BLM and TNC to develop a management plan that addresses the needs of the BLM and incorporates the thinking and concerns of the community.

The committee held its first meeting sans BLM in July 1995 to discuss who should be involved, explore the issues of significance to the community and to make decisions about how the planning process should proceed. The participants in this meeting agreed:

Process should be open to those residents of the river corridor, TNC, BLM and other agencies with specific management responsibilities. Issues of particular concern included fire management, flood hazards, fence maintenance, public access, preservation of streamflow, security of BLM lands, and exotic species. The process should take place over a six month time frame, the plan should be concise and try to address the major issues of the community, BLM and TNC.

Since that initial meeting there have been 10 formal meetings and several field trips which involved a variety of community members, NRCD cooperators and TNC representatives. The meetings have been for the most part facilitated by BLM personnel. Costs and the work of carrying out the process have been shared by BLM, TNC and Redington NRCD. Information regarding the process and specific outcomes have been communicated through direct mailings of minutes to participants and to the overall community by publication of minutes in the Redington NRCD newsletter. The BLM was tasked to draft the plan and handle other mandated public involvement processes.

At present the Cascabel Management Committee has completed the planning process and is reviewing and revising the draft plan. The participants view this plan as a working document that will reviewed on an annual basis and revised if necessary. The life of the plan is five years. There is an understanding that funding and implementation of all components of the plan will likely require the involvement of the community, Redington NRCD, TNC, BLM and other agencies.

[1] Arizona Nature Conservancy, Tucson Arizona

ISSUES AND OUTCOMES:

Hydrology

All parties agree that preservation of stream flow and water quality are the number one priority within the planning area. All land use decisions will consider impacts to the hydrological and biological integrity of the San Pedro River.

Fire

- This is an issue of great concern within the community and a great many recommendations were developed in the course of the planning process.. There is a recognition that the areas of high fuel buildup and high fire risk occur mainly on private lands within the community. The Nature Conservancy and BLM have offered to provide expertise and recommendations regarding fire management issues but the community is divided on how best to resolve fire threats to private lands. The BLM fire policy for its own property is immediate and complete suppression of all wildfires.

Access And Recreation

- Access will be by non-motorized means only through two access points that have been specified by the community. Parking at access points will be developed to accommodate a few ears and will include gates so that the access areas can be closed as needed. Foot trails may be developed to guide visitors to the river. Overnight camping is not allowed. Hunting will be allowed but information will be made available to hunters that describe the locations of dwellings and property lines. Signage related to hunting will be provided under programs of Arizona Game and Fish Department. Plinking or target practice is not allowed.

Sanitation

- Litter control will be addressed on a site-specific basis but trash cans will not be provided to discourage trash accumulation and wildcat dumping at access points.
- Sanitary facilities will be provided at parking areas to avoid sanitation risks.

Boundary Fencing

- Old internal fencing within the BLM properties will be removed.
- Perimeter fencing will be repaired or replaced as necessary and signage installed to delineate private and public lands boundaries. Fencing materials will supplied to adjacent private land owners for maintenance of fences.

Land Management And Stewardship

- The formation of a voluntary "friends" group is desirable and will be encouraged to assist the BLM in the management of the public lands.

Vegetation And Wildlife

- Vegetative and wildlife biological diversity are important ecological values and should be considered in all land management planning issues and resolutions.
- Exotic vegetative species are a concern to all parties and their control will be sought through a variety of methods as this plan is implemented.

Livestock Grazing

- The public lands within the riparian floodplain will not be grazed to allow riparian regeneration to occur at the most rapid rate. The Cascabel community is exploring the possibility of developing a "Cascabel Commons" grazing plan on private property to lessen fuel loading and achieve economic benefit to livestock operators. The community is divided over the place of this concept within this public lands management plan.

Process Considerations

Many of the participants were veterans of the San Pedro River Coordinated Resource Management Planning Process and this experience has played a role in the acceptability of certain concepts. A strict consensus process was rejected by the group in favor of a limited consensus process that relies on the BLM to play the role of referee in contested issues. Likewise there was some concern that the process be "open, but not too open" to prevent uninvested parties from unduly influencing the process or outcomes strongly supported by the community.

Certain issues that transcended the purely public lands management charge such as fire management and grazing have become controversial and their inclusion is not favored by all members of the community. While no decisions have been finalized it is likely these issues will not be addressed in the final plan but will be transferred to some other arena for further discussion and resolution by appropriate sectors of the community.

In general the basic issues of concern to the community, TNC, and BLM surrounding the public lands have been discussed and addressed in a reasonable fashion that can be accepted by all the participants.

Grasslands Management on Public Lands: Panel Discussion

Jeanne Wade[2], Moderator[3]

I'm Jeanne Wade and I'm a District Ranger at Sierra Vista Ranger District on the Coronado. Someone said something that was very noteworthy in light of today's session as well as our life-long journeys: We need to celebrate our successes. What I find is that we don't do enough of that. Today's an effort to do a little bit of that. We need to feel good about things we accomplish and share that with others. I find that we're generally timid about that. In fact, when I heard Bill McDonald speak this morning about just scratching the surface of successes that related to the Malpais effort, which some people would deem as highly successful, I found that really interesting. What we tend to do as far as success goes is to measure it in the long-term, the final outcome, and we fail to acknowledge that there are incremental steps that go on that are in effect successful and we sometimes even fail to acknowledge that to ourselves and others. Today we want to acknowledge some of those incremental steps and successes on the way to successful grassland management strategies.

The University of Michigan just recently conducted a study on ecosystem management, which is sort of a broad term—management as it relates to resource management. It's an assessment of the current experience and it describes successes of projects all over the country. There are over 104 examples, including the borderland Malpais effort. They describe success in the participants' own terms. Successes were outlined as specific positive outcomes. There were twelve of them and I'll talk about the top five that were articulated in this research that was conducted by Steven Yaffey as well as many graduate students, including Paul Hardy who's with the TNC now in the San Pedro area. The first one, of which 74 of the respondents commented that it was a positive outcome, was improved communication and cooperation as a success measure. That involved federal agencies, local and state government, nonprofit, private land owners, the business community, and within agencies and organizations within themselves. Development of management plans was something that would articulate mutual goals and strategies for multiple stakeholders. 62% felt that that was a huge measure of success. Development of decision-making structures. 56% felt the creation of partnerships, committees, some sort of task force, that was collaborative in nature and transcended agencies and businesses was an important measure of success. Sometimes they could be very loosely formed, but some sort of structure that was coordinating the efforts that were going on. For 50% of the people a change in the approach to land management is really an important measure of success. People felt that that change was a shift in emphasis from a singular focus to something more broad, more multiple. It could be multiple species instead of single species or multiple issues. The fifth one was on-going restoration activities, such as restoration of the bioregime or re-introduction of native plants and animals. What's interesting to me is that much of the early success has been measured in process, not necessarily outcomes. I thought this was worth mentioning at the start of this panel because I think there is a lot of success in the process and I think it's been demonstrated nationally as well as locally. The examples that you're going to hear about today exemplify that.

The time we have will be split between two examples of that kind of success: the Muleshoe Ecosystem Management Plan and the Empire-Cienega Conservation Area.

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[2] Coronado National Forest, Sierra Vista AZ.

[3] Summarized by Jennifer Ruyle, Coronado National Forest, Tucson AZ.

The Muleshoe Cooperative Management Area

Grant Drennen[1] and Ed Brunson[2]

BACKGROUND

The Muleshoe Cooperative Management Area (CMA) is located in the Galiuro Mountains in southeastern Arizona within northern Cochise County and southern Graham County. The CMA is jointly managed by the Bureau of Land Management (BLM), Forest Service (FS), and The Nature Conservancy (TNC). The 57,500 acres comprise major portions of the Redfield, Hot Springs, and Cherry Springs watersheds. Included within the CMA are the Redfield Canyon Wilderness and Hot Springs Watershed Area of Critical Environmental Concern (ACEC), administered by the BLM, and a portion of the Galiuro Wilderness, administered by the FS.

In 1982, TNC purchased the Muleshoe Ranch and its grazing leases to protect and manage its riparian areas and associated aquatic, plant, and animal communities. A land exchange in 1986 allowed the BLM to acquire the state lands of the Muleshoe. The Muleshoe CMA was established through the signing of a Cooperative Management Agreement by the BLM, FS and TNC in 1988. The FS Galiuro Wilderness was originally designated by Congress in 1964 and was enlarged in 1984. The Redfield Canyon Wilderness was designated by Congress in November 1990. The Hot Springs Watershed ACEC was designated through the Safford Resource Management Plan in 1994 in order to provide special management for the significant riparian resources in the Hot Springs watershed.

Historically, the ecological sites on the Muleshoe were producing near their natural potential. The aspect of the rangeland was an open grassland dominated by perennial grasses such as plains lovegrass, cane beardgrass, black grama, slender grama, sprucetop grama, bush muhly, curly mesquite, vine mesquite and several threeawn species intermixed with leaf succulents including beargrass and amole (NRCS range site guides). However, partial or extensive invasion of mesquite, juniper, whitethorn, Mormon tea, mimosa, snakeweed, and burroweed has occurred over much of the area. Intense grazing pressure and wildfire suppression over the past century have resulted in the transition of much of the area from grassland to a desert shrub vegetative state. Continuous yearlong livestock grazing prior to The Nature Conservancy's acquisition of the ranch resulted in a reduction of some of the desirable perennial grasses (such as plains lovegrass and cane beardgrass) and an increase of invasive shrubs (such as mesquite and whitethorn) and succulents such as amole.

ECOSYSTEM PLANNING

The Bureau of Land Management (BLM) brought together an interdisciplinary team of resources specialists from the BLM, Arizona Game and Fish Department (AGFD), FS, TNC, Soza Mesa Ranch, Saguaro-Juniper Association, and Bayless and Bucketed Company to prepare a plan for the Muleshoe Ecosystem. The team members owned or managed land or resources within or adjacent to the Muleshoe Ecosystem and shared the common goal of restoring and enhancing the resources and ecological processes of the Muleshoe Ecosystem through cooperative effort. A draft plan was released in October 1996.

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[1] Bureau of Land Management, Tucson Field Office, Tucson AZ.

[2] Aravaipa/Muleshoe Preserves, The Nature Conservancy, Arizona Chapter, Aravaipa AZ.

The planning process included scoping for issues; analyzing resource information to develop specific, measurable objectives; prescribing management actions to meet objectives and solve issues; designing monitoring to measure success in achieving objectives; and evaluations which provide for the plan to be updated and improved on as new data or issues are brought up.

The major goal of the Muleshoe Ecosystem Management Plan is to restore natural processes. There are six primary objectives for upland vegetation, riparian vegetation, fish and wildlife, cultural resources, wilderness management, and social environment. Prescribed fire and rest from grazing are the primary actions to restore grasslands and riparian areas; Restoration of grasslands will benefit watershed condition and function which will in turn benefit riparian condition and function and the fish and wildlife species that live in these habitats.

PRESCRIBED FIRE PROGRAM

Inventories conducted by TNC and BLM showed that fire suppression and over-grazing had left the land with undesirable vegetation conditions. The vegetation communities, including riparian, shrubland and grassland were all below potential. Since 1990, TNC has conducted one or more prescribed burns each year with the exception of 1994 and has been monitoring their effects; these burns ranged from 20 to 300 acres in size. Monitoring results indicate that fire has been effective in reducing shrubs and in promoting new growth of grasses. In 1995, the first large scale burn was conducted on the Muleshoe in the watershed for Wildcat Canyon. The 2300 acre burn was a cooperative effort with TNC and BLM. The Muleshoe Ecosystem Management Plan proposes an expanded prescribed fire program. The plan designates 15 fire units which would each be burned on a 5-10 year cycle until the desired ecological state is reached. Three to six units on average would be burned annually. For the first five years, no more than 20% of the total acreage within all burn blocks will be treated with prescribed fire. After desired ecological states are achieved, the plan proposes to have less-frequent burns, preferably through prescribed natural fire, to maintain the desired states. The ultimate goal of the prescribed fire program is to restore fire as a natural process within the ecosystem.

CONCLUSION

A major purpose of acquisition and management of the Muleshoe is the protection and restoration of native grasslands and riparian systems. The key to successes so far has been the help of dedicated people who want to protect and restore the area. Focusing on common ground has helped to reduce conflicts and keep plans and projects going. The Muleshoe Ecosystem Plan is a product of such a partnership approach.

The Empire-Cienega Resource Conservation Area

Karen M.Simms[3], Mac Donaldson[4], and Joe Sacco[5]

INTRODUCTION

The Empire-Cienega Resource Conservation Area (RCA) is located approximately 50 miles southeast of Tucson and just north of Sonoita, in southern Pima and northern Santa Cruz counties, Arizona. The RCA is situated in a basin between the Santa Rita and the Whetstone mountains at elevations ranging from 3300 to 4900 feet. Annual rainfall is quite variable but averages 15 inches. Temperatures may vary from highs near 100 degrees F in summer to lows below 29 degrees F. The vegetation is predominately Chihuahuan semidesert grassland. These semidesert grasslands are perennial grass-shrub dominated rangelands positioned between the Chihuahuan Desertscrub type below and the Madrean Evergreen Woodlands above.

Just over 36,000 acres of public land within the RCA were acquired by the Bureau of Land Management (BLM) in 1988 through a private land exchange with Anamax Mining Company. BLM traded scattered urban parcels near Phoenix for these high resource value lands. Grazing leases on an additional 37,000 acres of State Land came with the private lands. Additional exchanges have brought the public lands within the RCA to just over 45,000 acres. There were several driving forces behind the land exchange. A major one was the threat of development. In the 1960's, a master plan was developed for the Empire-Cienega by Gulf America Corporation. If implemented, over 40,000 homes would have been built on the properties. Associated with this threat were Pima County's concerns about the potential loss of urban space near a growing metropolitan area, with aquifer recharge, and with the potential of flooding into Tucson if the area was developed. Another major factor was the high resource values of the Empire-Cienega.

RESOURCES

The Bureau of Land Management's purpose in acquiring the ranches was to preserve and enhance the high resource values. These values include a critical watershed which is important to Tucson for flood control and aquifer recharge, a Federal Register historic site, endangered species, extensive riparian areas, broad expanses of native grasslands, outstanding wildlife habitat, scenic open space and high potential for dispersed recreation.

The Empire-Cienega has a long and colorful history. The Cienega Valley has been inhabited by humans for approximately 5000 years. Evidence has been found for the Archaic, Ceramic, Protohistoric, and Historic periods of occupation along portions of Cienega Creek and its tributaries. The more recent history of the Empire Ranch dates to the early 1870's when Walter Vail acquired a small ranch which he added to over several decades until it encompassed over 1000 square miles. Vail added on to the original 4 room adobe house to eventually build a sprawling 23 room ranch house. The house is now on the National Register of Historic Places.

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[3] Bureau of Land Management, Tucson Field Office
[4] Empire-Cienega Ranch Allotment
[5] Arizona Game and Fish Department, Region 5

Cienega Creek dissects the broad alluvial valley between the Santa Rita and Whetstone mountains as it flows north. Cienega Creek and its tributaries support over 20 miles of riparian area including cottonwood-willow and rare cienega (marsh) plant communities (Hendrickson and Minckley 1984). The riparian zones are of great importance to many wildlife species which are obligate or show a strong preference for riparian vegetation and surface water. Three native fish inhabit Cienega Creek including the endangered Gila topminnow. Several other special status wildlife species including the Chiricahua leopard frog also depend on the riparian areas in Cienega Creek. Riparian areas create havens and provide food and water sources for migrating birds and other animals making seasonal or daily movements.

The Chihuahuan semidesert grassland is the most prevalent plant community in the area and generally occurs between 3600 and 4600 feet. Characteristic perennial grass species include black grama, sideoats grama, plains lovegrass, cane beardgrass, three-awns, curly mesquite, and big sacaton. These grasses are intermixed with various succulents such as yuccas, agaves, beargrass and sotols. Shrubs such as burroweed, whitethorn acacia, mormon tea, and wolfberry occur in varying densities. In some areas along Cienega Creek mesquite has invaded into the grassland type. Almost pure stands of big sacaton occur on the level floodplains, low stream terraces, and first and second order tributaries of Cienega Creek. These sacaton stands have also become a rare plant community (Humphrey 1958, Bahre 1991).

These diverse, native grasslands support a variety of wildlife including a reintroduced herd of pronghorn antelope and several other big game species. The endangered lesser long-nosed bat feeds on agave in the grasslands. A variety of bird species including northern harrier, Mearn's quail, Baird's, Botteri's and grasshopper sparrows also depend on the grasslands.

The grasslands provide forage for a successful livestock operation and support a variety of dispersed recreation activities such as camping, hunting, horse-back riding, mountain biking, wildlife viewing, and even hang-gliding. Competitive recreation events have included bird-dog field trials, mountain bike races, and mountain man rendezvous. Several research projects are on-going. Commercial uses include filming of movies and leasing of utility rights-of-ways.

Livestock Management

The Donaldson's management philosophy for livestock grazing on the Empire-Cienega is based on one herd of mother cows, moving through a series of flexible pasture rotations as the seasons progress. The one herd concept is used to maximize rest in all other non-grazed units and to better utilize the different species of grasses. Multiple selection of species is possible and regrazing of specific species is kept to a minimum. The husbandry of the cattle becomes more efficient due to their concentration. The ranch is divided into "Units of Useability", which are variable size units of rangeland that will support the base herd for a certain period of time during a certain time of the year. The units are tied to "primary" water sources. The units are determined and affected by location and quality of water sources, topography, fencing, rainfall patterns and amounts, vegetative composition , salt and mineral use, and wildfire. The key to this management approach is to have a variety of options available for any planned grazing rotations, and to be able to quickly change from the plan when range conditions or livestock needs are different than anticipated (Empire-Cienega Ranch Interim Livestock Management Plan, 1995, BLM, Tucson Field Office files).

A "Biological Planning" process is being used to determine planned livestock management actions. This planning is conducted in February (prior to the spring growing season) and September (following the monsoon rains). The Units of Useability are evaluated for their suitability for livestock use during the upcoming pasture rotations. A proposed rotation strategy is developed based on the animals physiological needs and the condition of the vegetative resource. The proposed rotation is charted on graphs. This strategy is then presented to the biological planning team to identify and resolve any conflicts with other resource uses or objectives. This team is composed of a diverse mix of resource specialists, agency representatives, wildlife managers, University of Arizona professors, neighboring land users, environmentalists, and other interested publics.

The team discusses the biological plan, visits both grazed and proposed grazing units, assesses the condition of the resource, and makes any necessary changes to the proposed plan. If consensus cannot be reached the BLM Field Manager makes final decisions. Once the biological planning has been completed and the upcoming grazing rotations scheduled, the livestock graze the particular unit of useability selected until monitoring of forage utilization levels and animal performance indicate the need to proceed to the next unit in the rotation. Desired levels of utilization may vary based on the "key" forage species selected, plant phenology, time of the year, current condition of the unit, and intensity of past grazing use of the unit. Generally utilization of key forage species will not be allowed to exceed an average of 40% of the current years production.

Land Use Planning

The Bureau of Land Management (BLM) has initiated long-term land use planning to guide management of the 45,000 acres of public land within the Empire-Cienega RCA. The BLM is striving to increase and improve public involvement in planning and management activities on public lands through community outreach, education, and the formation of partnerships with various organizations to balance the needs of people and resources. These concepts are reflected in the new approach that BLM is taking for planning on the Empire-Cienega. The approach involves greater public participation in all aspects of planning as well as improved communication and coordination with surrounding landowners both private and public. A community partnership has been initiated to chart the future management of these lands. The partnership is completely open and includes all individuals, organizations, groups, and government entities interested in participating in development of the future of this area. Working groups have raised a variety of issues related to public lands in the Sonoita Valley. They are generating goals and specific, measurable resource objectives and will be developing management recommendations to achieve the objectives and solve the issues. They will provide input on monitoring design and on an evaluation process which provides for the plan to be updated and improved on as new data or issues are brought up.

There are many potential conflicts between the variety of uses of these grasslands including livestock, wildlife, and recreation. Increasingly, the area around the Empire-Cienega is becoming popular for ranchettes and Sonoita is growing. This interface between public and private property also creates the potential for conflicts such as fire management of grasslands. Our panel today presents perspectives on some of the strategies we're using for maintaining the grasslands and managing them for a variety of uses.

Karen Simms, Ecosystem Planner and Wildlife Biologist, BLM:

Ongoing planning and management activities on the Empire-Cienega Resource Conservation Area illustrate several successful public land management strategies:

1). Land Exchanges: The BLM has completed several land exchanges where parcels with low resource values and relatively high development value have been exchanged for high resource value lands in more rural areas. Through this process, the BLM has been able to block up public lands in manageable units and large areas of open space, such as grasslands on the Empire-Cienega, and associated resources have been protected from development. At the same time, scattered tracts near urban areas which are difficult to manage effectively and have low resource values have been disposed of.

2). An endangered species success story: On the Empire-Cienega, we have grassland and riparian habitats which support 3 endangered species (a fish, bat, and plant). We also have a successful grazing operation. Many of the conflicts that we read about in the newspaper have been avoided by working together, sharing diverse views, and recognizing that having a healthy resource base benefits everyone. An example:

Biological planning meetings are held twice a year on the Empire-Cienega as part of the grazing plan. These allow diverse interests to have input into the upcoming pasture rotation and other aspects of the grazing operation and provide an opportunity to look at resource conditions on the ground. This open communication builds trust and reduces conflicts. As an example, it has allowed the grazing operation to be adjusted to provide fawning cover for antelope at the appropriate time and to protect habitat for the endangered fish.

3). The Sonoita Valley Planning Partnership (SVPP). The SVPP is a volunteer gathering of agencies (federal, state, and local), organized groups and interested public who share a common interest in the future of public land resources in the Sonoita Valley. It developed from the need of the BLM to prepare a management plan for the Empire-Cienega. Two working groups (natural resources and people) meet monthly. The groups have raised issues and helped develop goals and objectives for the public lands. They have provided input into several BLM and USFS proposals and will be working on recommendations for management actions.

There are several factors which have contributed to the success of these strategies. The first is increased communication on a variety of levels. Communication has included education on scientific and technical topics, sharing diverse views, and finding common ground. The second is the opportunity to have a greater level of participation in planning for and managing public lands by being directly involved in preparing a plan and implementing projects. The third is the emphasis on partnerships which allows the agency to accomplish a great deal even with limited resources. These partnerships, although implemented at the local level, result in a blending of national and local level issues and priorities.

Mac Donaldson, Rancher, Empire-Cienega Allotment:

Management of grazing and problems with resources, land, and grass:

- Rest is vital to restore/maintain land.
- 30% fluctuation in livestock numbers is used as dictated by resource conditions.
- Success of grazing strategies under management by Donaldsons for past 20 years and combined with BLM management for past 8 years measured by:
    - expanding springs and increased length of perennial water in streams
    - increases in native grasses, e.g. Plains lovegrass
    - erosion control with grass, grass filling in gullies.
    - T& E species--have seen increase of quality of habitat (grass and streams) and species

Coordination

- Twice each year, the BLM, ranchers, biologists from Arizona Game and Fish and U.S. Fish and Wildlife Service, and other interested agency representatives and public get together out on the ground. They review the grazing plan for the next 6 months, identify potential conflicts and resolve them, and visit areas of concern on the ranch. Biological planning team involvement is instrumental for improvement of resources and success of grazing operation. Communication has helped create trust with outside groups and reduced conflicts with natural resource groups.
- Sonoita Valley Planning--vision is to protect values of rural lifestyles and open space associated with grasslands, forest and wildlife. Groups are vocal-maybe not educated in natural resources but we can educate people to use and care for this region.
- From a rancher's point of view to work "with" agencies and interested public is much more productive than being in conflict.
- Bottom line: Healthy resources mean healthy cattle and business.

Joe Sacco, Wildlife Manager, Arizona Game and Fish Department:

Several positive results from both biological planning and Sonoita Valley Planning Partnership approaches:

- Decrease of conflict with natural resource groups. Biological planning working with diverse interests to implement ideas and management, Sonoita planning--generating community support in what is to occur;
- People recognizing how they effect wildlife.
- Good to see different perspectives of diverse groups and users.
- Educating the public to work together to accomplish success.

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Grassland Management on Tribal Lands: a Panel Discussion[1]

Gary Nabhan[2], Moderator

Gary Nabhan opened the session with comments on the importance of having two-way conversations among tribal people and others and pointing out that it used to be just "white men" telling people how to do it the white man's way. Therefore, he invited information from representatives present from the Tohono O'odham Nation, Navajo Nation, and the San Carlos Apache Tribe.

GRAZING MANAGEMENT ON THE TOHONO O'ODHAM NATION

Homer Marks and Erwin Juan spoke about management of grasslands on the 2.8 million acre Tohono O'odham Nation. The area is divided into eleven districts, each with its own management style and problems. Governing Councils make many decisions in a democratic fashion and in most areas activities such as round-ups are handled collectively. While some areas are fenced, many areas are not. The presence of highways, where lands are usually fenced may complicate management. The association owns the cattle and all have one association brand, but individuals run their own herds and have a second individual brand. The association rounds up cattle, taking 10% of the proceeds for upkeep of the area. They also round up wild horses. Homer Marks described management in the 293,000 acre district where he lives. There is no association and most decisions are made by consensus. The process is quite democratic and everyone has a voice. Although he is a "small owner" he is the President of his district for a two year term. The "big owner" is "just one of the guys." His district is working toward better management and trying the HRM method, but more fences are needed.

There are real management differences between the "old days" and the present, especially response to drought, which occurs about once each decade. In the old days, people kept cattle and let them die of starvation. Now they prepare for drought and reduce cattle numbers where appropriate. Problems arise when many cattle are placed on the market at once and the prices plummet. The association attempts to save money for drought periods.

Erwin Juan spoke about his 9,000 acre district which is divided into fenced off areas. Highway 86 cuts the district in half and is a conduit for the exotic lovegrass. His district is a little higher than the one Marks described and gets a little more rainfall, so conditions are different. Herefords used to be the main breed, but now they are cross-breeding for leaner meat for today's market.

In some areas the mesquite and acacia are so thick you can't ride a horse through, although cattle can get through. They have tried to eliminate mesquite by chaining to stimulate grass production, but found that sometimes it just stimulated tree growth. They have tried to break areas down into smaller pastures, but found that sometimes that just made it possible for more catclaw acacia to grow. They are also trying prescribed burns, but that is not allowed near Kitt Peak.

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[1] Summarized by Barbara Tellman, Water Resources Research Center, University of Arizona, Tucson AZ.

[2] Arizona-Sonora Desert Museum, Tucson AZ.

The association is trying to educate people on better management of the land, especially young people who are more responsive to new ideas than the older people are. Two or three families own most of the cattle and there is a need to work together.

MANAGEMENT ON THE NAVAJO NATION

Elsie Nez described conditions and problems on the Navajo-Hopi partitioned lands area where she works for the Bureau of Indian Affairs. The Hopi lands are surrounded by Navajo lands, divided into three districts. She manages one of 468,000 acres. When the lands were partitioned, an inventory was done of people, sheep, cattle, goats, horses, etc. Most of the Navajo area is open range with no regulations. The Hopi lands are fenced off and have regulations. Throughout the Navajo Nation each district is different and one chapter may have several different associations dealing with grazing matters. Bureau of Indian Affairs pretty much operates in a "hands-off" manner, with the associations and chapters being independent.

It is very difficult to manage grazing and most of the area is in really poor condition. Some of the worst depletion has been in the past ten years. They are trying to get people to reduce their livestock numbers voluntarily, but without great success. Regulations are being held up by politics and BIA has little money for management. BIA maintains windmills and fences, but is mostly into education and persuasion. There are many project in the planning stage, such as earth dams and erosion control measures, but everyone is just waiting for regulations to be accepted by the Navajo Nation and the federal government.

MANAGEMENT ON SAN CARLOS LANDS

Teresa Goseyon talked about problems on the San Carlos Apache lands, which are very different from either the first two areas discussed. The lands range from desert to high mountain alpine conditions and are divided by mountain ranges. There are seven major cattle ranches, all with Herefords. Five associations govern the areas with elected boards. Each ranch has its own brand. Cattle can't be moved from desert to mountains during drought periods because of ranch boundaries. Politics plays a big role in decision making. The "big owners" have a great deal of power and the "little guys" have little say.

Traditionally, all the cattle have been Herefords, genetically bred for that environment. Some recent attempts at cross-breeding have not been too successful because the biggest ranch owners don't want change. San Carlos Apaches have been very successful in rodeos, training on the local cattle in the mesquite-juniper lands.

The recent drought hit the area pretty badly and there were few backup resources. One major problem was in transporting water from San Carlos Lake to the cattle. The water is owned by the San Carlos Irrigation Project (Anglo, not the tribe). Only the top 18" of water in the lake belong to the tribe. Laws to protect fish may help the tribe since the Project may have to close the dam gates to protect the fish. This was one of the few times that the tribe appreciated environmental laws.

SOIL CONSERVATION AND WATER DISTRICTS

Kristin Egen, representing the Natural Resources Conservation Service, described the role of Soil and Water Conservation Districts which occur on all Indian lands except the White Mountain Apache Tribe. The Southwestern Indian Association is attempting to coordinate dialogues among tribes to discuss farming, grazing and other issues, so that tribes can learn from each other and improve their methods.

Tohono O'odham Tribal Herd Ranch

Erwin Juan[1]

The Tohono O'odham Tribal Herd Ranch is located about 40 miles west of Tucson, Arizona in the Upper Sonoran Desert Shrub resource area. The ranch is approximately 20,000 acres with 21 paddocks for the grazing rotation. The ranch is a cow/calf operation with Barzona/Hereford crosses.

The Tribal Herd was established in 1933-34 by the Bureau of Indian Affairs (BIA). Then it was known as the Papago Tribal Herd. Primarily it was started as a demonstration project to show the accepted methods of proper animal husbandry, geared to the O'odham stockmen. The Herd Ranch also had a bull rental program available for ranchers wishing to upgrade their herds through breeding bulls or replacement heifers. The bull rental program was phased out in 1985, but the replacement heifer program is still in place today. The only difference is that now the stockbulls are sold to the individuals to be used at their discretion and then disposed of at no loss to the tribe.

The Tribal Herd Ranch still utilized the services that are offered by the Branch of Natural Resources formerly the Land Operations of the BIA. Technical assistance is provided by the USDA Natural Resources Conservation Service with monitoring transects to measure forage use and species changes over time.

Grasses and Livestock on Native American Lands

Homer Marks[1]

The Tohono O'odham-Nation is the second largest reservation in Arizona, with 2.8 million acres plus divided into 11 districts. The problems encountered within the boundaries of the Nation, in reference to the livestock business are many, but to me the one main thing is .. .management. Without proper management of our land and its resources our livestock, wildlife, and all other things dependent on these resources will suffer. The type of management needed at this point is different to the O'odham and therefore resistance will be encountered. Traditional management of livestock is still being applied on our Nation's lands, but times have changed and the O'odham ranchers need to change also. A change in the type of management being applied on the Nation's lands is needed. With the decline in numbers of cowboys, we as livestock owners need to re-evaluate our mental outlook as far as the livestock business is concerned. As time goes on the older generation of cowboys is dwindling and new breed of livestock owners is coming in with a different outlook on life.

The time is right to try new approaches and methods of range management. Different areas of our Nation's lands have applied newer forms of management such as Holistic Resource Management or Rotational Grazing and it has improved their land as well as their resources. Even now, other ranchers are trying new methods and approaches to proper range management and the upcoming years will see a positive direction for the livestock owners on the Tohono O'odham Nation.

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[1] Tohono O'odham Nation, Sells AZ.

Chapter IV
Seeking Solutions to Grassland Problems

A wide range of possible ways of dealing with the threats to grasslands was presented in a series of panels. New techniques in grazing management were discussed by Karl Hess and three ranchers from New Mexico and Arizona, in a session chaired by Diana Hadley. Ron Tiller chaired two panels on grassland restoration. Papers from these sessions and summaries of some of the talks are supplemented by poster presentations. Nontraditional uses of grasslands were the subject of a panel led by Nathan Sayre from which summaries are presented. A session moderated by Thea Uhlen included a paper by Bonnie Colby on the economic benefits of preserving open space and open space issues in Cochise County, Arizona. A panel on planning and zoning led by David Yetman looked at land use planning as a management tool, and panels led by Doug Koppinger and Luther Propst looked at alternatives available to private landowners for preserving their land - including conservation easements and land trusts. Cooperative partnerships were discussed in a panel led by Ann Moote with case studies of successful partnerships offered by a private rancher, a non-profit group representative, and a Bureau of Land Management representative. The technique of conflict resolution was presented in the form of a simulation in which people played roles in dealing with a fictional grassland conflict. This session was run by Kirk Emerson and the Udall Center for Public Policy.

Innovations in Grazing Management

Grassland Restoration

Breaking the Mold: A New Approach to Range Reform

Karl Hess, Jr.[1]

ABSTRACT

Public rangeland policy is failing for fiscal, ecological and equity reasons. Federal agency grazing programs are plagued by deep deficits, range conditions are unsatisfactory in many areas, and range resources are not equitably distributed. A new policy approach is needed—a market-driven one that shifts costs to range users, protects range resources, and ensures equal opportunity to all. Under such an approach, existing grazing permits would be grandfathered-in as 30-year (or more) public land leases and would be fully marketable for uses and users that include but are not limited to ranching and ranchers. Prescriptive management of public rangelands would be replaced by outcome-based management. Lease holders would enjoy broad managerial discretion within the bounds set by localized standards. Elected resource councils would give policy direction to land agencies and set local standards. Bio-Diversity Trust Funds, financed from public land revenues and distributed by resource councils, would be used to protect non-market amenities.

RANGELAND POLICY: AN HISTORICAL OVERVIEW

Since the turn of the century, three issues have set the theme, pace and direction of debate for public rangeland policy. Those issues are:

1) the **fiscal state** of public rangelands;
2) the **ecological condition** of public rangelands; and
3) the **degree of equity** in the allocation of public rangeland costs and benefits.

Fiscal State of Public Rangelands[2]

Grazing fees were first assessed on public lands in 1906 by the U. S. Forest Service for the purpose of covering the administrative costs of livestock grazing. Over the years, controversy has arisen regarding 1) the comparability of public land grazing fees to private land lease rates and 2)

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[1] Karl Hess, Thoreau Institute (Portland OR), rangeland ecologist and environmental writer Las Cruces, NM.

[2] As applied in this paper, the terms "public rangelands" and "public lands" refer to both BLM and Forest Service lands.

the extent to which fee revenues do or do not cover government administrative costs.

The GAO concluded in 1991 that the current fee formula significantly understates the market value of grazing on public lands.[3] In contrast, economists at several western universities believe that the same formula "capture[s] the market value of the [public] forage if the rancher's investment in the grazing permit is recognized."[4]

Both arguments are true. The GAO is correct: the current grazing fee does not return revenues to the U.S. Treasury commensurate with private land lease rates. Also, fees have not kept pace with inflation. The 1980 fee, when inflation adjusted, is 300% greater than the 1996 fee. Economists, too, are correct: below-market grazing fees are capitalized into the value of grazing permits. The real fee paid by ranchers is the formula fee plus the cost of interest on capital invested in the permit.

Taxpayers, of course, collect only the portion of the value of public land grazing that is set by the formula fee (minus the 50 percent of fee revenues returned, by law, to ranchers in the form of range improvements). The greater residual value, the capitalized "subsidy" so to speak, goes elsewhere. It is traded among ranchers, sold initially as windfall profit and then paid for as a routine cost of ranch operations.

The grazing fee problem entails more than a public shortfall in revenue, though. Even if taxpayers captured the full market value of public land forage, the grazing programs of the Bureau of Land Management (BLM) and the U.S. Forest Service would still be selling grass at below taxpayer cost. Official agency figures put the combined public land grazing deficit at almost $100 million per year.[5] That figure, however, likely understates the true deficit and the true cost of the federal grazing programs. Data from the Office of Policy Analysis in the U. S. Department of the Interior, for example, place the actual BLM grazing deficit at or above $200 million annually.[6] Assuming the Forest Service deficit is similarly understated, the real taxpayer tab for public land grazing may be as much as $400 million each year.

Higher grazing fees, even if elevated to full market value, will not substantially reduce the current public land grazing deficit. Instead, federal costs must be reduced.

Ecological Condition of Public Rangelands

Questions of rangeland health cast the darkest cloud over the public land grazing programs of the BLM and the Forest Service. Data collected since 1935 show only moderate improvement in rangeland ecological condition. Moreover, most of that improvement comes from ending the pre-1935 open range, not from intensive federal management and vast, taxpayer-financed range reclamation and restoration projects. If anything, a long history of prescriptive management by the federal land agencies in conjunction with disincentive-laden public policies and federally-subsidized rangeland projects have fostered and deepened degradation of arid public lands.

Regulatory factors, such as the federal grazing permit system, its formalization of overstocking, its politicization of grazing management, and its institutionalization of market failure, have made

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[3] General Accounting Office, "Rangeland Management: Current Formula Keeps Grazing Fees Low," June 1991.

[4] E.T. Bartlett d al., The Market Value of Public Land Grazing: Implications for Grazing Fee Policy," in Current Issues in Rangeland Economics (Moscow: University of Idaho, 1994), p. 91.

[5] "Reforming the Western Range," Different Drummer 1:2 (Spring 1994) P 39.

[6] Robert Nelson, "An Analysis of Revenues and Costs of Public Land Management by the Interior Department in 13 Western States Update, Office of Policy Analysis, U.S.D.I, September 1982. Nelson later revised and updated the report's finding to 1995.

poor grazing practices a predictable outcome on public rangelands. The stewardship disincentives inherent in small and community grazing allotments and the managerial disincentives implicit in regulatory prohibitions on grazing non use add to the problem. Further, a long history of intensive federal range improvement projects, rising permit tee indebtedness, emergency feed allocations, range betterment funds, subsidized experimental stewardship programs, government technical support services, and taxpayer-supported animal, insect, and brush control have perpetuated and rewarded non sustainable livestock use of public lands.[7]

Environmental groups have added to the controversy over ecological condition by expressing dissatisfaction with the slow improvement in public grazing lands. Studies by the General Accounting Office, for example, indicate that two-thirds of public rangelands remain in less than good condition and that the majority of western riparian areas and streams continue to be overgrazed and degraded.[8]

Despite an abundance of data, there is no national consensus on whether rangeland health and the rate of its improvement are satisfactory or not. What is satisfactory to ranchers or to the federal agencies is often unsatisfactory to hunter groups, recreationists, wildlife enthusiasts and wilderness devotees. Yet, the absence of an absolute standard against which to gauge the health of public rangelands does not alter the fact that increasing numbers of Americans are dissatisfied. Their public land expectations are not being met.

Science aside, the conflict over public land health is ultimately a clash of land-use values made inevitable by the politicization of rangeland resources. For this reason alone, a tightening of federal control and regulation over public land use is unlikely to attain the varied landscape outcomes sought by a highly complex and expanding universe of public rangeland users.

Equity in Allocation of Public Rangeland Costs and Benefits

Public rangeland policy was formulated during an era when 1) the rural West was dependent on natural resource extractive industries; 2) federal subsidization of agriculture, including livestock production, was deemed appropriate by society; and 3) demand for alternative uses of public rangelands, such as recreation, wilderness, clean streams, and abundant wildlife, was minimal. Today, those conditions have changed. The economy of the public land West is no longer dependent on extractive industries. Agricultural subsidization is now frowned upon in public policy. And demand for non-livestock uses of public rangelands is ascendent.

These trends clash with the reality of current public policy. Federal rangeland permits, for example, can only be acquired and traded by and between bona tide livestock operators. Americans who want to participate on an equal footing with public land ranchers but who have no desire to harvest federal grass with cattle and sheep are virtually locked-out of the system of allotment privileges accorded to grazing permit tees. Except for costly and time-consuming changes in land-use plans, non-ranchers cannot as a rule acquire a grazing permit, retire the permit, and dedicate forage resources to non-tractive ends. Nonetheless, all taxpayers--even those who oppose

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[7] Carl Hess, Jr., Visions upon the Land: Man and Nature on the Western Range (Covelo, CA Island Press, 1992), Carl Hess Jr. and Jerry L. Holechek, "Policy Roots of Land Degradation in the Arid Region of the United States" Environmental Monitoring and Assessment 37(1995), pp.123-141 and "Beyond the Grazing Fee: An Agenda for Rangeland Reform,"Cato Institute Policy Analysis No. 234, 13 July 1995.

[8] General Accounting Office, "Rangeland Management: More Emphasis Needed on Declining and Over stocked Allotments," June 1988 and "Public Rangelands: Some Riparian Areas Restored but Widespread Improvement Will Be Slow," June 1988.

livestock use of public rangelands--must pay for the deficit-ridden grazing programs of the BLM and the Forest Service and bear the ecological costs of bad public policies.

Inequity on the public range is often user-blind. Ranchers who wish to allocate forage to nonconventional uses—whether for conservation or economic gain—are frequently stymied by non use proscriptions. Moreover, federal regulations do not discriminate between better and worse land stewards. All ranchers, irrespective of their grazing records, face the same regulatory hurdles, costs and disincentives. If anything, federal subsidies have rewarded ranchers with the least management acumen and put more skilled ranchers at a competitive disadvantage.

Strict federal regulations, in turn, have made it increasingly difficult for caring and innovative ranchers to profit from successful management. There is no certainty in federal law that ranchers will reap any or all of the benefits that come with healthier rangelands. At the same time, ranchers are unable to engage in alternative economic uses of rangelands in response to changing public demands. They are stuck with raising cattle, even if that contravenes the public's will and the economic demands of rangeland visitors. Federal law--not private intransigence--limits the economic uses of riparian and upland areas to fodder and water for livestock. Ranchers cannot stop grazing livestock and start growing wildlife, fish and vegetation, even if doing so makes economic, social and ecologic sense.

Public rangeland reform, if it is to succeed, must correct the glaring inequities in the current distribution of public land amenities and associated costs and benefits.

MARKET-BASED REFORM OF PUBLIC RANGELAND POLICY[9]

Rangeland reform to date has been misdirected and sidetracked, focusing on failed or largely inappropriate strategies. Higher grazing fees will not balance the grazing deficit, foster better grazing practices, or necessarily improve public land conditions. Regulatory management and gratuitous federal subsidies are not the panaceas that land agencies once envisioned them to be. Indeed, they have encouraged bad land practices to the same or greater degree than they have resolved them. Further, the distribution of federal rangeland resources remains riddled with inequity. Too many Americans are excluded from equal participation in rangeland use, and too many ranchers are needlessly constrained from, or penalized for, stewardship innovation.

Privatization is advanced as one solution. History, though, argues against it. In the 1870s when western settlement began in earnest, the arid range was seen as "vacant" and primed for settlement (occupancy by native Americans was ignored). Today, public lands—despite their federal ownership—are fully claimed by ranchers, farmers, miners, loggers, hunters, water districts, recreationists, all shades of environmentalists, and rural and urban communities. For privatization to occur and to be equitable, it would have to account for all pre-existing claims on public ranges--a politically improbable, economically costly, socially divisive, and ecologically questionable feat.

A different policy strategy for western public lands is needed, one that can set right the fiscal ills of the past, correct the ecological deficiencies of the present, and offer equal opportunity to all rangeland users in the future. The essence of that strategy is marketization. Its elements are:

1) fully marketable public land leases;

2) outcome based management in lieu of traditional prescriptive management;

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[9] Range reform discussion is drawn from "Reforming the Western Range", "Beyond the Grazing Fee," and Karl Hess, Jr., "Political Rights and Policy Wrong: The Ecology of Conflict on American Western Public Lands," forthcoming in Human Ecology Review. Spring 1997.

3) democratically elected and self-governing resource councils; and
4) locally-administered Biodiversity Trust Funds.

Marketable Public Land Leases

Existing grazing permits, and the rights and privileges attached to them, should be fully marketized. To attain this goal, the following steps must be taken:

- Transform grazing permits into secure, long-term (30 years or more) public land leases, grandfathering-in current permit holders;
- Remove statutory and regulatory proscriptions that constrain public land lessees and their allotments to domestic livestock production;
- Remand decisions on the degree of proper forage use--or non use--to lessees;
- Eliminate barriers (like base property requirements, sub-leasing prohibitions, and non use rules) to the trading of leases between willing buyers and sellers;
- Terminate all public land subsidies and entitlements to lease holders;
- Shift costs of management and monitoring to public land lessees; [Lessees assume responsibility for land protection, restoration and monitoring.]
- Assess a minimal universal public land lease fee that covers reasonable agency oversight expenses and that is indexed to the national rate of inflation of goods and services; [Because of other cost savings, lease rates would not have to be significantly greater than current fees to balance the grazing deficit.]
- Broaden the range of allowed economic uses on public rangelands to foster and encourage diverse and sustainable land practices; [Lessees who use public grass to profit from livestock should be able to use that grass to profit from growing more wildlife, improving fisheries, and enhancing recreation.]
- Remove all barriers to lease holders for non-economic uses of public lands.

The advantages of marketable public land leases are apparent. Fiscally, they offer the prospect of shifting land-use costs from taxpayers to land users and erasing the deficits that plague agency grazing programs. Ecologically, they will enable new and more appropriate land uses on federal rangelands, facilitate shifts in land uses toward those demanded by the general public, and eliminate subsidies and other policy disincentives that foster non sustainable land practices. Marketable leases will also enlarge the pool of lessees, diversifying the management strategies needed to protect and restore America's public lands. In equity terms, they will democratize federal ranges by expanding public input and opening public lands in *substantive* ways to all citizens. Marketable leases will effectively level the public land playing field for everyone and provide the incentive environment to encourage and reward good land management and to dissuade and penalize bad land practices.

Outcome-Based Management

For market reform to be effective and workable, outcome-based management should replace prescriptive management. To do this, two policy conditions must be met: 1) lessees should have flexibility in the disposition and use of their public land leases and 2) the side-bars or conditions within which private land use on federal lands takes place must be clearly defined and consistently enforced.

De-Regulation

Prescriptive management on public lands has not worked. It has not prevented poor land practices and it has not led to better resource stewardship. It has proven costly, adding to agency deficits. It has formalized and enforced management that is more detrimental than beneficial to the nation's public rangelands. It has, by virtue of its historic inflexibility, mounted barriers to change and innovation in rangeland uses.

Outcome-based management, a vital ingredient of market-based reform, is strikingly different. For ranchers, it would mean deep de-regulation of the day-by-day activities of livestock production by removing all federal targets for livestock numbers, approved grazing systems, and times and seasons of livestock use. For other lessees, including ranchers who choose to experiment with non-livestock forage activities, it would be equally de-regulatory. It would expand management latitude by facilitating new land practices and by freeing lessees from the regulatory burdens of the past.

Locally-Appropriate Standards

Outcome-based management entails more than de-regulation. Historically, federal land policy has operated on the assumption that appropriate scientific management leads invariably to desirable outcomes. This has not happened on federal rangelands. A de-regulatory approach can partly, but not entirely, rectify this failure. Markets and incentives, for example, can effectively protect and optimize the specific resources and uses that come with public land leases. They cannot, however, always conserve the non leased amenities retained by the public--the intangibles of ecosystem process and the structural elements of biological diversity.

Standards, when site-specific and vigorously enforced, can, in part, help safeguard non-leased, public amenities. In a market-based reform regime, the attention of federal agencies would shift from mandating land practices and management details to monitoring the ecological effects of multiple land activities and enforcing compliance with locally-appropriate yet democratically-set standards. Such standards would establish the bounds within which private lease-holders could exercise their forage use claims without impairing ecological processes integral to habitat potential and associated rangeland life.

Standards would be the means to separate private lease claims to federal rangelands from general public claims to access to and enjoyment of those lands. They would give lease holders and the public predictability in the allocation of ecological costs and benefits (by identifying the rights and obligations of each), offer to both the consistency and predictability of enforcement, and provide effective judicial redress for mitigation of either resource damage or infringement of leasehold privileges.

Outcome-based management built on the twin pillars of de-regulation and locally appropriate standards would enable implementation of market-based reform, enhance environmental protection, and safeguard the interests of all rangeland users.

Popularly-Elected Resource Councils

Market and outcome-based rangeland reform are predicated on establishing governing policies and standards that reflect local conditions and respond to the values and resource demands of both resident and non-resident rangeland users. Under such a reform paradigm, ultimate responsibility for establishing management policy and setting appropriate standards would be transferred, to the extent possible, to self-governing and popularly elected resource councils.

Resource councils would be set-up on a watershed basis or rely on traditional administrative boundaries, such as BLM districts and resource areas or Forest Service districts and national forests. Voting membership in each resource council (as distinguished from universal rangeland access enjoyed by all citizens) would be allocated to 1) resident lease holders and 2) other users, irrespective of residence, who select a specific council area to exercise their participatory rights and who meet minimal membership qualifications. Such qualifications could range from none (open voting membership) to an annual membership fee and/or a voluntary contribution of time to local resource management.

Regardless of how the resource councils are internally structured, their roles would be substantial and clearly delineated. Federal agencies would continue to monitor the state of the land and to enforce standards and applicable federal laws. They would, however, devolve policy making duties and responsibility for formulating standards to individual resource councils (or, as situations might dictate, to federations of councils within common ecological landscape units, such as watersheds). Resource councils would enjoy a degree of independence and discretion comparable to that exercised by public land lease holders, but they would wield it over a wider array of public resources and across a more expansive public landscape.

Bio-Diversity Trust Funds

Markets are powerful conservation tools. They offer people incentives to steward and protect range resources having economic value--such as grass for cattle, elk for paid-hunting, and trout for fee-fishing. They also create opportunities for people to combine and pursue common goals that are not just economic. Land conservation by private groups like The Nature Conservancy exemplifies this creative use of markets. However, many public land amenities stubbornly elude market solutions because they lack economic value (like endangered species), because they have a value that cannot be fully captured in the market place (like open vistas and watershed health), or because the funds needed to acquire and protect them exceed private means.

As a compliment to markets, locally-controlled Bio-Diversity Trust Funds should be established within each council jurisdiction (or among alliances of adjacent councils) and financed from a percentage of local, across-the-board public land fees (including fees charged for general recreation). Trust dollars would be administered by resource councils within their respective jurisdictions and would be awarded on a merit basis to citizens, citizen groups, or agencies submitting the best proposals for restoration and protection of non-market public resources and amenities.

CONCLUSION

Support for market-based range reform is on the ascendancy in the United States.[10] If implemented, it would comprehensively address the fiscal, ecological and equity concerns that have plagued and undermined public rangeland policy in the past. Marketable leases would transform public rangelands from an exclusive sanctuary for livestock production and public land ranchers to

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[10] Environmentalists voiced strong support for market approaches in lieu of rangeland legislation proposed by the Senate and the House during the 104th Congress. Currently, leaders from the major national environmental and ranching organizations are meeting to discuss elements of market-based reform of public land policy.

an open and democratic landscape where all Americans could find a place and a home for their landscape visions. Deregulation and locally-appropriate standards would set the parameters within which market forces and private management would function and flourish. Self-governing resource councils and Bio-Diversity Trust Funds would round-out rangeland reform by both complimenting and supplementing market mechanisms and private action. Together, these several elements of range reform would forge a durable and workable alternative to past policy and land management on America's western range.

Restorative Grazing

Jim Winder[1]

Due to past and present abuses, many people question the logic of grazing rangelands in the western United States. Although some lands are certainly unsuited for grazing, it seems foolish to eliminate a renewable food source when the human population continues to spiral upward. Fuzzy statistics are often quoted in an attempt to minimalize the significance of western beef production. It is important to realize that I am able to produce enough beef from 30 sections of land to feed 2000 people for an entire year. The question then is how to manage our rangelands to produce healthy food while restoring biodiversity.

The single, most important aspect of rangeland management is the attitude of the manager. A little humility goes a long way. In the past, ranchers tried to mold nature to meet their needs. Today we must fit our operations within natural systems and manage for biological diversity.

With this increased management scope, it is necessary to go beyond being a rancher and become a true resource manager. Although we have many excellent people working in the universities and government agencies, there are very few people who are able to take the science and apply it effectively to the land. At this level, with thousands of species and billions of interactions, the complexity pushes us beyond the capabilities of science and into the realm of the artist. A resource manager must blend theory with an intuitive feel for the land to perfect the art form.

The first step in active management, is to remove the negative effects of ranching. Much of the damage caused by livestock grazing is secondary in nature. We must look beyond the cows and grass and recognize the interdependencies inherent in our ecosystems. I avoid grazing my riparian areas in the growing season, preferring to graze during dormancy. This has had far reaching and unplanned beneficial effects. The riparian vegetation has flourished, and wildlife has a reliable source of food and shelter even in drought years. The effect on my operation was to give me ten times more forage from the same pasture. A win/win situation.

Perhaps the easiest negative effect to alleviate is the extirpation of predators. I quit killing coyotes about ten years ago and noticed a sharp decline in calf death loss although the number of coyotes has risen significantly. Steps taken to decrease susceptibility to depredation have actually increased my profitability. Another win/win solution.

The next step is to take livestock and turn them into powerful tools for restoration. To do this we need control of the livestock, where they are and what they are doing. The co-evolution of grasses and herbivores developed many other interactions besides the removal of leaf tissue. Soil disturbance, predator-prey relationships, herding behavior, natural cycles and even man have influenced the behavioral and physical characteristics of plants and animals. A good resource manager strives to understand these interactions and to use livestock to trigger responses that the ecosystem remembers from the time of free herding ungulates.

Multiple species of livestock grouped in a herd with the concomitant predators impact the ecosystem much the same as wild ungulates. Among other things, I use cattle to disturb the soil surface to alter micro climates, plant seeds, and to disturb fungal hyphae. At times the results have been dramatic.

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[1] Rancher, Deming NM.

When the negative effects of grazing are eliminated and livestock are viewed as tools changes will begin to occur on the land. Because of the complex interactions between species many of the results are unpredictable. Considerable monitoring is necessary to correct errors and to recognize opportunities. Although I have many long term transects in place I rely most heavily on near daily observation of three measures: seedling establishment, rate of organic decomposition, and erosion. In my opinion the most important measure of rangeland health is seedling establishment of key species. I have been on many ranches that are said to be in great shape because they had all the grass species present. However, under close examination no seedlings could be found. A population that is not reproducing is not sustainable. However, a population that is actively reproducing can be sustainable even under adverse conditions.

Whether measured by their effect on the community or by sheer mass, decomposers are more important to ecosystem health than any other species group. Therefore a measurement of their well being is essential. I measure decomposition rates very unscientifically by observing termite activity and the breakdown of fresh and dry manure. Erosion is monitored in reverse by watching how well grass is colonizing arroyos and rills.

Although these methods may produce marked improvement in the land, the solution is not total until the human aspect is addressed. Public lands resource managers face an additional challenge of working with an absentee landlord with multiple personalities. To be effective these managers must be able to build consensus with public lands agencies, environmentalists, hunters, and a variety of other interests.

My approach to this task has been to become active in a number of environmental organizations and to invite anyone and everyone to the ranch to see things first hand. The key is to constantly add to one's knowledge and to remain open to discussion and change. This has brought about acceptance of my management from key groups and, most importantly, it has given me a tremendous education.

If ranching is to remain a viable industry on public lands we must transform ourselves into true resource managers. This requires an appreciation for species who's worth cannot be readily measured on a balance sheet. We have a responsibility to our landlords to protect and improve the land for future generations, not claim it as our own.

Grazing Management In Arid Grasslands Using Principles of Holistic Management

Kirk Gadzia[1]

The majority of grass species that dominate arid grassland communities around the world are adapted both physiologically and morphologically to periodic removal of the above ground portion of the plant. For countless centuries these plants have supported occasional and even frequent fires that swept across the prairies and plains. Their primary production has also supported vast herds of wildlife and livestock, and in turn, the people who depended on them for their survival.

A closer look at a typical arid land bunchgrass plant reveals that the growth points are near the ground level in the crown of the plant. When the top portion of the plant is removed, the plant regrows from the base. Removal of the actively growing portion of the plant results in below ground responses in the root zone that range from complete cessation of root growth, to almost no change in growth, depending on the severity of the removal of photosynthetic material. Even almost total removal of above ground growing leaves and stems will normally not permanently damage the grass plant. Recovery is dependant upon enough time, temperature, and moisture to replace the photosynthetic material and regrow roots. No calendar date will substitute for on the ground observation of such recovery.

One of the key points to managing arid grasslands is controlling the time frame of actively growing plant removal and providing adequate recovery periods following disturbance such as grazing or fire.

Another consideration of arid grasses is their tendency to stagnate or greatly reduce growth if they are not subjected to periodic disturbance. The above ground material builds up and causes a reduction in the rate of nutrient cycling as material is oxidized chemically by the sun and not cycled biologically. The physical evidence of this reaction is that a large proportion of the old stems and leaves turn progressively darker grey in coloration. Underground, root growth also stagnates and roots become weak.

Actively growing portions of such plants are normally a light shade of green or even a chlorotic yellow in response to the buildup of old material. The nutritional value of such plants to wildlife and other grazers is very low. Once such a buildup of oxidizing material occurs, these plants will be continually avoided by grazing animals unless the old material is removed or the animals have nothing else to eat.

Another key point to managing arid grasslands is to understand that most grass plants in the community will benefit from periodic removal of old material. This material will benefit the community most if it is cycled biologically as soil cover, animal manure or otherwise incorporated into the nutrient cycle more rapidly than standing vegetation that is chemically oxidizing.

If these two points were all that mattered, our management systems for arid grasslands would be simple. Just burn, mow or graze the areas periodically and everything will be fine. Indeed, we search for such simplicity in management solutions to the problems on our arid grasslands in nearly every country where these environments exist. Unfortunately, nowhere

[1] Resource Management Services, Bernalillo, NM

are simple stocking rate reductions or burning prescriptions working to reverse the trend toward desertification on a global scale.

Community stability within arid grasslands depends not only on the health of the adult populations of plants and animals, but also the recruitment of young. Seeds of grasses that dominate arid grassland communities must therefore be able to germinate and establish for the communities to remain healthy. Seeds must be incorporated into soils and have seed to soil contact in a firm seedbed to successfully establish. While this concept is simple and well known to every farmer or gardener, it seems missing from our conception of arid grassland health. The crusting or sealing of soil surfaces in bare arid soils occurs in response to rainfall events. Such crusting inhibits the penetration of seeds and their subsequent establishment. The seeds of some species exhibit mechanisms to penetrate such crusting, yet many other species which are an essential component of a diverse and healthy community do not have such advantages.

While fire plays an important role in cycling nutrients, invigorating some species, and removing old vegetation in arid grasslands; it cannot break crusted soil surfaces. In fact, fire exposes large areas of soil surfaces to raindrop sealing action which tends to negatively affect the cycling of water. However, another role of fire is to attract grazing animals to the nutritious forage available in areas that have burned. These grazers in turn can break the soil crusts and provide necessary seed to soil contact for improved germination and establishment of new plants.

Periodic droughts and high rainfall years also played a role in the vast wheel of life rolling on the arid grasslands. Years of above average precipitation produced an excess of plant material, and afterwards a buildup in the game populations. Fuel buildups in turn encouraged fire that were eventually followed by drought years. High utilization levels occurred as forage resources became inadequate to support the game populations. Locusts, and other major influences also played their roles. In short, such a dynamic population and production situation could hardly be described as static.

It is clear from considering this large view that it is not enough to weigh only the needs of the grass plant as a component of the arid grassland environment. We must consider the community as a whole. Such consideration will involve the interacting roles of plants, animals, soils, people and the changing rules and regulations we create to manage these interactions. Management of such complexity must be responsive to the needs of this overall community.

When we shift our view from managing arid grasslands to the larger whole of recreation, agriculture, forestry, fisheries and other interactions between humans and their environment we see few success stories in sustainability. Where we do see successful management, in nearly every case it is because the principles used to manage are based on natural laws or the simulation of natural processes. Such sustainable management systems rely on building biodiversity to retain stability. In addition, people are viewed as an essential component of the process, and not considered "foreign" to the ecosystem.

The natural principles that governed arid grassland development, biodiversity, and stability in nearly all areas of the world have been periodic disturbance by grazing animals, drought, floods, and fire. Migrating herds and their predators including humans responded to regional climatic variations and natural and human induced fires to create an incredibly complex whole. Such community development is not easily duplicated by management prescriptions of stocking rates, season of use, fire management regimes, and other regulations governing the current management of many arid grasslands.

In Jordan, ancient Byzantine mosaics and hunting lodges in the desert attest to the once abundant wildlife of the area in times past. The arid oak savannah grassland and nomadic people that lived in these areas with their livestock are also depicted. Today these areas are treeless except for the monocultures of pine planted by the government and protected by armed guards. Perennial grasses still exist, hanging on in the shelter of rocky cracks, but are largely absent from the community. The majority of the surrounding countryside is being nibbled to death by settled nomads and their small resident herds of sheep and goats. Yet, where large herds and planned seasonal recovery has been used, rapid improvement has been documented.

While far from perfect, the nomadic livestock grazing that existed and sustained populations for many centuries in these areas was an approximation of natural grazing patterns by wildlife. Populations of both humans and livestock grew and starved in response to prevailing weather. In the last instant of time we have settled nomads in foreign countries, built fences, firebreaks and other developments in our own countries' arid grasslands, and done our best to impose a static management regime upon a completely dynamic situation.

The change from relative productivity and stability towards instability and lowered productivity of arid grasslands in this country is well documented in some areas. In the desert southwest a shift from grassland to shrub dominated communities is often considered irreversible without major human and technological intervention. The long term rest or non-disturbance that is often recommended in such areas has produced few positive changes in overall ecosystem functioning. Without the vital component of large animals interacting within the system, rest alone seems insufficient to create much change.

There is no single simple prescription to manage arid grasslands and their myriad of values and functions. The changes wrought by human population buildup in our arid grasslands preclude the "return to nature" approach favored by some. This is because the human infrastructure of pipelines, roads, towns, etc.., will not disappear even if livestock grazing is halted. Management models such as holistic management that recognize and attempt to mimic the pulses of energy that were an integral part of these environments show great potential. The concept of using life to make more life is a simple way of expressing this interaction. Arid grasslands did not develop as plant communities. They developed as communities of soil organisms, plants, herbivores, predators and human intervention.

Improvement of grazed arid grasslands in terms of biodiversity, soil cover, and other monitoring criteria is documented in many areas of this country and others around the world. There is abundant evidence that livestock can be utilized as a major component in the improvement process. Their role in providing periodic disturbance to soil surfaces, removal and cycling of plant materials must be emphasized and concentrated to be effective. These impacts must be incorporated with adequate time periods for soils, plants, and animals to recover and utilize the energy provided by large animal in the system. If time and impacts are not controlled, the results will be negative as evidenced by the state of many arid grasslands around the world.

A biological planning process must be used to coordinate and incorporate the needs of people, plants, animals, and other factors. The typical prescription of lowering stocking rates, changing season of use, and other such commonly used criteria for livestock grazing management have met with little success. It is crucial to understand and work with the natural process that governed the development of arid grasslands. This will require a philosophy that is flexible in terms of stocking rates, delineations of grazing areas, season of use, and the ability of managers to change plans easily and frequently in response to monitoring data and weather patterns.

The Malpai Borderlands Group: Ecosystem Management in Action

Bill McDonald[1]

BACKGROUND

The Malpai Borderlands Group, a grassroots, landowner-driven organization, is attempting to implement ecosystem management on nearly one million acres of virtually unfragmented open-space landscape in southeastern Arizona and southwestern New Mexico. The area involved is roughly pyramid-shaped, with the base of the pyramid running just east of Douglas, Arizona into New Mexico to the far eastern boundary of the 500-square mile Gray Ranch. The apex is just south of Rodeo, New Mexico, on the Arizona-New Mexico state line, and runs go the Mexican border.

The elevation for this area ranges from 4,500 feet, which is characterized by desert scrub and tobosa grasslands, up to 8,500 feet which features Arizona Ponderosa Pine and Douglas Fir. Within this diverse area of mountains, canyons, and valleys are numerous riparian corridors with Sycamores, Cottonwoods, Oaks and Black Walnuts.

Several rare, threatened, or endangered plant and animal species are found here. In addition, it is the only area in the United States where Gould's turkey and white-sided jackrabbits occur naturally. It is also home to such popular big-game species as Coues deer, mule deer, pronghorn and Desert Bighorn sheep. Perhaps the most remarkable thing about this huge landscape is that fewer than 100 human families reside on it. Except for two small wildlife preserves, this is cattle ranching country.

The diversity of the land ownership is nearly as great as the country itself. The patchwork of ownership includes 53 percent private and 47 percent made up of state trust land in New Mexico and Arizona or public land managed by the U.S. Forest Service or the Bureau of Land Management.

CONCERN FOR THE OPEN-SPACE FUTURE

On the surface, little has changed since the homestead days of the turn of the century when many of our families established ranches in the area. It was a time when a regime of survival of the fittest set the carrying capacity of the land for people and their livestock, although not without cost to the land. 'Today, however, change is in the works.

In 1990, several area ranchers met at the Malpai Ranch in the San Bernardino Valley. The ranch is so named after the volcanic malpai rock prevalent in the area. We met to discuss what we saw (Is a deteriorating situation. Cattle ranching in the West, especially grazing on public lands, is under attack and on the defensive. Also, we were concerned about the future of the resource we depend upon for our livelihoods. The grassland with some shrubs were moving inexorably to shrublands with some grass--for many reasons, a principal one of which is the absence of a crucial natural element: fire.

Living on our remote ranches, we felt ill-equipped to deal with all this. It seemed as though the

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[1] The Malpai Group, Douglas, AZ

"dig in your heels" approach was doomed to failure, so we decided to embark on a different approach -- to reach out to our critics and find common ground.

For two years, a small group of ranchers and environmentalists, together with scientist Ray Turner, met to discuss our mutual concern for the health and the open-space future of our land. We called ourselves the Malpai Group. Eventually, we drafted a Malpai Agenda, which addressed two major concerns: first, the threat of fragmentation of the landscape. Already, some of the ranches on the fringe of our area had been subdivided. Fragmentation would permanently limit future options for a desired sustainable condition for the land. Second, we were concerned about the declining productivity and loss of biological diversity accompanying the encroachment of woody species on grasslands. We felt that more government regulation was not going to help. At best, it would replace one set of problems with another. The inevitable result of the free market would seem to be 20-acre ranchettes. This was not the future we wanted to see for this land.

We were not sure what we needed, but we knew that whatever it was should be driven by good science, contain a strong conservation ethic, be economically feasible, and be initiated and led by the private sector, with the public agencies coming in as our partners rather than with us as their clients.

Two subsequent events took us to the next step. One was the suppression of a small brush fire just inside our area. The fire was suppressed, at great expense, by the land management agency in authority over the objection of the private landowner whose land intermingled with that managed by the agency. The fire was burning in some three-awn grass interspersed with creosote brush. The fire was bounded on one side by a road and on all other sides by bare ground and creosote brush. It wasn't going anywhere.

The ranchers felt strongly that this fire should not have been put out. Fire suppression was believed to a be a major factor in the encroachment of brush which has accelerated in this century, and many ranchers, as well as others, felt it was time for fire to regain at least some of its naturally occurring role in the ecosystem.

Another, larger meeting was held at the Malpai Ranch. Out of that meeting came a request for the land management agencies to work with the ranchers on a comprehensive fire management plan for the area. Before long, ranchers and agencies -- the Coronado National Forest, the Bureau of Land Management in Safford, Arizona and Las Cruces, New Mexico, and the State Land Departments of New Mexico and Arizona--committed to work toward coordinated ecosystem management for the whole area. After all -- fire crosses land ownership boundaries, and is just one tool in managing landscapes. Clearly, it was time to figure out how to work across political boundaries to improve the land.

The second event that transformed our group was the purchase of the Gray Ranch by the Animas Foundation from the Nature Conservancy. The Conservancy had purchased the ranch in 1993 from a Mexican national to protect its outstanding biological diversity. Following the purchase, the Conservancy began to look for a buyer. The community, fearful that the buyer might be the federal government, went to the Hadley family, which has owned the Guadalupe Canyon Ranch for 20 years, and asked them if they would be willing to purchase the Gray.

The Hadleys, who have substantial resources beyond their cattle operation, were able to create a private organization, the Animas Foundation, with which to purchase and manage the Gray. It was important to the Conservancy that the Gray be sold to a party which would keep its open-space character and preserve and maintain it's natural beauty. The ranch was purchased, therefore, with conservation easements on the private land guaranteeing that it would never be subdivided and with conditions establishing monitoring procedures to record the health of the range land habitats.

To help manage the Gray, the Animas Foundation has invested in a Geographic Information System and has offered to extend its use to ranches involved with the Malpai Group. The foundation has also provided some seed money to the group to help start up its operations. The Conservancy became interested in our group and its goals and assigned the senior vice president, who had negotiated the Gray Ranch purchase with the Animas Foundation, to work with our group and the Foundation at the request of the ranchers.

ESTABLISHMENT OF THE MALPAI BORDERLANDS GROUP

The upshot of these events was the establishment, in 1994, of the Malpai Borderlands Group as a 501-C3 nonprofit organization. Our nine member board includes local ranchers, a scientist, and a businessman. Our cooperators include ranchers in our planning area in Cochise and Hidalgo counties, the State Land Departments of Arizona and New Mexico, the Coronado National Forest, U.S. Forest Service, U.S. Fish and Wildlife Service, the Natural Resource Conservation Service in two states, the Bureau of Land Management in two states, the Hidalgo Soil and Water Conservation District, the Whitewater Draw Natural Resource Conservation District, the Game and Fish Departments in two states, The Desert Laboratory of the University of Arizona, The Nature Conservancy, and the Animas Foundation.

The goal statement of our group reads as follows: "Our goal is to restore and maintain the natural processes that create and protect a healthy, unfragmented landscape to support a diverse, flourishing, community of human, plant and animal life in our borderlands region. Together, we will accomplish this by working to encourage profitable ranching and other traditional livelihoods which will sustain the open space nature of our land for generations to come."

The following is a checklist of our progress to date in specific program areas and an assessment of the challenges which remain:

Land Protection

We have moved aggressively in this area using grassbanks and land use easements. To date, four different ranchers have completed agreements with the Malpai Group and the Animas Foundation, owners of the Gray Ranch, to convey land use easements to the Malpai Group which will preclude sub-division development on private land of their ranches in the future. In return for the easements, the Malpai Group is paying for forage on the Gray Ranch which is being made available to the rancher's livestock. The amount of forage made available to each rancher, measured in animal unit months, will be equal to the development value given by each ranch. The challenges which have arisen to this approach are many. First, the cost of the forage is great. It will require large amounts of capital to be raised by the Malpai Group in the future in order to continue grassbanking for easements, even at this level of participation. Clearly, this model has limited application for the long term. Variations on the theme are being explored, but are still in the talking stage to date. Additional uses for grassbanking, focusing solely on its benefit as a range restoration tool, are being discussed. Two grass bankers have combined their herds for a time and this suggests some interesting possibilities. The Malpai Group also stands ready to consider holding donated land use easements, or even purchasing the land itself, in the case of an emergency (for instance, pending sale to subdivision within our working area). Hopefully, this will not be necessary, as these monies would be difficult, if not impossible to replace. They must be used with extreme care.

Science and Research

This arm of the Malpai program is moving forward on several fronts. The research that is being done as a result of the U.S. Forest Service Rocky Mountain Station grant has graduated from a research literature review to the establishment of experimental plots on different sites within the working area. All sites are chosen with the full consent and cooperation of the landowner, or in the case of state and public land the lessee or permittee. Most of this research will center on different approaches to addressing woody species encroachment. A vegetative survey is being conducted in coordination with this research.

The Malpai Group has also contracted to have baseline monitoring conducted on the ranches which are being rested as a result of use of the grassbank. Again -- this is done with the full consent and cooperation of the landowners.

In addition to these efforts, several independent survey and research projects are being conducted in the planning area. The group has contracted a position to track and coordinate these efforts so that useful information can be made available to landowners and managers. This position reports to the Malpai Group's Science Advisory Committee and ultimately to our Board of Directors.

The Malpai Group will continue to try to find ways to get the best scientific information available to landowners and managers while, at the same time, zealously guarding private property rights and aggressively addressing any risks (perceived or real) which landowners may encounter by allowing research efforts on their property.

Fire Management

This group came together around the issue of fire management and it continues as a major focus of the Malpai Group. The regional fire map, put together by private landowners after our first meeting, has been updated on a Geographic Information System. The government agencies with which the group works, are becoming more familiar with how to use the map.

Communication, rancher to rancher and rancher to agency, has increased on fire-related issues. As a result, thousands of acres have benefitted from a more thoughtful response to fire starts, a thousands of dollars in suppression costs have been saved. Meanwhile, the Coronado Forest has taken the lead on a programmatic approach to prescribed burning in the area. The success of the Baker Burn, both in overcoming the complexities of jurisdictions and regulations involved in the approval process and in the execution of the initial positive results of the burn itself, has increased the confidence of all. Planning on the next burn, the Maverick Burn, which will involve the Coronado Forest and three private landowners, has been initiated. The Malpai Group feels confident that opportunities for the use of fire as a positive land management tool will increase as a result of our efforts so far.

Conservation Action

This is as a catch-all for what are traditional on-the-ground land management projects. Already completed is as a 310-acre brush removal and reseeding project. The success of this native reseeding has, so far, exceeded everyone's expectations. This project will be monitored closely; we continue to grapple with what can or cannot be done successfully and economically in range restoration.

The group is currently engaged in gathering support for an effort to replace 13 miles of deteriorated boundary fence which borders one of the ranches being rested from grazing. This will prevent trespassing by cattle from a neighboring ranch onto the rested land. The Malpai Group is working with the landowners involved, the lead agency (Bureau of Land Management) and other groups and agencies which might be able to contribute support to this project.

The Malpai Group is intent on initiating a watershed restoration project involving multiple ownerships in the near future. The willingness of the landowners and agencies is there and only the commitments of time and resources to other projects has delayed the start of this particular effort.

Endangered Species

The Malpai Group has helped a local ranch family establish permanent water at a site on their ranch which is home to the threatened Chiricahua Leopard Frog. This action will also enhance the rancher's grazing management by establishing a more dependable water for livestock Another site where the frogs reside is still in need of a more secure water source. The group is working with the rancher, nationally renowned herpetologists, and the Arizona Game & Fish Department, using funds from their Stewardship Program to establish this second permanent water. We are hopeful that this may set a precedent for more cooperative private landowner-public agency endeavors to benefit wildlife species and improve land management for the future.

The riparian restoration efforts taking place on several ranches will help decrease soil erosion, improve herbaceous cover and forage conditions, and increase ground water infiltration as well as benefit songbirds migrating through our ranches We are also working to make research biologists available to any interested ranchers who would like more information on the rare, threatened or endangered plants and animals of the region

We believe that putting ranchers and biologists together can yield tremendous results. For example, one ranch in our group has, for the past eight years, allowed the Fish and Wildlife Service to monitor the tiny Cochise Pincushion cactus found on their property. This is an extremely rare cactus, coveted by cactus poachers throughout the world. It lives in a highly specialized habitat on an extremely small range. The result of this lengthy monitoring, close to a record in Arizona, has shown that grazing does not appear to have a negative effect on the plants and the population is stable. It's likely that the constant presence of the ranchers on the land will continue to deter cactus collectors from harming it. Another survey by a scientist working with our group showed that burning areas with agaves (a flowering, desert plant) in the summer did not affect that plant's ability to meet the need or endangered, nectar-feeding bats which use it as a food source.

Agency Participation

The enthusiastic participation of agency personnel in the Malpai Group's efforts continues to be a hallmark of our progress. Turnover in key agency positions results in much of the Malpai Group's private landowner's time being occupied with bringing in new personnel "up to speed" o our effort. A familiarity with our project grows within the agencies we are hopeful that this aspect of our partnership will become less burdensome.

Economic Development

The future of an unfragmented open space landscape depends upon the existence of a stable economic underpinning. In our area, livestock grazing remains the principal livelihood capable of sustaining such an environment. The Malpai Group is exploring ways in which cooperative ventures by area ranchers might be able to yield higher returns for their product than are now obtained through traditional market routes.

This is obviously a very challenging area. It is nothing new for cattle producers to attempt "niche marketing." There are a few success stories, but many more failed attempts. The group is currently having market research conducted on different possible approaches. We intend to proceed cautiously.

In addition, we are investigating possibly marketing low impact recreational opportunities as a supplemental source of income for private landowners. Low impact recreation brings with it the risk of overexposure of the area and the resulting unwanted impacts associated with large numbers of people. We remain in an investigating and planning mode here, on the theory that having a plan in place is better than simply reacting to changing circumstances.

Operations

Probably the biggest challenge of all is simply to keep this effort moving ahead and in control of its destiny. Our quick success has brought us attention and support beyond expectations as well as opposition from a small, but very vocal segment of our community. Individually, we are experiencing the exhilaration of finding "something that works", and the anxiety and frustration of trying to keep up with the effort required to make it work. The correspondence, bookkeeping and reporting requirements of a non-profit group, receiving the support we have received, have become quite a load for people already engaged in full-time enterprises. Our isolated location and the distance of the participants, one from another, puts a heavy reliance on electronic technology to keep up with communication needs. This, in an area which had no electric lines coming in 5 years ago, no telephone or television 10 years ago.

We continue to spend a considerable amount of effort on outreach beyond the boundaries of our working area. We think this is important, not only because it helps others, but the exposure to other efforts and ideas contributes to our own growth. However, hosting a seemingly endless stream of folks from outside the community who can help and trying to filter out those who wish only to use our name, time and resources for their own agendas can be taxing. 'Traveling to talk about what we are doing, to touch base with supporters or potential supporters, and to keep key political players informed can also be wearying.

In order to keep the wheels on the road in the years to come, the group must come to grips with the issues of how to avoid burnout of those who handle the bulk of the workload, and how to keep enthusiasm and interest high for the rest. Turnover of positions, compensation for time and personal expenses expansion of the board, contracting work out, formation of committees and advisory positions, holding regular meetings of different size and purpose these are some of the things the Malpai Group is trying to tackle. At our last board meeting, the group agreed to put more money into permanent positions to solidify our work. We now have a paid Director, a paid Financial Coordinator and Communications Coordinator to help us build long-term stability into our operations. We hope we can find and build the right balance. We are proud to say that we have completed a three year plan of work. This process was initiated by a brainstorming meeting of what we call the "greater board", which takes in most of our active participants. Coming out of the meeting, committees were formed and issued draft plans for their assigned categories (i.e., land management, community outreach, etc.). This approach to planning was very fruitful for both getting good community involvement and for getting out a good product. If offers a lot of promise for the future.

CONCLUSION

The group feels good about where we are at this time, but we are realistic about the enormous challenges ahead. Our initial trepidation at drawing attention to ourselves and the area, has partially given way to the job of trying to handle all the consequences of that attention while simultaneously moving ahead on the task we have set for ourselves. We remain very optimistic. One of our principals calls what we are doing "God's work." If by definition that is work that brings good people together for a noble cause, then "God's work" it truly is.

In conclusion, the success of this effort so far has resulted from the local community, the landowners, being the drivers. The enthusiasm, support, and participation at this point exceeds our expectations. In a political climate where the traditional position on this issue of land use is usually to be at one end of the spectrum or the other, we find ourselves in the "radical center." We invite you to join us right there.

Use of Native Species in Revegetation of Disturbed Sites (Arizona)

Richard D. James[1]

ABSTRACT

Seeding disturbed sites to establish native species in desert and desert grassland areas of Arizona has been shown to be successful. A growing awareness of and appreciation in the role native species play in ecosystem functioning is a major factor in their use. There is also an increasing interest and acceptance of arid lands as valuable beyond livestock production. Land values in term of esthetic appeal, wildlife, fisheries, watershed, tourism and other forms of recreation are of significant public importance. Native flora and fauna contribute immeasurably to the value of these entities. Using native species for revegetating to closely approximate the original pre-disturbance, or contiguous native flora will best meet restoration goals. This can often be accomplished using certain simple technologies of site preparation and direct seeding.

The practices described in this paper are involved with acutely or drastically disturbed sites as considered by Box, (1978). These are sites such as deep construction cuts and fills where vegetative communities have been removed and the natural surface soils have been lost, altered, or buried. These sites are ones which do not typically restore themselves in reasonable time. Adequately applied common soil surface modifications combined with the appropriate materials can dramatically accelerate the process of secondary succession.

There has been a phenomenal increase in drastically disturbed sites due to construction activities in recent years. This coupled with increased environmental awareness has created a demand for restoring natural vegetation. Erosion control has been a major objective and still is on many projects. However, esthetics are of greater perceived importance due to land values based on visual appeal of real estate.

Traditional landscaping solutions have often been used. Drip irrigated landscape container plantings and transplanting are relatively expensive often running in excess of $30,000.00 per acre. Using small containerized plants Bainbridge, et. al. (1995) reported planting costs alone of $0.50 to $3.00 per plant. This was for installation only not indicating plant costs or irrigation and subsequent management costs. Direct seeding is much less costly. A greater density and variety of plants can be realized for less than 1/10 the cost of containerized plants.

[1] Western Sod/Western Sere, Casa Grande, Arizona.

Species Use

Until very recently there has been resistance to the use of native species. It was believed that native species primarily grasses were difficult or impossible to establish. Cox, et. al. (1982) reviewed the history and literature of revegetation activities in the Chihuahua and Sonoran Deserts. Most research focused on restoring grasses, not necessarily native grasses, to overgrazed ranges to promote livestock production. Treatments were typically minimal because of the large land areas which were degraded. Less regard was given to other entities such as floral and faunal diversity. Seeding failures were common. Introduced exotic grasses such as Lehmanns lovegrass, *Eragrostis lehmanniana*, and bufflegrass, *Pennisetum ciliare* appeared to give easier initial success prompting their extensive use. Roundy, (1995) in a review of G.L. Jordan's revegetation work indicates that Jordan stopped testing natives not only because of failure but likely also because of the lack of quality native seed. It is probable that other researchers had difficulty obtaining quality native site specific seed.

Even though Cox, et. al. (1982) recognized success of eighty-three species their conclusion was that only fourteen should warrant general use. This included 11 non-native species. Their widespread use is considered to be ecologically detrimental (D'Antonio and Vitonsek, 1992).

Typically differing from past projects is the use of a relatively high variety of native species combined with good soil surface modification. It appears that this "shotgun" approach to species use particularly suits many of these arid lands due to the unpredictability of environmental factors such as weather and the resultant dynamic plant communities as elucidated by Burgess (1995). Although other factors resulting in success may be attributed to using diverse seed mixes. Miller, et. al. (1983) showed that mycorrhizal colonization was more likely to occur with interspecific associations. This may give greater long term success.

The southwestern deserts and desert grasslands have a wide variety of plant communities. Many diverse species are found here on many diverse soils. Some of the grasses found here are grasses usually associated with prairies such as plains bristle grass, *Setaria macrostachya*, and side oats grama, *Bouteloua curtipendula.* These are likely arid-adapted ecotypes. Other species are more specialized desert types found in unique habitats such as big galleta, *Hilaria rigida,* often associated with sandy desert areas such as dunes. This high diversity makes for a great selection of species for revegetation. Table 1 shows the variety of species commercially available for seeding use in desert grassland areas of Arizona. Most of these species have been used with a high degree of success in revegetation seeding since the mid 1980's.

Grasses
Side oats grama, *Bouteloua curtipendula*
Blue grama, *Bouteloua gracilis*
Squirrel tail, *Sitanion hystrix*
Purple three awn, *Aristida purpurea*
Green sprangletop, *Leptochloa dubia*
Plains lovegrass, *Eragrostis intermedia*
Curly mesquite, *Hilaria belangeri*
Sand dropseed, *Sporobolus cryptandrus*
Plains bristle grass, *Setaria macrostachya*
Vine mesquite, *Panicum obtusum*
Alkali sacaton, *Sporobolus airoides*
Arizona cottontop, *Trichachne californica*
Tangle head, *Heteropogon contortus*
Indian ricegrass, *Oryzopsis hymenoides*
Forbs
Firewheels, *Gallardia pulchella*
Prairie aster, *Machaeranthera tanacetifolia*
Mexican poppy, *Escholtzia mexicana*
Firecracker penstemon, *Penstemon eatonii*
Sonoran penstemon, *Penstemon parryi*
Palmer penstemon, *Penstemon palmeri*
Desert globemallow, *Sphaeralcea ambigua*
Desert marigold, *Baileya multiradiata*
Shrubs & Trees
Four wing saltbush, *Atriplex canescens*
Apache plume, *Fallugia paradoxa*
Squawbush sumac, *Rhus trilobata*
Wait-a-minute bush, *Mimosa biuncifera*
Cat claw acacia, *Acacia greggii*
White thorn acacia, *Acacia constricta*
Velvet mesquite, *Prosopis velutina*
Desert willow, *Chilopsis linearis*

Table 1
ARIZONA NATIVE SPECIES FOR ELEVATION OF 3,500' - 5,500'

A greater probability of success can be attained when certain technologies are used in dryland revegetation seedings. Three basic phases should be considered; 1) site/soil preparation, 2) seeding, 3) surface mulching. All three done with specific techniques and materials will interact to give a greater probability of success.

Soil Preparation

Soil properties such as erosiveness, compaction, surface roughness, structure, fertility, and water capture and retention capacity can be modified to increase plant establishment and growth. These factors are often interacting and can be significant determinates in plant establishment. The effect of good soil preparation techniques prior to seeding has been well documented. Soil surface modifications to relieve compaction, reduce runoff, and capture and retain moisture is generally considered to be of benefit to plant establishment (Verma and Thames 1978, Packer & Aldon, 1978, Wright, et. al. 1978). Most projects we have worked on show a marked increase in plant establishment and growth when contour ripping is done. This simple technique can be accomplished with widely available equipment. A minimum of four inches depth of ripping on 10-20 inch centers is recommended. On steeper slopes or more heavily compacted sites, crawler tractors are employed. The resultant roughened or furrowed surface helps to stabilize the surface, reduce runoff and infiltrate moisture. Ripping also provides an improved environment for root growth. Soil should not be pulverized with discs or rototillers.

In general, very little is known on the mineral nutrient requirements of native arid land species. Standards for soil fertility testing in the arid southwest are based on land used for agricultural crops such as cotton. Native drought tolerant species likely utilize nutrients very differently compared to field crops. Interacting effects of microbial symbioses further complicate the picture. However, it is well known that arid land soils are typically deficient in nitrogen and available phosphorus (Bauer, et. al. 1978). Subsoils and drastically disturbed sites are even lower in these nutrients. We have noticed a great benefit to plant growth by the supplementing of these nutrients. It is common practice to add 200 to 400 lbs per acre of ammonium phosphate (16-20-0) preferably tilled into the soil during tillage. It appears that supplements of organic soil conditioners such as compost high in humus compounds are also of benefit. However, because of complicated interactions, especially regarding soil microbes, an accurate identification of what is happening remains elusive. It has been shown that mycorrhizal fungi improve plant survival (Miller, 1987). However, commercially available mycorrhizal symboints for practical addition to revegetation projects have been restricted to container plantings until recently. We have established many species without the artificial addition of microbe symbionts.

If inoculation is occurring on these sites, it may be that symbionts such as mycorrhizal fungi are occurring naturally by wind (Warner, et. al. 1987), or as spores in organic residue during the addition of organic matters applied as surface mulching. Supplementing a site with chemical fertilizer may allow for initial growth of desirable species until natural symbiosis can occur. However, St. Johns, (1987), suggests that chemical fertilizer strongly favors weeds and the resultant detrimental competition limits establishment of desirable later successional species. He suggest a method of anti-fertilization whereby carbon:nitrogen ratios are increased thereby, reducing nutrient availability by microbes resulting in less nutrient availability for weed growth. We have never tried anti-fertilization on our projects, but it could be a solution on sites heavily infested with the non-mycorrhizal Russian thistle, *Salsola spp.* or wild mustards, *Brassica spp.*, *Sysimborum spp.* among others.

Nutrient modification is likely occuring with the addition of high carbon mulches, such as straw and wood fiber. It is recommended that drastically disturbed sites be prepared and seeded before weedy species can colonize. This is one reason we feel that newly disturbed sites should typically not be left fallow anticipating a preferred seeding season.

Seeding Methods

The objective is to place seed in a stable environment conducive to germination and emergence. A stable environment is one in which soil movement is limited, in which rainfall will not wash the seed away, in which wind will not blow the seed away, and in which moisture and temperature variations are relatively low. Birds, insects, and other animals should not have easy access to the seeds. An environment conducive to germination and emergence is one that retains available moisture, that does not form a hard, crusted surface, and that allows relatively low fluctuations in moisture and temperature. Most of the revegetation seeding being done now in Arizona employs hydroseeders. The hydroseeder is very versatile and can far exceed the limitations of drill or dry broadcast seeding.

The hydroseed slurry, if composed of specific types and quantities of materials and sprayed over well prepared roughened sites with loose surface soil, meets many of the criteria that define a stable environment conducive to germination and emergence. The slurry sprayed over loose soil combines mulch and soil to a depth of one-half inch. This mulch/soil layer is resistant to erosion. If quality materials are used, it will move very little with rainfall and virtually not at all with wind. Tackifiers are used in the slurry as adhesives to increase the mulch's resistance to erosion. Birds, insects, and other wildlife have difficulty finding and removing the seed. The mulch material reduces surface crusting caused by rainfall impaction. Moisture softens the mulch/soil layer, allowing water percolation and seeding emergence. Seed placement is excellent, in that the surface soil/mulch layer meets the depth requirement for nearly all desert seeds.

The basic materials used in hydroseeding, other than seed, are mulch, tackifier, and fertilizers.

Mulch materials produced solely for the hydroseed industry are highly engineered; some are more effective than others. Among the better hydromulches are wood fibers from the byproduct wood chips of the lumber industry. Other materials, such as waste paper, sawdust, wood shaving, and grass clippings, have proven to be only about sixty percent as effective in creating a germination environment. Waste paper tends to flatten, wash out, and compact; the other types in this group lack integrity and wash out easily.

Tackifiers, too, come in a wide range of material types. Some have very effective adhesive and cohesive qualities. Two of the better materials are plantago mucilage and guar-based mucilage. Plantago mucilage is derived from the Indian wheat, *Plantago insularis*. It is a powder that, when mixed with water, forms a sticky, gel-like glue. Tackifiers should be applied to impart good binding characteristics to the slurry as it sets up.

Surface Mulching

Many studies have shown that surface mulching increases soil moisture, and stabilizes the soil temperature. Kay (1978, 1987), compared the effectiveness of a variety of surface mulching materials in terms of temporary erosion control and eventual plant establishment.

Hydromulch used in the seeding process is considered a surface mulch. Hydromulch is in intimate contact with the soil and seed. This is of definite benefit to seed germination but of less benefit in modifying moisture and temperature fluctuation in the soil profile. Hydromulch, therefore, is very good for germination but less so for seedling establishment. During the cool season, hydromulch used as the sole mulch material generally gives as good a result in terms of seedling establishment as straw mulch. Added quality grade tackifiers greatly improve effectiveness. Used together, hydromulch and straw mulch give an excellent combination of erosion control and germination and seedling establishment. It is one of the most cost effective techniques.

Long lived stands of diverse native species have been established using good tillage, diverse site specific seedmixes, and well affixed surface mulching of hydromulch and/or straw mulch. Table 2 lists a seedmix which was used employing some of the techniques outlined here establishing native vegetation along a pipeline corridor where surface soils were drastically altered. After pipeline construction, ammonium phosphate (16-20-0) was broadcast at 200 lbs/Acre. The site was tilled with crawler tractors leaving a roughened furrowed surface. Seed was immediately broadcast. Straw mulch was applied at 2 tons per acre and crimped on 8 inch centers. Today the site is dominated by the species which were seeded. The stand appears as dense as adjacent natural undisturbed areas.

With improved methods and materials and attention to detail, many disturbed sites have been dryland seeded using native species with a long term measure of success. The costs are very low compared with landscaping solutions but higher compared with most past attempts at restoring desert grassland.

Species	**PLS rate lbs/Acre**
Grasses	
Side oats grama, *Bouteloua curtipendula*	3.0
Blue grama, *Bouteloua gracilis*	1.0
Green sprangletop, *Leptochloa dubia*	3.0
Plains lovegrass, *Eragrostis intermedia*	1.0
Sand dropseed, *Sporobolus cryptandrus*	1.0
Plains bristle grass, *Setaria macrostachya*	3.0
Shrubs	
Four wing saltbush, *Atriplex canescens*	3.0
Apache plume, *Fallugia paradoxa*	1.0
White thorn acacia, *Acacia constricta*	1.0
Cat claw acacia, *Acacia greggii*	2.0
Velvet mesquite, *Prosopis velutina*	1.0
Forbs	
Sagewort, *Artemisia ludoviciana*	1.0
Desert globemallow, *Sphaeralcea ambigua*	1.0

Table 2
MULESHOE RANCH SEEDMIX (Seeded -August, 1986)

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Natural Site Conditions and their Effects on Establishment in Grassland Restoration[1]

Margaret Livingston[2]

Factors influencing establishment of three native species of grass, Arizona cottontop, plains lovegrass, and bush muhlenbergia were investigated. Natural habitats of these grasses were examined for conditions favorable to these species. From these observations, experimental plantings were established to test the emergence and establishment of these grasses, and some influences of associated species were determined.

Differences in germination requirements between bush muhly and plains lovegrass were evident and emphasized the importance of coordinating plantings with natural rainfall patterns. Seed retrieval studies revealed bush muhly germinates quickly but seedlings die if soil moisture is not replenished. Lovegrass exhibits variable dormancy and may germinate up to three years after planting. In areas with a summer monsoon season, the rainfall pattern in August provides the most reliable time for plantings of warm season native grasses. Mulch provided the best microhabitat for establishment of these species, compared to small rocks or furrows, by lengthening the time period that soil moisture was available to seedlings. A layer of mulch may also reduce germination of weedy or aggressive species such as Lehmann's lovegrass, which has a light requirement for germination.

Characteristics of sites where these species were established in association with other species were examined, and differences between species were evident. Arizona cottontop was versatile, and plants were found either in the understory or in open areas. In some sites, plains lovegrass was more dense in the open, but in other sites, there was no difference in density between full sun and understory habitats. Bush muhly was always found in greater concentration under canopies provided by mesquite, cholla or creosote, and may choke out creosote in some sites.

Although abiotic site characteristics may appear favorable for seeding a particular species, nearby aggressive species may choke out the desired plant. Land managers must determine ways to control invading species for successful establishment of native plants. Establishment is a lengthy process. Seeded species may remain dormant for several seasons or migrate to microsites that meet their requirements. Irrigation, or other alteration of natural conditions, may provide microsites suitable for native plants that are not usually able to establish in the area.

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Considering Genetic Diversity in Grassland Restoration [1]

Steve Smith[2]

Biodiversity is a multifaceted characteristic of a biological system that may involve the variety of organisms present, the genetic differences among them, and the communities and ecosystems in which they occur. Arranged in a hierarchical fashion, one could consider the patterns and connections between landscapes and regions. The next level of the hierarchy would examine the characteristics of communities and ecosystems such as abundance, frequency and richness, and at the species level, the abundance or frequency of individual species. Genetic diversity would be found at the base of this hierarchial scheme, and although may be the least appreciated of the levels, is the most important. Genetic diversity is the source of variation among and within populations, and is the ultimate source of biodiversity at higher levels.

Examination of model populations of grass species in minimally disturbed sites yields information on community organization and genetic variation for use in restoration. A few sites in southern Arizona have not been exposed to disturbance and serve as good sources of information. For collection of native seed, three rules should be followed to enhance genetic diversity. Restorationists must remember local adaptation to changes in environment may occur over a very short distance, so collections from model populations at or near the restoration site are recommended. The second rule relates to the size of the sample. The probability of sampling the full range of genetic variation present in a population is directly related to the size of the sample, so at least one hundred individuals in the model population should be sampled. Random sampling, rule three, stresses the importance of elimination of bias in the sampling procedure.

Genetic diversity among and within the population is the ultimate source of all biodiversity. Successful grassland restoration depends on selection of reasonable model communities and populations. Samples from model populations for use in restoration should be large, and should be collected randomly. To obtain a truly random sample is complicated, and very little is known about the genetic characteristics of some plants. Collecting an overly large sample may provide an allowance for error.

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Revegetation of Abandoned Agricultural Fields in the Sonoran Desert

Jerry R. Cox[1] and Gary W. Thacker[2]

ABSTRACT

Historical records show that southeastern Arizona was a grassland before 1880. Today, shrubby plants dominate the region. From 1880 to 1920, dramatic changes in the composition of vegetation took place along major waterways. Flooding and the resulting channelization, plowing of the floodplains, and livestock grazing essentially eliminated the natural process of shallow groundwater recharge. The purpose of this paper is to determine why the changes occurred, and determine if the resource can be reclaimed.

INTRODUCTION

Early Descriptions

Early explorers in southeastern Arizona maintained journals describing vegetation. Their records provide descriptions of grazing areas and vegetation prior to 1880:

Santa Cruz Basin. "We were off this morning (from Tucson)...and soon entered a thickly wooded valley of mesquite. A ride of nine miles brought us to San Xavier de Bac...a mile farther we stopped in a fine grove of large mesquite trees near a river, where there was plenty of grass. The bottom-lands resembled meadows being covered with luxuriant grass and but a few trees. The bottoms (between San Xavier and Tubac) in places are several miles wide...and covered with tall, golden colored grass...divided by a meandering stream a dozen yards wide and as many inches deep, this shaded by cottonwoods, willows, and mesquites" (Bartlett 1854).

San Pedro Basin. "The valley of this river is quite wide and is covered with a dense growth of mesquite, cottonwood, and willow. The majority of the valley has good grass...the bottoms having very tall grass. There is excellent trout fishing, but the grass makes travel by wagon very difficult" (Cooke 1938).

Sulphur Springs Basin. "This vast area is without either running streams or timber, but covered to a great extent with fine grass. Approaching Sulphur Springs from the east, the road lies for miles through a dense growth of sacaton grass" (Hinton 1878).

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San Simon Basin. "The valley of the San Simon is...25 miles in width, and contains much fine grazing and some agricultural land. It is covered with gramagrass. Mesquite is most conspicuous and abundant from the base of the mountain (Mount Graham)...and sparse on the mesa...the sacaton and grama cover the plain.... The country abounds in game, such as deer, antelope, wolf, wild turkey, duck and quail" (Hinton 1878).

IRRIGATED AGRICULTURE

Farming in southeastern Arizona was concentrated initially near major lowland drainage areas. Water was taken directly from rivers. This practice was hazardous on the San Pedro River because beaver would build dams in irrigation ditches at night and limit water flow to cropland. During the floods of 1895 and 1900, channel cutting resulted from the combination of farming, wagon trails, and grazing. The soils associated with lowlands were extremely rich because above- and below-ground growth of sacaton added organic carbon and nutrients.

Sacaton grasslands had slowed floodwater, trapped sediment, and enhanced soil fertility on southeastern Arizona floodplains for thousands of years. Once removed by plowing, burning or grazing, there was nothing to slow water movement in the lowlands. The result was channelization.

From 1930 to 1960, irrigated agriculture expanded rapidly in Arizona's southeastern counties (Table 1). Decades of peak acreage were in the 1940's in Cochise, 1950's in Pima and Pinal, and 1960's in Graham and Santa Cruz Counties. During periods of maximum cultivation, about 2.6 million acres were cultivated in the five southern counties; and if the areas farmed in 1980 are subtracted from the peak acreage, then 2.2 million acres of farmland have been abandoned in the past 40 or 50 years. Urban growth and water use in urban areas is predicted to increase dramatically by the year 2030 (Arizona Water Commission 1975). As urban demand for water increases, water will be diverted from agricultural uses, which have lesser value. This means the abandonment of more of the region's farmland, a phenomenon occurring nationally at an estimated average rate of 3 million acres per year (Sheets 1981).

Farmland is dominated by tumbleweed immediately after abandonment, and if undisturbed for 2 or 3 years, tumbleweed is replaced by mustards (Cox and Madrigal 1988). Annuals may be replaced in 3 to 10 years by half-shrubs such as baccharis and burroweed. After 10 years, abandoned fields are usually dominated by widely spaced half-shrubs and shrubs such as creosotebush, saltbush and mesquite.

	Counties - Acres of abandoned farmland					
Year	Cochise	Graham	Pima	Pinal	Santa Cruz	Total
1900	4,990	18,300	8,620	11,300	2,560	45,770
1910	4,900	38,820	10,160	25,430	4,770	84,080
1920	12,980	32,400	16,880	28,650	2,610	93,520
1930	377,010	136,410	280,550	75,740	4,990	874,700
1940	907,700	210,130	293,660	593,930	168,610	2,174,030
1950	359,120	405,610	353,330	871,690	126,210	2,097,960
1960	637,620	492,000	312,520	730,670	185,780	2,358,590
1970	90,920	51,850	50,030	260,110	2,100	455,010
1980	88,630	45,900	47,280	221,610	3,970	407,390
	819,000	446,100	288,050	509,060	181,810	2,244,090

Table 1. Acres of irrigated agriculture in southeastern Arizona between 1990 and 1980 and estimates of abandoned farmland in 1980. Abandoned farmland acres were obtained by subtracting 1980 estimates from peak production years (Cox et al. 1983).

Raindrop impact causes compaction of bare soil which reduces infiltration and enhances runoff, but wind erosion at the present is the most serious problem. In late June, moisture surges from the Gulf of Mexico generate long squall lines in southeastern Arizona. In front of the advancing squall lines, wind gusts approach 70 miles per hour, and visibility may decrease to zero. Dust storms, generated as the squall lines, pass over abandoned farmland were responsible for more than 440 automobile accidents between 1960 and 1980.

The following studies were initiated to determine if perennial plants can be established with irrigation water before water rights are transferred from agricultural to municipal uses, and to evaluate the survival of two grasses (big and alkali sacaton) which dominated abandoned farmland sites prior to cultivation and irrigation.

CAN PERENNIAL PLANTS ESTABLISH AND PERSIST ON ABANDONED FARMLAND?

Studies at San Xavier, Arizona

A study was conducted on abandoned farmland at the San Xavier Indian Reservation, south of Tucson. The site was plowed and sown to cotton or alfalfa between 1933 and 1971 and abandoned in 1972. Reclamation studies were conducted between 1980 and 1986.

A seedbed was prepared by disking in either spring, summer or fall, and seeding 7 perennial grasses. Perennial grass seeds need continuous soil moisture for 7 days to ensure germination, and additional soil moisture within 7 days after germination to ensure establishment. Therefore, grasses received either 0, 1, 2, 3 or 4 flood irrigations at either 0, 7, 14 and 21 days after planting. One-half of each irrigated area was hand weeded at 15, 30, 45 and 60 days after the final irrigation.

Conclusions

The intent of our study was to determine the effects of planting season, supplemental irrigation, and weed competition on the establishment and production of 7 perennial grasses. We found that small seed of "A-68", "L-28", "L-38" Lehmann lovegrass and "A-84" Boer lovegrass were unable to emerge from silty clay loam soil irrespective of planting season, irrigation amount or weed competition; hence, these grasses were unacceptable for reclaiming abandoned farmland (Cox and Madrigal 1988).

"Catalina" Boer lovegrass , and "A-130" and "SDT" blue panicgrass seedlings from seed planted in summer often persisted for 4 months or more after planting, whereas seedlings from seed planted in spring and fall always died in less than 4 months. Our most important finding is that "Catalina" and both blue panic grasses will germinate and produce seedlings under natural rainfall, but long-term persistence was unreliable because plants eventually died. We might have missed this important point and recommended seeding without supplemental water, if the study plan had not included long-term evaluations. Therefore, these grasses are not adapted for planting on abandoned farmland if their survival is dependant on natural rainfall.

Blue panicgrass "A-130" and "SDT" plants, established with 3 or 4 irrigations in summer, will persist for 52 months after planting and weeding to remove annual competition is unnecessary. The steady decline in plant persistence and forage production with time; however, may suggest that neither blue panic grass accession is adapted and both will disappear eventually. Thus, there is the distinct possibility that the methods and plant materials used in this study are not adequate to reclaim abandoned farmland in southeastern Arizona.

Studies at Three Points, Arizona

A second abandoned farmland study was conducted at the Buckelew Farm near Three Points. The site was sown to cotton between 1954 and 1975 (Thacker and Cox 1992). In 1976, the farm was purchased by the City of Tucson, and the water rights transferred from agricultural to municipal uses.

After irrigation water is diverted from agricultural lands to municipalities, wind-borne soil particles from abandoned farmland reduce driver visibility and contribute to vehicle accidents. To stabilize soils, a cooperative study was initiated with the City of Tucson, a local farmer, and the state of Arizona. The City contributed two irrigation wells and 1,000 acres of abandoned farmland, the farmer provided machinery and fuel, and the Arizona Department of Environmental Quality provided a grant. The purpose of the study was to establish perennial crops with irrigation before the water rights were transferred to the City of Tucson, and monitor plant persistence to determine relationships between plant survival, rainfall amount and distribution, and air quality after irrigation was discontinued.

A seedbed was prepared by plowing a sandy clay loam to 18 inches, and disking prior to the summer rains. In this experiment, we broadcast "Catalina" Boer lovegrass, "S-75" kleingrass, "Common" buffelgrass, "Cochise" lovegrass, "Kalahari" bottlebrush grass, and "Hatcheta" sideoats gramagrass seeds in 1986 and 1987, and collected data from 1987 to 1994. Irrigation treatments were flood applications at either 0, 2 applications at 7 day intervals, or 4 applications at 7 day intervals.

Conclusions

"Catalina" Boer lovegrass, "S-75 kleingrass and "Common" buffelgrass seed, germinated after the summer rains, but only "Common" buffelgrass seedlings survived for more than 6 months. Buffelgrass plants established under natural rainfall were still present in fall 1996, but plant densities were less than 1 plant per 9 square ft.

The native grass, sideoats grama, germinated after the initial irrigation, but most plants died before the second application, seven days later. Within 48 months, established sideoats plants began to die, and few plants were present in seeded plots during fall 1992.

"Catalina" Boer lovegrass, "S-75" kleingrass and "Common" buffelgrass seed germinated after the second irrigation, and after 1 year densities and production were similar on plots receiving either 2 or 4 irrigations. By years 2 and 3, "Catalina" and "S-75" densities declined by approximately 50%, but "Common" buffelgrass densities either remained constant or increased. We frequently observed quail feeding in kleingrass plots, and deer and javelina feeding in buffelgrass plots.

Observations in 1992 and 1996 indicated establishment of sideoats grama, three-awns and sand dropseed in irrigated lovegrass and kleingrass plots, but no native grass establishment in buffelgrass plots where plant densities have remained relatively constant for the past 10 years.

Studies at the University of Arizona-Romero Road Farm, Tucson, Arizona

To determine if sacaton could survive on abandoned farmland where water flows from natural drainage had been diverted, 40 big and alkali sacaton collections from sites in west Texas, southern New Mexico, southeastern Arizona and the states of Zacatecas and Chihuahua in Mexico, were transplanted at the Romero Road Farm during spring 1981. All plants were watered in spring, summer, and fall 1981, but only one-half of the plants continued to receive irrigation in summers between 1982 and 1987.

Conclusions

After discontinuing irrigations, all big and alkali sacaton collections died within 24 months.

IMPLICATIONS

Under current soil and climatic conditions it is unlikely that big and alkali sacaton, and sideoats grama will establish and persist on abandoned farmland without the annual application of irrigation water. In contrast, buffelgrass, an introduced perennial from Africa, can be easily established and will persist for 10 years after establishment with 2 or 4 initial irrigations. One important observation was the establishment of native, perennial grasses in plots seeded to kleingrass and "Catalina" Boer lovegrass, and irrigated 2 to 4 times.

We are not suggesting that introduced plants are the only perennial plants adapted on abandoned farmland, even though this does appear to be true. It may be that native plants will establish where introduced plants were initially sown after organic carbon and soil nutrients have accumulated; therefore, it may be possible to establish native plants within introduced stands. We have observed native plants invading fenced stands of Lehmann lovegrass in southeastern Arizona, and Dr. Bruce Roundy and graduate students have documented the establishment of native plants (from seed) in mature Lehmann lovegrass stands. It may be possible to use introduced plants to enhance infiltration and soil nutrients, and then seed natives into introduced stands.

As desert farmland is removed from production and the water rights transferred to municipalities, the new owners will be faced with management problems. To reduce environmental impacts, we recommend the establishment of a permanent vegetation cover before retirement, this will reduce the headaches and liabilities associated with land management. If adapted vegetation is established before retirement, the site will be stabilized with plant cover. Beneficial plant cover will limit blowing soil and inhibit tumbleweeds from dominating the land.

The costs of establishing vegetation are easy to measure, the benefits are more difficult to quantify because they relate to health, safety, and legal issues. The environmental costs of abandoning farmland are in the form of dust pollution, erosion from water runoff, tumbleweeds blowing onto roadways, and automobile accidents caused by blowing dust. In the past, society was either not concerned or not aware of potential environmental impacts from abandoned farmland. Today, however, most are aware of adverse actions, and we in agriculture and municipalities must offer alternatives and incentives to minimize adverse environmental impacts.

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Holistic Reclamation: A Natural Remediation Process Using Cattle and Other Natural Tools

Terence O. Wheeler[1]

Today, I believe that we are all here for the same purpose, at least I hope so. And that is to learn how to use one of our most valuable resources, our grasslands, in a multitude of ways for the betterment of our diverse society and to be able to pass this resource, in a healthy state, on to our heirs.

The National Research Council through the auspices of the National Academy of Sciences completed a new set of guidelines regarding range land health in 1994. In my opinion it is an excellent document. Anyone interested in managing for healthy grasslands should get a copy.

The committee defined "Rangeland Health" as the degree to which the integrity of the soil and the ecological process are sustained.

More specifically, the committee recommends the term "Rangeland Health" be used to indicate the degree of integrity of the soil and ecological processes that are most important in sustaining the capacity of the rangelands to satisfy values and produce commodities. In other words folks we need these healthy rangelands to not only be able to support healthy plant and animal communities but support the economic needs of our communities through grazing and other uses as well.

We are fortunate today to have on our panel two members of the committee that labored for several years to produce this document, "Rangeland Health". They are my friends Kirk Gadzia and George Ruyle.

The Title of Our Conference is "The Future of Arid Grasslands" As far as I am concerned the future of arid grasslands is solely up to us. We can make them be what we want them to be. We need to set our goals and manage toward these goals. We have all the tools at our disposal.

This morning I will show you how that can be done and on sites that are much worse than any grassland you will ever see. These sites are at their lowest point of successional development. These sites are mine tailings.

For many years people believed, and still do, that mine tailings were toxic piles of poisonous dirt. That they were problems to be solved. And for years we have tried to solve these problems using lots and lots of money with almost no lasting effect.

In 1986 it occurred to me that we were looking at the wrong thing. That we were not dealing with a toxic problem. We are dealing with an ecological phenomenon . Mine tailings are no more than pulverized rock with the minerals removed, one of the primary ingredients for soil. Once we begin to realize that we are working with an ecological condition the rules change, and we can begin to deal with the situation in a positive manner.

In today's complex world where competition for space on the earth's surface is increasing by the day it is mandatory that industry, even though essential economically, be responsible for cleanup of aftermath or residue of an industrial process. For many years the knowledge of this cleanup wasn't readily available, was too costly, wasn't effective, or a combination of these. Stability on reclaimed

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[1] Arizona Ranch Management, Globe, AZ..

sites has always been problem but today there has been a break- through that can cost effectively handle most of these problems. The ability for nature to repair itself has been part of the natural process since the beginning of time. We can now stimulate and speed up this natural process through the planned use of ruminant herbivores, particularly cattle, and other natural tools in context with applied technology.

Mining, next to agriculture, is probably the single most economically important industry not only in our nation but around the world. Yet in today's complex society these two disciplines are so interdependent on one another, as well as other disciplines, that it is often difficult to determine where one discipline starts and the other leaves off.

This is certainly the case with reclaiming land affected by mining and other industrial processes. Because these lands are a natural environment they are dependent on several agricultural disciplines to be to be successfully reclaimed even though much of the success of reclamation work depends on work of a mechanical nature and other technology.

Natural environments are dynamic and when stimulated will progress or regress successional as determined by an influence, whether that influence be mechanical, natural or a combination thereof. Therefore, natural progression toward successional more complex and diverse plant and animal communities can be achieved through the application of appropriate planned influences.

Knowing this, it is then possible to predetermine a reasonable future landscape description and then attain it by stimulating the natural process through the application of selected management tools in a timely manner.

Tools of management can be divided into two major categories; they are the natural tools (tools of nature) and tools of technology (mechanical tools).

During the mechanical revolution, especially in agriculture since World War II, the development of technology has been so fast, great and overwhelming that most of us in the natural fields have all but lost touch with the natural process. As a result we tend to look almost totally to technology for the answer to solve natural problems of agriculture and it's related fields including reclamation. We do this when in actuality these fields are dependent on the natural process for not only success; they are dependent on the natural process for their very existence. We rely on the mechanical process and then wonder why success ratios with natural resource projects are so low as well as costly.

To compound the problem, Federal and State policies regulating reclamation more often than not create rules that stymie the use of a natural process to improve natural conditions. This can be a result of ignorance, a faulty paradigm, or a lack of knowledge regarding ecological processes. Many times, however, policy is influenced by big business in order to create markets for technology. A perfect example of policy influenced by big business are weed control laws in many states. These laws force the use of costly chemicals to control weeds that seldom present a problem where there are good farmers because they can be controlled by cultural methods. The result is that much money has been spent, water, soil, people, domestic animals and wildlife have been damaged by chemicals and the weed problem is worse than before spraying because natural control systems have been poisoned and cultural control practices have been abandoned in favor of the chemical control.

The fact that we in the U. S., can, today, enjoy a prosperous economy buoyed by plentiful foodstuffs at the worlds lowest prices is not the result of superior agronomic skills based on intellectual! y superior natural resource knowledge. No, it is because we have the cheapest availability of fossil fuel combined with the most advanced and superior engineering capabilities the world has ever known. And although, on the face of things, agriculture and its many related fields are seemingly prosperous, a closer look will disclose that they are not. Soils once stable and fertile have been mined of their organic matter and are highly vulnerable to erosion. These soils are now dependent on vast amounts of chemical fertilizers to produce at all. The use of insecticides is at an all time high while at the same time insect problems are also at an all time high. Water is becoming contaminated with fertilizer, insecticide and herbicide residues. And because of these problems with technology, flawed governmental policies, and reduced use of natural practices we have wiped out a profit margin, have ruined many thousands of acres of productive land and have lost entire land based communities.

I have used this scenario to lay the groundwork for what I see as a mounting problem in the field of natural resources particularly as it refers to reclamation. We are now employing the same management paradigm, that is killing us in agriculture, to vegetate and stabilize, the worst case scenario, mine tailings.

Technology is neither good nor bad, but in itself is not the answer. Technology is just a large array of tools that if used in the right context can produce beneficial results. Many of today's resource problems would not exist if technology were used more judiciously.

Natural tools include rest, fire, grazing, animal impact, and living organisms. All except fire have been successfully employed in the new methodology termed "Holistic Reclamation" of using cattle for reclamation. The use of all of these tools, as well as technology, is part of a process that starts with the development of a three part goal. One part of the goal is a future desired natural landscape description that is managed toward, instead of creating an artificial landscape out of step with nature and, therefore, not sustainable.

Tailings are no more than ground up rock, the product of a mechanical process but basically no different than soil particles that resulted from a geological grinding process. The only real difference between the two mediums, i.e. soil and tailings, is the presence or absence of life. Mechanical stabilization more closely resembles a hydroponics unit than a natural stage of succession, and in order to produce stability on tailings the natural process must be stimulated, by an outside source, to produce a diverse and complex landscape. The missing ingredient was life, particularly the micro-organisms that decay plant material and provide the nutrient base for plant growth and soil development.

The most obvious source of this type of micro-organism was ruminant animals such as cattle. These microbes along with important enzymes, minerals and other nutrients are passed through the animal with the manure to provide life to the soil. This would be an excellent source of life for the tailings. Cattle and other grazers have other benefits as well. They provide the outside stimulus through hoof action which is extremely important for several reasons. It breaks the bare tailings surface creating miniature dams or air spoils that reduce air turbulence on the surface thereby reducing wind erosion. Farmers in the plains states learned this concept many years ago and when the winds began blowing dry bare fields they plowed them to provide the roughened surface to retard soil movement. When hoof action breaks soil capping it also prepares the surface to accept rainfall. It can prepare the seed bed by incorporating mulch (organic material) into the tailings surface, further stabilizing it, and planting the seed.

Cattle also remove old growth during the grazing process. This allows sunlight to penetrate to the growth points of a grass plant, located near the base of the plant. This stimulates new growth and promotes the health and vigor of the plant. This concept has proven to be exceptionally important in the maintenance of reclaimed tailings.

In the last six years approximately 800 acres of mine tailings have been reclaimed using this method by several mining companies working with Arizona Ranch Management, Globe Arizona including Cyprus, Magma, ASARCO and Kennecott.

Holistic Reclamation is also capable of solving several other problems that haunt traditional reclamation methods. For example, while many consider highly acid pyretic tailings nearly impossible to reclaim, this method can raise the pH level over two points. The micro-organisms incorporated into the tailings along with the mulch and straw create humic acid which raises pH and provides an environment for plant growth. In the process the blanket effect of the mulching robs the acid producing microbes of the oxygen necessary for them to function.

Although each reclamation effort is site specific and each offers different challenges, Holistic Reclamation methodology is flexible in its approach and makes the difficult process of reclaiming arid southwestern tailings more manageable. Failed reclamation projects of the past are being repaired and current mine operations have a more cost effective alternative to soil capping, hydro-mulching, fertilizing, seeding and irrigating. Above all this new management concept produces stable sites.

An unexpected but welcome side benefit of this management methodology is the wildlife. Tailings reclaimed in this manner have become magnets for wildlife of every size and description. Fauna observed on tailings dams in association with cattle include deer, javelina, coyotes, fox, other predators, burrowing animals, insects, raptors including bald and golden eagles and water fowl.

In conclusion, we have learned that using the hoofed animals the microorganisms and other natural tools along with the planned used of technology has given us the ability to produce stability on sites that were thought to be too sterile and toxic to produce life. This process is being done in a cost effective manner that precludes expensive soil capping. Tailings material is being converted into living soil with the capability of not only sustaining life, but developing to higher stages of successional plateaus to support diverse plant and animal communities.

Planting Giant Sacaton: Initial Results at Cienega Creek Natural Preserve

Julia E. Fonseca[1] and Ronald L. Tiller[2, 3]

INTRODUCTION

Giant Sacaton (*Sporobolus wrightii*) is a bushy, perennial grass that once was common along the floodplains of major river systems in southeastern Arizona (Humphrey 1958). The type locality for the species, as described in 1882 by C. G. Pringle (Hitchcock, 1971), today is found within the Cienega Creek National Preserve, within an abandoned farm field that is now the site of a revegetation project.

The field was selected for revegetation to improve wildlife habitat along an otherwise extensive riparian corridor. The site is being rehabilitated with funding from the U.S. Fish and Wildlife Service s Partners for Wildlife Program and the Arizona Game and Fish Department's Stewardship Program. Sacaton was selected as one of the species to plant because it was present at the site in 1972 (Lacey et al., 1975), and because the project team hoped that it could be established without irrigation. Only a few isolated sacaton plants have established in the 40-acre (16.2 ha) field since it was cleared in 1974.

SITE DESCRIPTION

The field is located in Township 16 South, Range 17 East, Section 35, at an elevation of approximately 3550 feet above mean sea level. Soils at the site are predominantly silt loams, with gravelly loams present at the southern margin of the field. Slopes are generally from 0 to 3%. Annual rainfall is approximately 14 inches.

The site's mesquite woodland was removed in 1974 using chainsaws and bulldozers; a root plow was used to remove stumps (Neal Hanna, personal communication). For the first several years, alfalfa was grown under irrigation. Bermuda grass (*Cynodon dactylon*) was then planted for livestock forage. Bermuda grass is still the dominant perennial plant at the site. The site was grazed by cattle until its acquisition by Pima County Flood Control District in 1988. The field was grazed by five horses from 1989 to May 1996.

METHODS

Archeological trenching at the site revealed the presence of buried pithouses and other features below a 1-foot (0.3 m) deep plow zone. Because the State Historic Preservation Office prohibits planting deep-rooted trees or shrubs above archeological sites, sacaton was one of the few plants suitable for these sensitive areas.

Sacaton seeds were collected in the Preserve by Arizona Native Plant Society in October 1995.

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The collecting site was located approximately one mile south of the field, along an ephemeral reach of Cienega Creek, where sacaton grows on infrequently flooded terraces with velvet mesquite *(Prosopis velutina)*, desert willow (*Chilopsis linearis*), and bush muhly (*Muhlenbergia porteri*).

The sacaton seeds were germinated by a local (Coronado Heights) nursery in April and June 1996 in flats in a shaded outdoor structure. One to three seedlings were transplanted into 4-inch and 14-inch deep containers. Half of plants were grown in the 14-inch by 4-inch container size. USFWS funded the seedlings at a cost of $0.80 and $1.85 per container, respectively.

A mid-August planting date was chosen to take advantage of higher humidity and soil moisture generally present during the summer monsoonal season. One week prior to planting, inspection of the soil profile demonstrated that rain had moistened the entire soil profile to a depth of 14 inches (Figure 1). On the day of planting, the top six inches of soil appeared dry in many of the planting sites. An automated rain gauge located approximately one mile from the site was used to monitor rainfall.

On August 10, 1996, 45 volunteers planted approximately 670 seedlings of sacaton over an area of approximately three acres. Groups represented at the event include the Audubon Explorers Post, Pima County Adult Probation, Southwest Center for Biodiversity and Arizona Native Plant Society. Two one-person gas-powered soil augers with 6-inch bits were used to drill holes for the deeper containers, otherwise seedlings were transplanted into holes dug by hand. All plants were planted and hand-watered in four hours.

On August 11, a crew of 10 volunteers watered the seedlings again by hand and planted several additional remaining containers. Because of slow infiltration rates, few plants received more than three liters of water during each watering. Pinflags marking clusters of plants and small, hand-dug basins helped to identify seedling locations.

Volunteers were encouraged to plant seedlings in clusters, with each plant no closer than four feet. The objective of clustering was to speed the creation of patches of the dense, upright sacaton for wildlife purposes. The clustering also helped locate individuals for subsequent watering. Volunteers were encouraged to plant the seedlings in natural swales in the belief that survival might be higher in the swales, but other, more xeric microsites were also chosen.

As part of a larger research effort funded by the Arizona Water Protection Fund, data on a number of vegetative characteristics of the transplants is being collected by the junior author. The goal of the monitoring effort is to facilitate an ongoing study of the ecology and recovery potential of *Sporobolus wrightii* to abandoned agricultural fields in southern Arizona. Other sites being monitored are along the San Pedro River.

Eighty-six transplants were marked for monthly monitoring, 39 of which are the smaller container size. Characteristics being measured include basal area, height of tallest leaf, phenological stage and development, topographic position (swale, alluvial fan, or level ground), and percentage of vegetative cover within a 1 ½ foot (0.5 m) radius.

PRELIMINARY RESULTS

Approximately 0.3 inches of rain fell on August 11. By September 11, a total of 3.5 inches of rain had been received (Figure 1).

By the end of December, only two of the 86 individuals had died. Both of these were from small pots (n=39). Both of these mortalities were evident by late October. With this low mortality rate, the influence of topography on survival is not evident. Thirty percent of the individuals grown from 14-inch containers flowered since planting. Flowering is typically preceded by development of several new shoots. Nearly all of the plants had senesced by late December. Plants in the swales appear to senesce more slowly than plants in other topographic positions. Larger plants maintained higher basal diameters than small plants. Although no statistical tests have been performed yet, plants growing in gravelly soils of the alluvial slopes appear to have grown more than individuals located in swales or on level ground.

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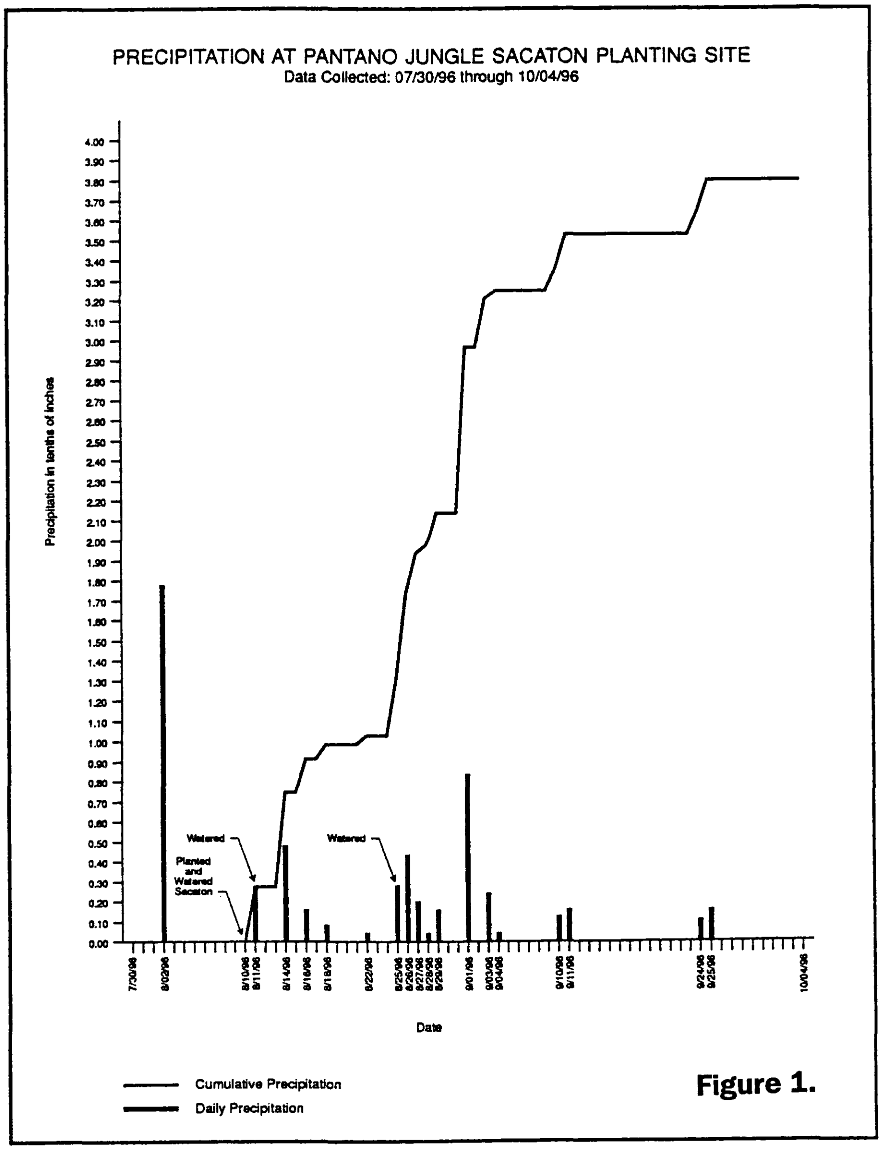

Figure 1.

Arbuscular Mycorrhizal Fungi, a Possible Tool for Restoration of Giant Sacaton Grasslands

Linda Kennedy Elliott[1], Jean C. Stutz[1], Ronald L. Tiller[2] and Juliet C. Stromberg[2]

Sporobolus wrightii Munro ex Scribn, giant sacaton, is a perennial bunchgrass found only in southwestern North America. Once a dominant species on upper terraces of riparian zones, giant sacaton is now restricted to only 5% of its original range as upper floodplain terraces were converted to agricultural use (Stromberg 1993). Recent changes in land management goals have generated interest in returning these sites to grasslands. However, many restoration attempts have been unsuccessful, and natural succession has been slow.

Inoculation with arbuscular mycorrhizal (AM) fungi has been an effective tool of restoration projects in many ecosystems. Many plants and AM fungi form mutualistic relationships within roots that provide benefits to host plants including enhanced nutrient status, increased drought stress resistance and heightened resistance to soil borne pathogens. Mycorrhizae form when plant roots are colonized by AM fungal hyphae from germinating spores or an existing hyphal network in the soil. This hyphal network exploits the soil matrix and serves as conduit for nutrient flow into roots of plants that are facultatively or obligately dependent upon mycorrhizae. Erosion or a history of tillage and pesticide use, conditions common in former agricultural fields, may disrupt this hyphal network (Johnson and Pfleger 1992). Some species of plant (i.e. Brassicaceae, Chenopodiaceae) are not dependent on mycorrhizal associations for nutrient uptake, thus are able to establish quickly in disturbed areas. Revegetation of later seral species of plant that are dependent upon mycorrhizae may not be successful until an effective AM fungal network is present.

It is important to determine the role of mycorrhizae in giant sacaton before inoculation with AM fungi is considered as a tool in restoration or revegetation projects, because effectiveness of AM fungi varies with species of plant and because populations of AM fungi from separate geographic locations have different impacts on plant hosts (Koide and Schreiner 1992). Our study of the mycorrhizal ecology of *Sporobolus wrightii* has three objectives: (1) determine levels of AM fungal colonization within giant sacaton roots from different habitats, and at different phenological stages of the host plant, (2) identify AM fungal species present in the rhizosphere of giant sacaton and (3) quantify the effectiveness of AM fungal inoculation on emergence, survivorship and growth of *S. wrightii*.

Objective 1: Giant sacaton plants in the riparian zone of the San Pedro River in Arizona were sampled six times in 1995 to determine differences in levels of AM colonization between habitats and between phenological stages of the host plants. Samples were collected from two sites on upper floodplain terraces where remnants of sacaton grasslands still exist, and from two sites on

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	Feb	Mar	May	Jul	Sep	Dec
Total Colonization[a]						
Lower Terrace	90.8±14.4	110.9±13.2	91.0±10.3	66.3 ± 7.9	61.5±11.3	65.3± 9.9
Upper Terrace	58.7 ± 9.6	68.8±10.2	59.6 ± 8.2	63.5±11.7	26.1± 4.1	32.9± 5.9
% Relative Moisture[b]						
Lower Terrace	42.6	46.6	27.7	21.8	29.9	29.5
Upper Terrace	41.1	37.9	21.2	20.3	17.7	18.7

Figure 1. Levels of AM fungal colonization within the roots of Sporobolus wrightii from upper and lower floodplain terraces of the San Pedro River. Phenological stages of the plants were assessed as: Dormant (D), Intermediate (I), Vegetative (V), Panicle (P), or Mature (M). Colonization varied significantly between upper and lower terraces (Pr>F 0.001) and between sampling periods (Pr>F 0.0004). n=24

lower floodplain terraces where *S. wrightii* grows in scattered clumps. Roots and soil were removed from the base of each plant with a soil auger and transported to laboratory facilities. Phenological stage of each plant was assessed and percent relative moisture of each soil sample was determined. Sections of root were cleared and stained (Kormanik and McGraw 1982) and levels of colonization were evaluated (McGonigle *et al.*, 1990).

Levels of AM fungi colonizing roots of *Sporobolus wrightii* varied significantly over an annual period (Table 1). Variation in total colonization of giant sacaton between sampling periods (Figure 1) may reflect changes in the phenology of *S. wrightii*, a perennial bunchgrass which exhibits a period of dormancy or near dormancy during winter. Colonization of roots during this stage of phenology may indicate parasitism by AM fungi. Early in spring, giant sacaton becomes photosynthetically active, evidenced by growth of new leaves, and an increase in total AM fungal colonization was observed. Elevated levels of AM fungal colonization may indicate increased demand on the fungi by the host plant to supply nutrients for actively growing tissue. The prolonged decline in total colonization during anthesis and seed maturation may indicate carbon allocation to the plant reproductive effort at the expense of the fungal symbiont (Koide and Schreiner 1992).

Sporobolus wrightii on lower floodplain terraces exhibited significantly greater total AM fungal colonization compared to plants on upper terraces (Table 1, Figure 1). This does not indicate mycorrhizal associations are less important to giant sacaton in drier habitats. Contributions of AM fungi in semi-arid conditions may be critical to the fitness of the host plant, and geographic isolates differentially affect water relations of the same species of plant.

Objective 2: AM fungal species are identified using characteristics of spores. However, not all AM fungal species sporulate under field conditions, or a species may sporulate at such low levels that detection in field samples is difficult. Several generations of trap cultures (Stutz and Morton 1996) from field soil cores are necessary to determine species composition. Trap cultures have been established using field soil cores from the above sites, and from riparian zones of other rivers in Arizona. Each trap culture is maintained in a glasshouse on the Arizona State University campus. Preliminary results indicate spores from several species of *Glomus* and *Acaulospora* are present in the rhizosphere of giant sacaton. Living cultures of AM fungal populations from each site have been established which may be used as inoculum for additional glasshouse and field restoration research.

Objective 3: *S. wrightii* seed has been collected and will be planted in soil from an existing giant sacaton grassland that has been autoclaved to destroy any fungal propagules. Twenty pots will receive AM fungal inoculum from the rhizosphere of giant sacaton on an upper floodplain terrace, 20 pots will receive inoculum from a lower terrace and 20 pots will serve as control. Effectiveness of AM fungal inoculation will be quantified as the difference in emergence, survivorship, and growth between plants grown with and without mycorrhizae and will be determined experimentally along a gradient of phosphorus availability. This experiment will be concluded in February, 1997, when all plants will be harvested.

If populations of AM fungi that promote growth or survivorship of giant sacaton are determined, land use managers may enhance revegetation projects by introduction of these fungal populations into abandoned agricultural fields. Mycorrhizal associations may serve as a biotic fertilizer, reducing the amount of time, seed and fertilizer needed to return upper floodplain terraces to sacaton grasslands. This study will increase our understanding of relationships between AM fungi and *Sporobolus wrightii,* and provide baseline data for further studies that may aid restoration and recovery efforts of this valued and fragile ecosystem.

	Feb	Mar	May	Jul	Sep	Dec
Total Colonization[a]						
Lower Terrace	90.8±14.4	110.9±13.2	91.0±10.3	66.3 ± 7.9	61.5±11.3	65.3± 9.9
Upper Terrace	58.7 ± 9.6	68.8±10.2	59.6 ± 8.2	63.5±11.7	26.1± 4.1	32.9± 5.9
Vesicles[a]						
Lower Terrace	14.9 ± 4.0	18.4 ± 5.0	17.5 ± 5.9	14.0± 3.8	13.3± 3.7	5.4± 1.3
Upper Terrace	9.6 ± 2.6	8.2 ± 2.3	7.0 ± 1.5	9.3± 1.8	4.5± 1.1	3.4± 0.9
% Relative Moisture[b]						
Lower Terrace	42.6	46.6	27.7	21.8	29.9	29.5
Upper Terrace	41.1	37.9	21.2	20.3	17.7	18.7

[a] Units are mean number of intersections exhibiting AM fungi per 200 intersections of root (McGonigle *et al.* 1990) ± SE

[b] Calculated as (net dry weight of soil - net dry weight / net saturated - net dry) X 100

Table 1. Arbuscular mycorrhizal colonization of *Sporobolus wrightii* and the mean % relative moisture of soil samples from floodplain terraces of the San Pedro River, AZ. Significant differences between upper and lower terraces were noted in total colonization, presence of vesicles, and % relative moisture of soil (Pr>F 0.0001, 0.0039, 0.0029 respectively). Levels of total colonization and % relative moisture were significantly different between sampling periods (Pr>F 0.0004, 0.0001). n = 24 for colonization.

ACKNOWLEDGMENTS

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Mineland Reclamation in Arid Environments[1]

Stu Bengson[2]

Mine reclamation involves the establishment of a healthy, self-sustaining ecosystem from severely altered substrate materials. Restoration of a site to the condition prior to mining disturbance is not a practical goal due to extensive disturbance of substrate and soil surface. Reclamation of mineland must focus on stabilization of the site and establishing conditions whereby the evolutionary processes which are part of a natural ecosystem may begin.

Mine tailings have no soil characteristics, but will support vegetative growth if managed carefully. Stabilization of the tailings and establishment of vegetation may be enhanced by spreading a layer of crushed rock over the surface of the tailings, creating microhabitats suitable for plant growth. Revegetation is faster if topsoil is available to spread over the tailings followed with hydroseeding and mulching with prairie or native hay. Prairie hay is preferred as a ground cover because the hay lays flatter than a straw mulch, includes seed and will last for years if properly tacked. Irrigation must be supplied as needed. This program has yielded productive and viable ecosystems, but the cost may range up to $25,000 per acre.

Native grasses do not fare well in projects which call for revegetation directly onto mine tailings without a soil layer. Native grasses have evolved with native soil and native soil microorganisms, components that are lacking in mine tailings. It is possible to use exotics to stabilize the sites, which then allows introduction of natives. Four-legged organic soil growers, otherwise known as cows, may be used to enhance revegetation roaming on sites where native hay or alfalfa has been spread. The cattle work the organic material into the surface, creating microsites on the tailing slopes. Their manure may be a source of seed, and provides germination sites and nutrients for growth. This starts a progression of annual grasses and forbs which may be grazed off, allowing perennials to become established.

In 1983 and 1984, reclamation of a site was begun with a topsoil spread of 6 inches over mine tailings. Livestock was turned onto the site for six months, after which two exotics and four natives were found. The soil surface was covered with vegetation. One factor which promoted this rapid growth was breakage of the soil crust by the cattle, promoting seed germination and emergence.

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[1] Summarized by Linda Elliot, Botany Department, Arizona State University, Tempe AZ.

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Revegetation of Native Grasses at a Mojave Desert Gold Mine [1]

Raymond Franson[2]

Cattle were introduced to the east Mojave Desert in the 1880's, and records indicate the vegetation was mostly grass, shoulder high by some accounts, with some herbs. Gold was discovered in 1906, and mines were established in areas already altered by grazing. The influx of miners, and the resultant effects of cattle drives to provide beef to the miners may have created even more disturbance. Currently, the area must be considered borderline habitat for grazing, as the land will only support one cow per 1000 acres.

At this elevation, 4300-5000 feet above sea level, there are reportedly 175 species of native plants, but many are rarely found. The rainfall pattern differs from that of Arizona, as most of the eight inches of mean annual precipitation falls in the winter months. Seed set in a given year is undependable, and successful establishment from seed is rare. These conditions, coupled with degradation from cattle and mining, make revegetation projects in the Mojave particularly challenging. Propagation of seed in a greenhouse, from plants collected locally, is an important element in revegetation of these mine sites, as is a salvage nursery for plants removed from sites that are slated for mining activities.

Grasses present a special suite of problems for revegetation. Many rarely set seed in native habitats. Propagation under greenhouse conditions is possible, but successful live plantings are very difficult, even if the plants are hardened off. Supplementation of sparse natural rainfall with irrigation brings salts to the surface. The planting substrate is crushed rock, so there is no topsoil to provide appropriate growth media for grasses. Without topsoil, there is no mycorrhizal network to provide nutrients to the grasses. These conditions, although unfavorable for grass, are conducive to the establishment of some exotics, namely Russian thistle.

Although many regulators now insist on the use of vesicular-arbuscular mycorrhizal fungi as a component of revegetation projects, most land use managers are not qualified to determine the appropriate fungal population for a given site, and may become victims of unscrupulous contractors. Independent assessment of the mycorrhizal component of a revegetation program may prevent abuses.

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Land Imprinting for Restoring Vegetation in the Desert Southwest[1]

Robert M. Dixon and Ann B. Carr[2]

ABSTRACT

During the past two decades land imprinting has been used to restore perennial grasses on 20,000 hectares of degraded rangeland in southern Arizona alone. Using homemade imprinters, several ranchers have profited from the greatly increased forage produced by the restored grasses. Elsewhere in the Desert Southwest, imprinter seeding has been directed to ecological restoration of native ecosystems. Seed mixes of early, mid and late seral species have been germinated in soil imprints at several locations in the Sonoran, Colorado and Mohave Deserts. V-shaped imprints funnel seed, rainwater, eroded soil and plant litter together where these resources can work in concert to germinate seeds and establish seedlings. Imprinting has established vegetation successfully on degraded land areas where annual precipitation ranges from 3 to 14 inches. The imprinting technology is currently being extended to the revegetation of steep slopes to control erosion and sedimentation. Future developments will be directed to using imprinting in wetland restoration.

INTRODUCTION

Revegetation is needed in the Desert Southwest to replace the perennial grasses nearly eliminated by a combination of cattle grazing and drought (Roundy and Biedenbender 1995). Loss of the grass cover has greatly decreased rainwater infiltration and increased water runoff, erosion, flash flooding and sedimentation. Reduced recharge of upland aquifers has lowered water tables, thereby reducing or stopping the flow of springs and streams.

Currently, rangeland revegetation objectives are changing to meet the needs of society. This is especially true for public lands managed by the U.S. Forest Service and the Bureau of Land Management. There is greater emphasis on ecological restoration for biodiversity, wildlife and recreation. Revegetation approaches have changed to achieve these new goals. When increased grass forage production was the principal goal, classical agricultural wisdom was applied, whereby existing vegetation was destroyed using a variety of mechanical and chemical methods to eliminate competition with the grasses to be seeded. Often the final plant community was essentially a monoculture of an exotic grass such as Lehmann love grass (*Eragrostis lehmanniana*). Thus the complex, although degraded, existing ecosystem was converted to a simple agricultural ecosystem of exotics including Eurasian livestock--usually cattle. Exotic grasses were not only easier to

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[1] Presented as a poster.

[2] The Imprinting Foundation, Tucson. AZ.

establish in the degraded rangeland, but also could cope better with the intense grazing of large exotic ungulates, having co-evolved with them in Africa and elsewhere.

RESULTS AND DISCUSSION

The new land treatment process, land imprinting, has been under development since 1976 when the first imprinter was fabricated in the machine shop at the USDA's Walnut Gulch Experimental Watershed which surrounds Tombstone, Arizona (Dixon and Simanton 1977) Development of this new method has been driven by two needs. First was the fact that the rangeland drill, often considered the best conventional method, was only marginally successful about one time out of ten. And next was the growing need for a method that would restore perennial grasses without destroying the existing vegetation; i.e., an effective method for inter seeding the missing ecosystem component.

Imprinter seeding, when done properly, has been successful about nine times out of ten both for increasing forage production and ecological restoration. The greater success of imprinting relative to drilling was attributed to greatly improved control of rainwater at the soil surface (Dixon 1990). Ranchers, using homemade imprinters, have inter seeded perennial grasses on some 20,000 hectares of degraded rangeland in southern Arizona, alone.

Failure of imprinter seeding has almost always been directly attributable to either poor imprints or poor seed or both. Poor imprints result from the use of substandard equipment and/or operating procedures. Poor imprints are those which are relatively shallow and/or unstable. Poor seed can have a number of causes, but perhaps the most common one is insufficient pioneer species in the seed mix to improve the microenvironrnent enough to help in the establishment of later seral species. These pioneer species serve as cover, nurse, mulch and green manure plants. They are especially needed where the land has been severely disturbed and the revegetation objective is ecological restoration.

Shallow or partial imprints result from a poorly designed imprinting roller, insufficient imprinter ballast or extremely hard soils. Ripping to soften extremely hard rangeland soils should not be done as an alternative to adding more imprinter ballast unless the imprinting pressure required for an adequate imprint exceeds 345kPa (50 psi.). Another alternative is to wait until a rain has softened the soil an approach especially appropriate for fall seeding of rocky rangeland soils.

Imprint instability may be caused by initial till age, lack of surface cover such as plant litter or gravel and coarse (sandy) soil texture. Time of imprinting also affects imprint stability. Fall imprinting is recommended because of the prevalence of gentle rains which settle and stabilize the imprint geometry. A rapid-growing cover crop of cool season annual grasses will further stabilize imprints before they are exposed subsequently to the highly erosive summer monsoonal rainfall. Special care should be taken to stabilize imprints in sandy soil which tends to be inherently unstable. Till age prior to imprinting should be avoided as it regresses the secondary succession back to the starting point or to a thick stand of severely competitive pioneer plants. Such till age, not only kills desirable plants, but also severely disrupts the soil ecosystem which otherwise would facilitate the establishment of perennial grasses and ecosystem restoration. Disruption of cryptogamic crusts, mycorrhizal fungi and invertebrate communities is especially harmful to the natural functioning of soil ecosystems. Till age also accelerates oxidation of organic matter and the breakdown of soil structure.

Increasingly, imprinter seeding is being directed to ecological restoration of desert savannas instead of grass forage production. Good seed mixes are fundamental to the success of such projects. Failure or limited success is often the result of not using enough early seral species. They stabilize and improve the soil for later seral species. Two large scale projects in the Sonoran desert near Tucson, Arizona will serve to exemplify the general approach to ecological restoration of severely degraded land through imprinter seeding (Dixon and Carr 1993).

In the first project, an 8-km stretch (240 ha) of severely disturbed floodplain along the Santa Cruz River was imprinter seeded during November 1987. The disturbed floodplain had been leveled, straightened, and walled to allow housing development within most of the outlying historic floodplain. Revegetation was required to mitigate the hydrologic effects of reshaping the floodplain including accelerated flow of floodwater, floodplain erosion, and downstream sedimentation. In the second project, a strip of severely disturbed land in the foothills of the Tucson mountains was seeded during November 1991. The 80-ha strip, 11 km in length, was disturbed during the installation of a large underground aqueduct by the Central Arizona Project to supply irrigation water to the San Xavier Indian Reservation. Complex native seed mixes, which were used at both project locations, included early, mid and late successional species to help accelerate the secondary succession toward a stable plant community with biodiversity equal to or greater than relatively undisturbed nearby areas. Thick stands of exotic weeds, present at the time of imprinting at both locations, served well in the roles of cover, nurse, mulch and green manure. Imprinting converted these weeds into a water saving, soil enriching mulch partially imbedded in the faces of the imprint. Many species within the seed mix responded rapidly to the imprinted seedbeds and seedling cradles. Consequently, plant communities at both locations are progressing rapidly toward the biodiversity goal. The V-shaped imprints funnel resources together at the imprint bottom where they can work in concert to germinate seeds and establish seedlings. The imprints also protect small seedlings against the desiccating effects of strong winds and hot sunlight to help them get their roots down before they have to face the severe macro climate above. The relatively long life of imprints and natural seed dormancy greatly increase the chances for imprinting success relative to conventional drilling of seed. Thus, imprints and seeds can last through several years of drought and still function to germinate seeds and establish seedlings when the rains finally come.

Land imprinting arose from extensive infiltration studies which found that degraded/desertified land surfaces become smooth and sealed and as a consequence shed most of the rainwater instead of infiltrating it (Dixon, 1995). Imprinting was conceived as the most benign method possible for restoring the surface micro roughness and macro porosity to, in turn, accelerate infiltration and revegetation processes (Dixon and Simanton 1977). Imprints are formed by downward acting forces (much like foot and hoof prints) without soil surface inversion, uprooting of plants, covering of plant materials, and destruction of cryptogamic crusts, mycorrhizae and soil invertebrates. Imprints are well-firmed and well-formed V-shaped pockets which funnel rainwater, plant litter, splash eroded soil and seeds together where these resources can work in concert to germinate seeds and establish seedlings (Dixon and Carr 1994). Since the imprints are small closed micro watersheds (usually about 30-cm square) they do not bleed resources downslope as do the furrows of conventional methods such as drill seeding. Thus, imprinting goes a long way toward achieving the long held conservation goal of holding soil and water resources in place to maximize biomass production while maintaining and building topsoil for sustainable productivity indefinitely into the future.

SUMMARY AND CONCLUSIONS

Imprinter seeding is highly successful in the Desert Southwest for increasing grass forage production for livestock and for restoring ecosystems for biodiversity, wildlife and recreation. However, these goals are often somewhat incompatible and thus cannot be achieved to the maximum degree on the same land area at the same time.

Correct use of the new imprinting technology requires a marked departure from conventional agricultural wisdom for growing annual crops and the application of ecological principles for accelerating secondary succession of plant communities following land disturbances.

Common problems and mistakes which limit the success of imprinter seeding include:

1. Poorly designed imprinting roller.
2. Prior till age for weed and brush control.
3. Inadequate ballast for a full-tooth imprint.
4. Operating imprinter in wet soil that sticks to the imprinting teeth.
5. Failure to rip soil that has been deeply compacted by heavy equipment.
6. Seed mix with insufficient early seral species present to accelerate the secondary succession

Finally success in imprinter seeding as in most no-till methods requires perseverance and the belief that it will work if done properly (Orchard 1996). It's not so much a question of whether imprinter seeding will work, but rather how can it be made to work?

Making imprinting work in a variety of new situations may require minor modifications in the standard equipment and operating procedures. Imprinting equipment is currently being adapted for use on steep slopes (Dixon and Carr, In Press). This entails the development of an imprinting tooth with a curvilinear triangular cross section to increase water and seed storage space on steep slopes. Additionally, crawler tractors with self-cleaning triangular track pads can be readily adapted to imprinting steep slopes. An imprinting roller clamped to the dozer blade will imprint the space between the tracks. This same arrangement can be easily adapted to wetland restoration.

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Non-Traditional Uses of Grasslands Panel

Nathan Sayre[1], Moderator [2]

INTRODUCTION TO THE PANEL

Wendy Laird, the Executive Director of the Tucson Audubon Society initially conceived the idea for this panel. She originally was going to call it *Alternative Use of Grasslands*. We talked a little bit. She didn't like that title. We were left wondering what is the traditional use that we are trying not to talk about right now. I thought I'd say a few things about that to start with before introducing our panelists. Clearly the first and primary use that we are suggesting is the traditional use in cattle ranching and I think it's been said enough already in the conference that late 19th century overgrazing and drought caused a whole lot of damage to the grasslands of this area. It also caused a lot of damage obviously to individual ranchers, but we don't mean to imply that ranching is incompatible with grassland preservation and ~~they are~~ a lot of other panels ~~going on~~ talking about issues of sustainable grazing. At least two of our panelists here, and perhaps more, Tom Orum and Tom Hildebrand, are talking about uses of grassland that can complement rather than replace ranching. I don't think anybody here is going to speak for a radical alternative to grazing.

Without going into detail then, I would suggest that the critical issue we're talking about is economics not cattle. 19th century destruction of grasslands can be traced to boom and bust cycles in the economy that prompted a massive overstocking of the range and then when times got bad, attempts not to sell cattle because the price was very low even if grasslands were being destroyed. I think these boom and bust cycles still persist today even if they are moderated relative to the late 19th century. From this perspective, the topic of our panel is how grassland owners and managers can organize their enterprises in such a way that economic pressures do not translate into ecological stresses; to what extent can revenues from films or from ecotourism complement ranching; how can alternative land ownership strategies such as land trusts or non-profit organizations insulate grasslands from market conditions.

I think there's also a second conventional or traditional use of grasslands that is implicit in our title and it cuts across issues of economics. For simplicity I'm going to call it state conservation. At its extreme, this is the polar opposite of cattle ranching as I've just described it since it involves the withdrawal of land not only from private ownership but from market forces as a whole—the attempt to set aside the land and say this will be the way it is regardless of what the price of cattle or the price of land may be. Publicly owned grazing land falls in between. The more strictly they are regulated by government agencies or the higher the lease rates rise, the more exposed the lease-holder becomes to market pressures. For various reasons we can't expect all grasslands to be withdrawn from private use and insulated from the market. Nontraditional uses therefore include uses other than or complimentary to state conservation. The Nature Conservancy and the Malpais Group are perhaps the best known big examples of this. Here we're hoping to find mechanisms that are available to more people more broadly who don't have the resources of the Nature Conservancy or the Malpais Group and they're looking for ways to participate in the management and acquisition of grasslands without being sucked into the pressure to subdivide and develop these lands.

One topic which I hope we touch on at least somewhat here is the issue of taxation. What is a nonprofit group able to do by virtue of being nonprofit and exempt from taxation? How do tax policies

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[1] University of Chicago, retired, now residing in Tucson AZ.

[2] The entire panel was transcribed by Boleyn Baylor, University of Arizona, Tucson AZ.

affect other ways of organizing enterprises? I'm hoping that Tom Orum will talk at least a little bit about the Saguaro-Juniper Project, which is not nonprofit even though it appears to pursue goals that would make it such.

Finally, the third use, which I think is not what we're talking about, is subdivision and development. This is no alternative but I think it lends the urgency to our discussion in this conference and reminds us that we can't simply declare that grasslands are valuable in the abstract. The value that we see in grasslands must be transformed in practice into livelihoods for people that do not undermine grassland ecosystems.

Our four panelists: Tom Hildebrand works for the City of Tucson coordinating large-production filming in the Tucson area and is going to speak about the way that is organized and the impact it has on the local economy and the way it has utilized grasslands in this area historically and more recently. Roseanne Hanson represents the Buenos Aires Natural History Association which is a nonprofit education association set up in partnership with the Buenos Aires Natural Wildlife Refuge. Chris Benish is from Field Guides Incorporated. He's a birding tour guide and is going to speak about grassland birding and the limits of ecotourism. And finally, Tom Orum from the Saguaro-Juniper Project, "a network of friends that have formed a for-profit corporation to combine cattle grazing and land stewardship." He'll be speaking about the history of that group and the obstacles they have overcome in their work.

Use of Grasslands for Movie-Making

Tom Hildebrand[1]

The Tucson Film Office was established about 12 years ago when the Tucson realized that there was a lot of potential economic development, which is what the movie business represents to Tucson and southern Arizona. I'll refer to Tucson, but our office covers the whole southern part of the state. Our office was formed in 1986 and we operate today with a budget of about $150,000. It's not a big department but the revenues generated into the economy here represents about $25 million yearly over the last two or three years. It's a pretty clean industry. I'm going to speak about the grasslands.

As you go back in history the westerns have always used a lot of the grassland areas. A lot of the John Wayne movies were shot here in Tucson. We're fortunate here in Tucson that we've got such a variety of looks. Within about 50 miles of where we're sitting here today you can be in almost any type of terrain that you can find throughout the United States. We're a little short of ocean, but other than that we're in pretty good shape.

I think the movie business can offer a heavy economic impact to the managers and owners of grasslands. The people in the San Rafael Valley, where the film "The Fantastics" was recently shot, got between two or three thousand dollars a day just for the use of the dirt and grass and scenery. There's unbelievable vistas when you're down in that area. They leave it in good shape. It's like any business that you're involved in. A film company will take advantage of you if they think they can. Sometimes it's not intentional. Sometimes it's just sloppy. We always tell people to handle it very well. Make sure you've got a good tight contract.

Make sure that when they leave it's all spelled out about how they're going to clean up the property when they leave, that there has to be re-seeding that will be done. There's no reason to have a situation that when they leave there's damage done to the property. They can usually go away and you never know they've been there. They built two houses and put in a cornfield and sunflower field with the help of the University on the site where they filmed "The Fantastics" in the San Rafael Valley. We were down there about a week ago and I couldn't tell at first where they'd been. On real close examination I could tell where they'd re-seeded, but the grass was almost back to completely normal. It is a good way to make quite a few thousands of dollars to help operate something like the Cienega Ranch down there because they will come in and utilize that facility and they pay usually very good money. That's just the feature films that come in. We have had in recent months two or three occasions where we've used those grasslands as the "Out of Africa" look for fashion and catalog shootings. Speigel's just came in and did quite a large catalog shoot and it was an "Out of Africa" look that they wanted to establish and it worked great. With a few props you don't know where you are.

Our office has put together photos of the grasslands and we will send these out. We'll get a request from a company and they'll say, we know you've got mountains and you've got saguaros but we want something more than that. They'll tell us what they want and then we'll go into our files. We put together photo panoramas so that they can get a good idea. To my knowledge, we've had very good working relationships with the film companies in their usage of these plants. They respect it for the most part. It's like any other segment of society. Once and while you'll get somebody who has no respect for the property and you just have to snap them into line. I think overall it's a good way to make a nice clean income. Something like the Cienega Ranch can make $25,000 to $30,000 income off of a film shoot, direct to them. That doesn't include all the money the film company will spend in hiring local labor and buying hardware and lumber and everything else that they might use in the production.

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[1] City of Tucson Film Office, Tucson AZ.

Using Grasslands for Environmental Education

Roseanne Hanson[1]

About a year ago, I became involved with the Buenos Aires National Wildlife Refuge and I will speak about that and how this organization came to be in relation to a wildlife refuge but I'm here because this could easily be applied to a private ranch or business that owns a ranch. I was asked to form this organization which is somewhat unusual. Normally these organizations, which are called natural history associations, are a group of community people who get together and form an organization as a friends group or a benefit organization that is private that works with the government. The fact that I was asked to form this organization is interesting in and of itself because it indicates a need which is being echoed in the private sector. I see that need as education and advocacy. Buenos Aires Natural History Association is membership driven. We have operated for a year and without trying very hard we have a very good base of about 50 members and 300 in a mailing list. I think that's quite good starting from zero. We publish a newsletter that we mail out to the members. We have begun to plan and operate tours for free as well as for a fee and educational workshops.

It is that interface between the urban members and the rural element. We bring people out and show them what's going on. On a ranch I think the cultural value would be very high as well. People have no idea what happens on a ranch and the educational value is exceptional because the advocacy that comes from learning is in the long run very valuable to a ranch. You would gain political allies as well as teach people what's going on. I prefer to answer questions. We've only been operating for a year so I really don't have a lot of experience except with the forming of the group as a nonprofit. There are certain things you have to do. It's complicated and you have to jump through an amazing number of hoops to get that status. It's not easy. They want to know everything about you and what you plan to do. The government sometimes inadvertently sweeps in and says, here we are, aren't we wonderful? And the community says, yuck! We're trying to mend that very, very slowly.

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[1] Buenos Aires Natural History Association

Using Grasslands for Birding Tours

Chris Benish[1]

There is a fairly sizable birding market in Arizona. I work for a company that is based in Austin, Texas called Field Guides Incorporated which has been in business since 1985. It's representative of where the business of birding and doing birding tours internationally has taken us. The business supports ten full-time guides, of which I'm one, plus a staff of five, and basically pays our bills and generates in the neighborhood of $100,000 to $150,000 profit every year. As part of that we do a few different tours in Arizona. Most of these tours are in some way centered around the grasslands. There are a number of species which are found either primarily or secondarily in grasslands. Access to those types of habitats are real important to us from a business perspective. It's to our advantage to encourage those who have land holdings to at least explore the potential for developing a birding market.

We are just one company. There are many others. I would guess there are perhaps 80 different organized tours that conduct birding trips in southeastern Arizona and probably all of those visit grasslands for some significant percentage of their tour. On that tour you're talking anywhere from five to sixteen people who are paying anywhere from $120 to $200 a day to this tour company and then some of that cost is going back into the community. In addition, there are many people who travel to Arizona on their own.

There are probably in the neighborhood of 10,000 birders, and that's a conservative estimate, who visit the state every year. They generally stay for a week to two weeks and base themselves in various places—Tucson, Sierra Vista, Nogales, Patagonia and further east. There are a few different people who have been successful at opening up bed and breakfasts and that type of thing that caters specifically to bird watchers and other nature trekkers. There's probably some market for that. It's hard to know just when you stretch the limits of the body of birders that are out there, but it's a market that's growing. Birding in general has really taken off in the last twenty years. Twenty years ago there were no companies like the one that I belong to now and now there seems to be enough of a market to allow certainly three big companies and 20 to 30 smaller companies to exist.

A couple of examples of other kind of activities that have been bringing some economic benefit to Arizona grasslands. The American Birding Association has about 15,000 members. About three times a year they conduct conferences in various parts of the country and once every two years they hold a big convention in an area. Arizona, because of its position biogeographically close to Mexico, yet politically in the United States, is very attractive to people who want to see an assortment of specialty birds, birds found in the grasslands of northern Mexico and southern Arizona, yet fall be the U.S. They've filled conferences of from two to three hundred people and conventions of up to 700 people and so there's some economic benefit to the community.

Sierra Vista has gotten into developing the Southwest Wings Birding Festival which they hold every year in August, which brings in anywhere from 500 to 1,000 people for a long weekend there. There's some potential for that elsewhere. If there were a few more ranches that developed bed and breakfast situations, particularly ranches that offered some riparian associated vegetation or oak woodland mix. Those would be popular. There are a lot of people who are looking for an alternative to staying right in Sierra Vista or Tucson and would like to get away from things. Birders are generally pretty affluent people and have some disposable income.

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[1] Field Guides Incorporated, Tucson AZ.

Rural-Urban Grassland Connections

Tom Orum[1]

Saguaro/Juniper is a group of friends that has grown since 1988. We have land in the San Pedro near the community of Cascabel with a grazing lease associated which has a three and a half or four mile boundary with the Muleshoe Nature Conservancy/BLM joint management area to the north of us. We share Hot Springs Canyon with that joint management area so we have a lot of interest in Hot Springs Canyon as a corridor between the riparian areas on the BLM/Nature Conservancy area and the San Pedro. It also includes a lot of grassland and that's where the connection here would be. One of the things that we're trying to figure out—and I say it's a process, not a conclusion—is how people of modest means can acquire a management or an ownership interest in rural land without contributing to fragmentation and subdivision. We're really working against the subdivision aspects and I think that subdivision is probably a bigger threat to grasslands and wildlife communities than cattle ranching.

We have about 4,000 acres or seven sections of leased grazing land from the State and private and now about 1,000 acres of deeded land. In order to do this we are organized as a for-profit corporation and in order to hold our grazing lease we do have cattle. We've tried to translate private ownership rights into more land rights, although Leopold has influenced our thinking a great deal, so we've recorded some of our deeded land in Cochise County with a real estate covenant. I'll read from the preamble of that covenant:

> "The Saguaro/Juniper covenants preambles and principles establish a common ground for group discussion and deliberation. They are to function primarily as queries that guide decision making, not as conclusions that override deliberations. In acquiring private governance of land we agree to cherish its earth, waters, plants and animals in a way that promotes the health, stability and diversity of the whole community. This entails attentive stillness to meet and know the land as an active presence. It entails study, observation, shared reflection and cumulative corporate experience to increase and bequeath our understanding of ecosystem health, stability and diversity. It entails symbiotic naturalization into the planned community, the communion of actual nurture and shelter. As elaborated by these entailments, fully accountable governance, stewardship, is the distinctively human way of bonding into one society with all who share in the land's life, which is the foundation for instituting a biocentric ethic among humankind."

The five principles that we try to hold in guiding us in terms of managing the land:
The land has a right to be free of human activity that accelerates erosion. Native plants and animals on the land have a right to life with a minimum of human disturbance. The land has a right to evolve its own character from its own elements without scarring from construction or the importation of foreign objects dominating the scene. The land has a preeminent right to the preservation of its unique or rare constituents and features. The land, its rocks, waters and minerals, its plants and animals, and their fruits and harvest have a right to never be rented, sold,

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[1] Saguaro/Juniper Project, Tucson AZ.

extracted or exported as mere commodities.

I say that these function primarily as queries that guide decision-making and not conclusions that override deliberations. That's the way we're working. There's a lot of deliberation and there's a lot of talk. The other element which is crucial and which has been touched upon again and again is the importance of the surrounding community and neighbors and the whole community process. Cascabel is now a much more unified community than it was eight years ago, but it's still highly diversified. We work hard. The Nature Conservancy works hard. The people in the community work very hard at trying to understand each other. We don't always succeed, but we keep working at it. Currently there are seven members of Saguaro/Juniper who do live in Cascabel. It's this rural-urban connection that we're working very hard to try to develop.

Economic Benefits of Preserving Natural Areas

Bonnie G. Colby[1]

ABSTRACT

The focus of this paper is on values that can be quantified in dollar terms. It is important to acknowledge that natural preserves—such as grasslands and riparian areas—have psychological, cultural, and spiritual values that may be just as, or more, important than the values which economists are able to quantify. While economists have developed methods to quantify natural resource values beyond the direct use of resources for commercial purposes and recreation, even these modern economic methods cannot capture the full range of benefits that natural areas provide.

QUANTIFYING THE ECONOMIC VALUE OF NATURAL AREAS

The notion of measuring the value of nature in dollar terms may seem distasteful. Money is a cold unit by which to characterize grasslands, clean air, scenic views, open space, endangered species and other amenities which are important to our quality of life. Nevertheless, there are some valid reasons to cast the value of nature in monetary terms.

In times of tight government budgets, public policies require closer scrutiny of how taxpayers dollars are spent. Consequently, when an agency is considering spending money to acquire or to manage land for a natural preserve it typically must document the benefits anticipated from the preserve, as well as the costs of leaving the land in a natural state (including the foregone benefits of more intensive land uses). Over the last five years, popular concern regarding the potential impact of government activities on private property values has swelled. This has led to more use of economic analysis by public agencies because they are subject to added scrutiny of the impact of their proposed regulations, land acquisitions, and land management plans on private property. For instance, Arizona statutes now require review of proposed state agency rules by the Governor's Regulatory Review Council and the agency must submit an economic impact statement on the proposed action to the Council for their consideration. Other states have passed stronger measures to prevent takings (the diminishment of private property values caused by government action). Congress has considered such legislation as well. These policies, which seek to protect private property, have the effect of increasing the pressure on agencies to document the costs and benefits of their activities, including acquisition and management of lands as nature preserves.

Private firms and environmental organizations also must weigh economic costs and benefits associated with natural areas. For instance, to obtain a final certificate of a water right for instream flow purposes in Arizona, the holder of the right (a federal agency or the Nature Conservancy, for example) must document the benefits of preserving streamflows. Even in instances where examination of economic values is not required, it still is a useful exercise for an environmental

[1]Agricultural and Resource Economics, University of Arizona, Tucson AZ.

organization or a public agency to weigh the economic costs and benefits of setting aside a natural area for wildlife and recreation.

This paper briefly reviews the different types of economic values associated with natural preserves. Strong economic arguments can be made for preserving natural areas for recreation and wildlife habitat and for maintaining the aesthetic appeal that wide open spaces have in the American West.

TYPES OF ECONOMIC VALUES GENERATED BY NATURAL AREAS

Direct Benefits to Recreationists

Many natural areas in the West are heavily used for recreation and generate increased economic benefits as population and demand for outdoor recreation grows. Urban westerners demand outdoor recreation opportunities and place a high value on them. A comprehensive survey of economic benefits to recreationists at outdoor recreation sites in the western United States indicates recreation benefits of $18 to $27 *per visitor day* for general hiking and wildlife viewing (Walsh et al, 1992). Data collected for southern and central Arizona riparian areas indicates values *per visitor* (in a one-time contribution) of $65 to $102 to maintain the quality of the Hassayampa River Preserve, and $65 to $97 to protect the riparian ecosystems of the San Pedro Riparian National Conservation Area and the Nature Conservancy's Ramsey Canyon Preserve (Kirchoff, 1994, Crandall, Colby and Rait, 1992). These values lie far above the nominal fees charged to enter federal and state parks and recreation areas.

Contribution to Local Economies

In addition to economic benefits to the recreationists themselves, small businesses and outlying communities depend on spending by outdoor recreationists. Outdoor recreation brings millions of dollars each year into the Arizona economy. Restaurants, retail stores, motels, bed and breakfasts, gas stations and other businesses benefit from preservation of attractive outdoor recreation sites.

Tourism linked to outdoor recreation is a particularly important component of the economy of rural Arizona, including Arizona's tribes and their reservation economies, many of which contain Arizona's last unspoiled natural areas.

Bird-watching opportunities in Cave Creek, Madera Canyon, Ramsey Canyon, and other sites are known worldwide and bring relatively high-income visitors to these parts of Arizona. In the Sierra Vista area alone, expenditures by visitors to prime bird-watching areas stimulate $3 million per year in local economic activity (Crandall, Leones and Colby, 1992). The San Pedro Riparian National Conservation Area and the Nature Conservancy's Ramsey Canyon have annual visitation of approximately 12,000 and 26,000 visitor days, respectively.

Several factors affect the extent to which natural areas contribute to the economy of nearby communities. Local economic stimulation is increased as the percentage of nature preserve visitors that are non-local increases and as visitors stay overnight in the area (instead of just making a day visit) and thus spend more on lodging and meals. As the local economy diversifies, dollars spent by tourists circulate more times within the local area and further stimulate local business activity, before "leaking" out of the local economy as payments for goods and services produced elsewhere (Crandall, Leones, and Colby, 1992).

Habitat Preservation

Natural areas preserve wildlife habitat and can help avert a species becoming listed as threatened or endangered, thus averting the complex and costly formal Endangered Species Act processes for designating critical habitat and developing species recovery plans. These averted costs and conflicts are a notable benefit of nature preserves, a benefit that can be appreciated by examining the enormous costs incurred in the Pacific Northwest over salmon and spotted owl issues. Indeed, the threat of a species becoming listed as threatened or endangered and of triggering the formal Endangered Species Act (ESA) process has proved a powerful incentive for setting aside habitat for species.

Water Protection

Natural preserves that maintain the ecological integrity of watersheds can protect water quality and stream flow levels. Preserving the quality and volumes of flows reduces the costs of complying with surface water quality standards for downstream towns and industries which discharge into rivers. High quality stream flows from protected natural areas provide economic benefits to these dischargers by averting or postponing the costs of providing more sophisticated sewage treatment (and the huge capital costs of upgrading treatment facilities) to remain in compliance with surface water standards. If streams become degraded, downstream pollutant loads become more concentrated and the probability of surface water quality standard violations increases, as do costs and fines for non-compliance (Colby, 1994).

Private Property Values

The value of private property located adjacent to or near natural open space preserves is enhanced when water quality, open space and wildlife habitat are protected. Studies elsewhere in the U.S. indicate a twenty percent increase in private property values due to water quality protection in nearby water bodies (Young, 1984). In the Tucson area, economic studies document an increase in property values associated with proximity to wildlife habitat, such as washes and riparian areas (King, White and Shaw, 1991). Southern Arizona homes and resorts that are located adjacent to open spaces (such as national forests and monuments) enjoy a property value premium associated with the natural areas. The growth of residential construction in the Sonoita/Patagonia area, and the accompanying rise in property values, is an example of the positive influence of attractive open space on private property values.

Values Unrelated to Direct Use

People who don't actually visit natural areas still benefit from them and are willing to contribute to their preservation. Economists divide these nonuse values into three categories, based on the underlying motivations. *Existence value* stems from knowing a particular species will continue to exist in a natural state. *Option value* is based on a collective desire to keep options open for the future. Option value emerges when faced with an irreversible decision—do we develop a natural area for agricultural or urban use—altering the area forever, or do we leave it as it is for now, knowing it can always be developed in the future? Policy choices to preserve a species rather than let it become extinct (irreversibly lost), also exemplify the option value concept. *Bequest value* stems from wanting to preserve natural areas and wildlife for the future, for our own heirs or for future generations in general.

These nonuse values represent substantial economic benefits associated with preserving endangered species, wildlife habitat, and unique natural sites. These preservation values (also termed "nonuse or passive use" values) have been affirmed by the courts as a valid component of economic costs and benefits (State of Ohio v U.S. Department of Interior, 880 F.2d 432 (D.C. Circ. 1989)), and are incorporated into assessments of proposed federal regulatory actions as well as in assessing liability for environmental damages under CERCLA. These values are expressed through donations of time and money to wildlife and environmental organizations, and through political support for species recovery programs and for laws and policies that preserve habitat and prevent environmental degradation.

Examples of the application of nonuse values to examine environmental policies in Arizona include the Federal Bureau of Reclamation's Environmental Impact Statement for Operations of Glen Canyon Dam (1995) and an earlier federal study on changes in air quality and visibility in the Four Corners region.

Recent studies of preservation values associated with nature preserves in the western United States indicate economic benefits of $15 to $80 annually per household located in the general region of the site (Sanders, Walsh and Loomis, 1990 and Brown, 1991). Studies in Colorado, Canada, Wyoming and Alaska indicate $40 to $80 per *non-user* household in cities located within a few hours of nature preserves. These nonuse values may seem esoteric (less tangible than spending by recreationists, for instance), but they are real values and economic studies on natural areas around the West suggest these values are even larger than the direct values people place on their recreational use of such areas.

IF NATURAL AREAS ARE *SO* VALUABLE, WHY DON'T THEY RECEIVE MORE PROTECTION?

Despite the numerous economic benefits provided by natural areas, they are not "supplied" by market forces to an extent commensurate with the benefits they provide. This "market failure" occurs for several reasons. First, benefits provided are *real,* but often not readily "collectible." There is no easy voluntary way to collect money for acquiring open space and wildlife habitat. Only nominal fees are charged to enter parks and recreation areas. Recreationists' "true" values, their willingness to pay, are not collected by anyone. Of all the types of economic benefits described, the only money actually going into someone's pockets is dollars spent by recreationists. However, these expenditures are not a complete measure of the value of a natural area. Part of the "collectibility" problem is the absence of a clear, well-defined constituency to collect money from. It requires a tremendous effort to raise money from a dispersed constituency through voluntary donations, as environmental groups do. Recreationists and environmental advocates are dispersed among the general population. They do not tend to be as identifiable and tightly organized as commercial users of land and water. Developers, farmers, ranchers, loggers, and mining interests have effective lobbies to promote their access to land and water. Another reason for the "collectibility" problem is free-rider tendencies. Once a preserve is established, many can benefit from its existence even though they made no donations to help establish the preserve.

There also is a lack of information that handicaps protection of natural areas. In contrast to the benefits provided by nature preserves, the values of other land uses (industry, agriculture, subdivisions) are easier to measure, "collect," and recognize as an economic investment. There is plenty of information from the real estate market on the value of land in growing crops, houses, and golf courses, but very little documentation on the value of wildlife habitat and recreation areas.

In response to the inability of the free market to supply nature areas to the degree justified by the benefits provided, two broad approaches are taken to acquiring land for recreational and environmental needs. First, private organizations such as the Nature Conservancy and Trout Unlimited buy land and water, using money they have raised from donors and investments. Second, public agencies acquire land and water. However, new public agency acquisitions have become difficult in times of tight budgets. Funds are tight for managing natural areas already held by federal, state, and local governments.

A two-pronged approach involving both the private and public sector is necessary for improved protection of natural areas. Private groups, such as the Nature Conservancy, can't do it all on their own due to the "collectibility" problem. State, local and federal agencies use tax dollars and need not rely on voluntary donations alone. Private-sector participation can be facilitated through favorable tax policies that encourage contributions of money, water rights, and land to non-profit wildlife and environmental organizations. Enhanced public-sector participation requires continued authorization and funding for federal, state and local agencies to acquire and manage natural areas.

Cooperative strategies involving public-private partnerships are a hopeful approach that combines the strengths offered by public agencies with those of the non-profit sector. Examples include the Nature Conservancy's acquisition of land when it becomes available at the right price, at times when a public agency is not able to secure funds quickly enough to make a timely purchase. In many cases, the Nature Conservancy later turns the land over to a public agency, such as the BLM, for long term management, with the Conservancy eventually reimbursed for some or all of their acquisition expenses.

SUMMARY

To summarize, many (though not all) of the benefits provided by natural areas can be quantified in dollar terms. It is increasingly necessary to quantify these values in order to respond to increased scrutiny of public agency spending in times of tight budgets and to concerns over takings. The market forces of supply and demand do not provide adequate protection of natural areas, so continued involvement by public agencies and the non-profit sector is essential.

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The Future of Grasslands in Cochise County, Arizona: Identifying the Issues

Judy Anderson[1]

ABSTRACT

Grasslands in Cochise County are increasingly under development pressure from "wildcat land divisions and new residential subdivision development. If grasslands are to be maintained, methods must be employed that accommodate this growth in a manner that retains the natural resources and rural open feeling including the grasslands.

INTRODUCTION

The quality of life in Cochise County creates challenges along with opportunities. After the Civil war, pioneers pushed westward with hopes of striking it rich in mining or establishing their own ranch or farm. Others followed, creating communities to provide necessary services. Doctors, teachers, storekeepers and entertainers clustered in the communities throughout the County. In 1881, when the County was established, land seemed endless, water infinite, clean air was taken for granted and a rider could travel for miles without seeing another person. Measures to protect the rivers, grasslands and mountains were not considered.

Times have changed. Cochise County is now one of the three rural Arizona Counties with increasing population. The County is located within a reasonable commute to Tucson, has economic opportunity and is an attractive place to live. People move here hoping to escape the problems of the city and enjoy the pleasures of the country.

As a result of this influx of population, the attractions that draw people are in danger of being lost. Traditional industries such as ranching are experiencing economic downturns making it difficult to for them to maintain the rural character they provide which is so valued in the County. The vast open spaces are increasingly being subdivided, often in an unguided fashion. These trends create a challenge to plan in a manner that helps preserve, protect and enhance natural resources, existing communities and neighborhoods, and rural character, while at the same time recognizing the desire for economic opportunities and the likelihood of growth.

GENERAL BACKGROUND INFORMATION

Cochise County is located in the southeast corner of the State, sharing boundaries with Mexico, New Mexico, Graham, Pima and Santa Cruz Counties. The County is 6,219 square miles in size, seventh in land area of the fifteen Arizona counties. The number of people per square mile is estimated to be 16.3, tied with Coconino County but a little less densely populated than Santa Cruz and Pinal Counties. The annual growth rate is 3.77 percent similar to the overall rate of growth for the State. The Planning Department issues approximately 1400 building permits per year.

Forty-one percent of the land is privately owned, the highest percentage in the State - Santa Cruz County, our neighbor to the last is a close second with thirty-nine percent of their land in

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[1] Cochise County Planning Department, Sierra Vista, AZ.

private ownership. Maricopa and Pima Counties, the most intensively developed Arizona Counties have respectively thirty-one and thirteen percent of land privately owned.

DEVELOPMENT PRESSURES

Grasslands in Cochise County are concentrated east and north of the Huachuca Mountains in the southwest corner of the County. They are found in the Palominas/Hereford area between Sierra Vista and Bisbee on both sides of Highway 92.c Grasslands can also be seen along Highway 82 approaching the boundary with Santa Cruz County. The San Simon/Bowie in the northeast corner of the County can also be considered grasslands.

All of these areas are zoned to allow development at a density of one house per four acres although under a density bonus option, used to encourage the formal subdivision process rather than "wildcat" land splits, the density can increase to one house per three acres. Much of this grassland is located on privately owned land.

The areas along Highways 90 and 82 are subject to the most development pressure. Residential development, on forty acre splits that subsequently split down to four acre parcels as allowed by state law, is beginning to extend westward along Highway 82 from the Whetstone area.

Along Highway 90, a similar trend of development is occurring at an even faster pace. Additionally, a 7,000 acre tract of land was sold several years ago which is now developing; two subdivisions have been approved, with a total of 156 three acre lots; and the remainder of the land has been divided into 160 acre parcels some of which are being surveyed into forty acre parcels and advertised or sale as five, eight acre parcels which could then be further split into two more four acre parcels by new owners.

EFFORTS TO PRESERVE OPEN SPACE ON PRIVATE LAND

During the recent update to the Comprehensive Plan, it was clear that the rural, open character of the County, including the wide open grasslands, was cherished by longtime and recent residents like. The question asked was "can this character be retained". The response an adamant "Yes but voluntarily!" Given this response, County Regulations include three methods for property owners and developers to voluntarily retain more open space on their land.

The first is the subdivision cluster option, which was recently opted allowing developers in the rural areas to cluster housing at a higher density on part of the site, leaving the remaining property in natural vegetation and open space to be used for passive recreation, such as hiking and horseback riding, or retained in agricultural use.

The second is voluntarily downzoning from smaller lot sizes to larger lot sizes; this option has been used by developers to help guarantee that buyers of thirty-six acre or larger "rural lifestyle" parcels do not find neighboring parcels split into postage stamp lots. No fee is charged for this action.

Third, the *Comprehensive Plan* offers property owners the opportunity to establish *Resource Conservation Areas* on their own property, to protect significant resources such as untouched grasslands, stands of oak trees or washes that serve as wildlife corridors .

In addition to options found in the regulations, also available, are options which fall outside the realm of County jurisdiction such as private deed restrictions and conservation easements.

CONCLUSION

The provision under State law that allows dividing of land into five separate lots by an individual owner down to the minimum lot size allowed by zoning means that much of land development in the county occurs outside of our jurisdiction. Clearly, to preserve cultural resources and retain some regulatory control, the County could rezone the rural areas to larger lot sizes thereby, for example, requiring minimum lot sizes of thirty-six acres. In the current climate with heightened concern over violating property rights, the County Board of Supervisors does not support such voluntary downzonings. Given this reality and the steady residential growth in the County, it seems most likely that the grasslands will be developed in four acre parcels each with its own house, fence, driveway, corral and swing set unless other innovative measures are found or property owners take advantage of existing options.

The Use of Zoning to Protect Grasslands A Panel Discussion[1]

David Yetman[2], Session Moderator

The biggest player concerning decisions that affect the land is the county. In Arizona, Santa Cruz County retains the highest acreage of grassland.

Concerning zoning, every landowner has the right to request a change in zoning and it must be heard at the county level. At present, it is almost guaranteed that the rezoning will then happen unless it could constitute an emergency such as relating to public health and safety (flood protection, for example). When there are exceptions, there is usually a time frame attached whereupon the reason for caution will be mitigated.

In Arizona, the procedure is to petition for a change in zoning. Planning and Zoning considers it and makes a recommendation to the Board of Supervisors. But if P&Z gives a negative recommendation, most often the Board will ignore it and rezone anyway. Landowners do have ultimate say.

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[1] The entire panel was summarized by Nancy Zierenberg, Sky Island Alliance, Tucson, AZ.

[2] Southwest Center, University of Arizona, Tucson AZ.

Planning and Zoning as Land Managment Tools

Arlan Colton[1]

Planning is a guideline that communities can use to define the future for land use. The Plan is authorized by the State for local governments to enforce. Zoning is a tool to implement planning. There are also other tools such as subdivision regulations, private covenants, and restrictions to implement planning.

All counties in Arizona have the power to zone. In some states, such as Texas, counties do not have zoning power. Oregon, Hawaii, Florida, and Vermont are examples of states which have strong state-wide planning directives. There is no State planning in Arizona except in two areas--for pest management and manpower. In Arizona law, "open space" is given a definition as a place of natural beauty, and not mentioned again.

Arizona's enabling legislation for planning and zoning is contained in Title 9 concerning cities and towns, and Title 11 concerning counties. Where grasslands are concerned, most action happens at the county level. The zoning ordinance contained in the Pima County Comprehensive Plan is only 4 paragraphs long and is not good. Those things not contained or discussed in those 4 paragraphs are prohibited, unlike most counties where an item which is omitted is permitted unless there is language somewhere else in the plan which says otherwise. Agriculture, mining, ranching, railroads, and utilities are all excluded from the P&Z Titles so only private lands are considered.

Lot Splits was brought up in a question to be clarified. In Arizona, a landowner can split his land down to 40 acre chunks. He does not have to go through a special process to do this. He can do up to three splits under his ownership. The next landowner can do the same, etc. There were no requirements for roads, sewer or water systems, nothing. This law was finally changed to allow for services, however the tradeoff was that the landowner could now do five splits instead of just three.

In 1985, Pima County went through Rural Zoning Category changes. Base rural zoning is now just over four acres, so a property owner can't split rural zoned land below that acreage. The highest zoning is 36 acres, but those are mostly found in parks and on public lands so already have a measure of protection. The solution for protecting grassland is not large lot zoning as there are still no regulations concerning what private landowners can do on it. The solution is in good planning for development; to get something in place before development becomes inevitable so that it is managed correctly.

Arizona Game & Fish Department has been active with Planning and Zoning over the last ten years, especially in the southern counties, says Sherry Ruther of the Department. Their interest has been in situations concerning Threatened and Endangered Species, and for critical or sensitive wildlife and habitat. They are treading lightly regarding private land P&Z issues. They would like to influence public concern for G&F interests.

Tools that citizens may find useful in order to become active in P&Z issues:

1) A web site called ALIS; Arizona Legislative Information System.

2) ALRIS; Arizona Land Resource Information System. This has one of the most comprehensive GIS systems in the country. Citizens can use it to download maps with overlays, etc.

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[1] Arizona Preserve Initiative, Arizona State Land Department, Phoenix, AZ.

3) Through the Arizona Department of Commerce (whose main goal is economic development), you can ask for community planning help including training and rural and local governments. Contact is Deb Sydenham @ (602) 280-1350. She is a good resource.

4) The American Planning Association has been working on model state enabling legislation to help states in planning. Their web site is: http://www.planning.org

5) The Thoreau Institute has done a good case study called "Transitions: New Incentives for Rural Communities". It makes use of the commons theory. Web site: http://www.glasswing.com/~rot/transits.html

6) A book called *Rural by Design*, by Randall Arant describes how to use clustering techniques to preserve open space. It does not mention grasslands, but much of this information can be applied to grasslands planning.

Land Use in Santa Cruz County

Brian Friedman[1]

The Rio Rico subdivision in Santa Cruz County is the second largest in the US. Over the last year, we have worked with eight subdivisions in the county, indicating fast growth. A popular idea of late is "cluster" development, where houses are clustered in close proximity to each other, leaving the rest of the private acreage as a continual open space surrounding the cluster for all to enjoy. Managing viewscapes seemed to be the big reason that planners consider this cluster idea a good one. An example of such development is one called "Casas Arroyo" west of the Santa Rita Mountains. It is a 220 acre subdivision with 190 acres held in common. Housing is on ½ acre lots. There was a question concerning grazing use of these common areas. In Casas Arroyo those areas are occasionally grazed for fire protection.

In Santa Cruz County the rapid pace of growth is outstripping managers' ability to keep up with regulations to control it with good planning efforts. Traditionally, P&Z has been weak. For example, in a Conditional Rezoning--one in which the Board attaches conditions to the rezoning--often there is no verification that these conditions are met before the rezoning takes place. This is one area where we are working to put this verification process in place. I have been in my current position for a year and am working to strengthen P&Z's role and relationship with the County Board.

Community participation has been sporadic. Recently, there has been quite a bit of public controversy over the Star View development, containing 5 acre parcels. The county finished their Comprehensive Plan in 1990. The Plan established a systematic way of dealing with things outside of the plan.

[1] Santa Cruz County Planning Department, Nogales AZ.

Being a Sticker

Dan Dagget, as presented by Luther Propst[1]

When folk singer Joanie Mitchell sang about paving paradise to put up a parking lot, she warned that: "You don't know what you've got till it's gone."

Well,... what have we got when a ranch is gone? Or better yet, what haven't we got? Maybe the only way we can really know what a ranch provided while it was alive is to discover what we've lost after it's gone. Perhaps that's how we can make something positive out of the turmoil we're seeing in the American West today, where in Colorado alone an acre of agricultural land is converted to some other use every 4 minutes. Maybe it's worth it to lose a few ranches if that's what it takes to discover how they enrich our lives, our culture and our environment; or if that's what it takes to convince us that we need to work to sustain the ones that are left.

Anyone who's bothered to think about it knows that pressures threatening ranches are growing and will continue to do so. Baby Boomers are coming to the West in droves, tantalized by a media that uses western landscapes to sell everything from pickups to preservation. Fleeing cities that are becoming uninhabitable; freed by the information superhighway from having to live where their jobs are, this new wave of modem sod-busters is coming West convinced that their destiny is manifest and that the ranching culture they are replacing is a liability and a relic. In this scenario is it any surprise that ranches are dying?

So, what do we lose when a ranch dies? The most obvious answer is that we lose some of the wide open spaces, the broad panoramas, the pure, uncluttered sweep of nature that defines the American West. And in its place we're left with sprawling suburbs and strips of fast food joints.

And that's just the beginning.

We lose the viability of the agricultural economy that enables rural communities to resist the seduction of suburbanization; that serves as an essential element of the sense of place and neighborliness that cause the residents of those communities to want to stay there and inspire so many of the rest of us want to move to them.

When a ranch dies nature loses too. While pronghorn, sage grouse and even mountain lions and wolves can find the pure grasslands, unfragmented stands of sagebrush, and expansive areas of undisturbed landscape they require on well-managed ranches, subdivisions can fragment and destroy the viability of the very habitats that are essential for these animals' existence. For people who have lived and worked, even been born on a ranch, its loss is a personal tragedy the rest of us can, at best, only partially understand. Frequently, this loss occurs when a family member dies without an estate tax plan and the family discovers that they owe the government more than half the value of a large piece of property assessed as a potential high-end development. More often than not the only way to pay that bill is to sell the ranch.

Personal loss, the loss of the West's wide open spaces, of some of its most productive wildlife habitat, of its cultural diversity and sense of place; the loss of viability of agricultural economies and the destabilization of the rural communities they support-this is some of what we lose when a ranch dies. But the greatest tragedy is that many of these deaths could be avoided; avoided easily enough that it's fair to say that some ranches die of plain, ordinary negligence. Some, it could be said, come pretty close to committing suicide.

It's no news that ranches have been going belly up for as long as there have been ranches. They've been going bankrupt, been gobbled up by suburban sprawl, been bought out and tossed aside by celebrities, cut up into forties, and turned into wildlife refuges, parks or preserves. And it's

[1] The Sonoran Institute, Tucson, AZ.

old news (but it's still news) that those who have managed to survive all this are the ones that have been able to change. To switch from longhorns to herefords to Barzonas. To hay the meadows and rotate their herds. To host a few hunters. To live frugally and learn to be what writer Wallace Stegner called a "sticker."

The ranchers who survive in today's West, the stickers, are the ones who are learning to adapt to the changing economics and land-use patterns that unavoidably are shaping the future of the West. They're the ones who are learning to ranch more than livestock; to ranch the view, the ecosystem, the lifestyle, even wilderness. We know it can be done because it's already being done.

The ranchers who will be here tomorrow are those who are willing to learn to use all the tools at their disposal: conservation easements, estate planning, conservation development, collaborative planning. Today that's as important as knowing how to use a rope and a good cow horse. (Even more so, but we hate to admit it.)

Because these tools are unfamiliar to most ranchers, and because to use them properly requires a high level of expertise, those who are going to be stickers are also going to have to learn to effectively use help from others to get the job done. You've always prided yourself on being independent? Now you're going to have to learn how to be interdependent.

Some have already taken the plunge. In many cases they had to. From their successes we can take heart and inspiration. From their failures we can learn what not to do.

Ranchers on the Elk River near Steamboat Springs, Colorado--home of one of the fastest growing ski areas in the West--used a tactic more commonly associated with martial arts than with Western politics to keep their ranches alive. Instead of resisting the stampede of boomers threatening to inundate the Elk River Valley with a tidal wave of recreation homes, they redirected the energy of that tide, as an aikido master might redirect the charge of an aggressor. In the process they not only saved their ranches but made them more prosperous.

With consulting help from a Denver conservation planner, a couple of pioneering Elk River Valley ranchers marketed a limited number of building sites on their ranches in areas where they would have little or no impact on agricultural operations. Then they placed conservation easements on the undeveloped remainder of their land. By creating homesites that were able to demand top dollar, those ranchers were able to maximize return while developing a minimum amount of land. By applying conservation easements to the rest of their land, they were able to reduce its taxable value sufficiently that when it comes time to pass the ranch on to the next generation, as Colorado rancher T. Wright Dickinson puts it, they won't have to buy it back from the government first.

Remedies used to save ranchlands can even involve cows! (Now, there's a novel idea!) That's the case in northern Arizona, where an internationally known artist bought a ranch that encompasses 106,000 acres of private, state and Forest Service land surrounding a landscape-sized art project that's attracting worldwide attention. The artist/rancher is applying the profits of a cow-calf operation rejuvenated by holistic management practices to buy back some of the 500 forty-acre parcels that were created when part of the ranch was subdivided about thirty years ago. Just four years into the rejuvenation the cows are buying their first five forties, and inholders who threatened to shoot the rancher's cows when he first started up are now offering to kiss them.

As good as these stories sound, they are in some ways a distortion. Some of the ranchers applying these remedies are "deep pocket" ranchers who don't rely on agriculture for their main means of support. Working ranchers scraping to make a living in an unpredictable market and a hostile political climate have proven less likely to grant or even to sell easements on real estate that may be their family's only ace in the hole when the going gets rough.

Though it is true that taking chances with your best bet is not something you should do lightly, there is a growing number of ranchers around the West showing that they can succeed in shaping the future of their lands, their families and their communities if they know all the tools in their toolbag, know how to choose the one they need when they need it, and know how to use it after they've chosen it. In the process these people are proving that they are their own best bet. They're proving that they are stickers. So can you.

Note: This article was originally published in *Range* Magazine, Summer 1996, and was taken from the script of a slideshow presentation written by Dan Dagget for the Sonoran Institute of Tucson, Arizona. In addition to the slideshow, the Institute's Ranch Outreach Program offers a *Private Land Options Guidebook* that highlights successful examples of ranchers in the Rocky Mountain West who have protected their agricultural land base and generated income with flexible conservation strategies, such as limited development and conservation easements programs. This publication also provides estate planning strategies, an annotated bibliography on pertinent articles and books on preserving ranches and open space, and a list of resources and organizations that provide technical assistance on private land conservation. For more information on this program contact: Luther Propst, Executive Director, the Sonoran Institute, 7290 East Broadway, Ste M, Tucson, AZ 85710, (520) 290-0828, fax (520) 290-0969, e-mail soninst@azstarnet.com.

The Value of Your Land Today and into the Future - Choices Landowners Face

Lane Coulston[1]

"SMALL HOMESTEAD - LARGE LANDSCAPE"SM

Financial compensation to landowners for conservation easements

"This deal saved a ranch!" is an exclamation rarely heard at the conclusion of a ranch real estate transaction. Yet those were Zach Wirth's words as he closed the transaction which compensated his family for protecting their ranch from rural subdivision. The Wirths, who live in Wolf Creek, are the first Montana family to receive cash *from a private individual* for granting a conservation easement.

Conservation easements are voluntary legal agreements which landowners make to restrict the type and amount of subdivision and development which may take place on their property. Landowners choose the restrictions to safeguard the agricultural productivity and ecological health of the land.

In additional to protecting the future of agriculture and wildlife, conservation easements are useful financial planning tools. To understand this financial planning role, first consider the sources of land value. The top market price for a ranch generally reflects the high bids of speculators and developers. Agricultural value -- the productive value of the ranch -- tends to be much less than development value.

A common mis-perception is that conservation easements reduce ranch value from development to agricultural levels. In practice, a conservation easement usually lowers ranch value to a level *between* agricultural and development values. We call this level "open space value." Many affluent ranch buyers look for scenic, spacious, and ecologically diverse ranches. They will pay more than agricultural value for such properties, even if the land is under a conservation easement. Development value, open space value, and agricultural value can all be determined by a qualified appraiser.

The appraised reduction in market value resulting from the donation of a conservation easement -- perhaps 25 to 35 percent of development value -- usually qualifies the landowner for income and estate tax breaks. Yet many ranchers are "land-rich" but "cash-poor," and therefore benefit little from income tax deductions associated with the donation of a conservation easement. As part of their land use and financial planning, these ranchers may wish to *sell*, rather than donate, a conservation easement. The landowner negotiates and grants the conservation easement to a land trust organization.

Land trusts are private, nonprofit organizations with small budgets dependent on private donations. They cannot afford to buy easements unassisted. However, the American Conservation Real Estate Co. (ACRE) is working with land trusts to create a new market for privately "purchased" easements. This market is driven by buyers who have clear, motivating land ethics. Such people strive to protect our natural heritage.

Conservation buyers understand that the demand for ranchette subdivisions threatens our

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[1] American Conservation Real Estate, Helena, Montana.

heritage of native plant and animal communities. They seek alternatives to honor lands which have outstanding natural resource values. *In return for a single homesite in a secluded location, and for limited, low-impact recreational privileges, a conservation buyer may be willing to pay a rancher to grant a conservation easement.* The landowner creates value by choosing restrictions on future development of the property.

Usually, conservation buyers cannot fully compensate a landowner for the loss of development value due to a conservation easement. However, through their purchase, these buyers can help ranchers get out of debt, buy out partners, or acquire more land. Conservation buyers have shown interest in paying anywhere from $100,000 to $1,000,000 for this type of opportunity. On especially large and valuable ranches, it may be possible to generate well over $1,000,000.

UNDERSTANDING THE "PRESENT-DAY VALUE" OF A CONSERVATION EASEMENT

Granting a conservation easement means restricting certain rights that usually accompany the ownership of land. Some of these rights may be worth a lot of money. Examples of potentially valuable rights include the right to convert a working ranch to a vacation home subdivision, the right to clearcut timber, the right to engage in mining and other forms of land resource development. There are other privileges of land ownership which are ecologically significant but do not provide a significant financial return to the owner.

The monetary worth of the various rights of land ownership can be appraised. Some ranches are encumbered by deed restrictions which limit development, such as conservation easements or agricultural zoning districts. Development of many other properties is limited only by the county subdivision review process. Speculators and developers bid on ranches which do not have deed restrictions, driving up the price of such properties. Qualified appraisers determine the market value of development rights by comparing the sale prices of deed-restricted ranches with the sale prices of properties open to development.

Different appraisal techniques may be employed to learn the value of other land ownership rights. For instance, a timber cruise reveals the monetary value associated with different logging practices and rates of timber harvest.

In the scenic Northern Rockies, the right to subdivide a working ranch into recreational "ranchettes" is the predominant value of a conservation easement. People often use the terms "conservation easement value" and "development rights value" interchangeably, because the two values are so similar.

The landowner's primary benefit from restricting development rights with a conservation easement is peace of mind, knowing that the land will be preserved in the future. There can be other benefits as well: income and estate tax advantages, or even an immediate influx of cash.

DIRECT MONETARY COMPENSATION FOR CONSERVATION EASEMENTS

Many property owners are "land-rich" but "cash-poor," and as a result benefit little from income tax deductions associated with the gift of a conservation easement. As part of their land use and estate planning, some landowners seek to sell a conservation easement. The conservation easement is negotiated and granted to a land trust organization.

Land trusts rely on the contribution of money, gifts of conservation easements, and of land by private parties to support their work. They cannot afford to buy easements unassisted. However, there is an emerging market for "purchased" easements by private individuals. This market is driven by buyers who have clear, motivating land ethics. Such people endeavor to live their life in a way that promotes and protects our natural heritage. They understand the conservation roles played by land trusts.

Like many people, dedicated conservationists enjoy the open spaces, recreational opportunities, and natural values of the Northern Rockies. However, the demand for ranchette subdivisions threatens our heritage of native plant and animal communities. The purchase of a rural ranchette is inconsistent with the open spaces we enjoy in the West.

Conservation buyers choose to honor lands which have outstanding natural resource values. In return for a single homesite in a selected location, and for limited, low-impact recreational privileges, a conservation buyer may be willing to pay the rancher to grant a conservation easement. The landowner creates value by choosing restrictions on future development of the property.

Another market for purchased conservation easements is supported by government agencies. The US Fish and Wildlife Service at times has program money to purchase easements on wetlands and associated uplands. The Montana Department of Fish, Wildlife and Parks has a small but stable supply of money for securing easements which augment wildlife habitat and recreation opportunities. They may request hunter and fisherman access, or negotiate limits on agricultural activities to improve wildlife and fisheries habitat.

Each land trust organization has a different character, which is reflected in their easement documents. The Nature Conservancy emphasizes biological diversity. The terms of a Nature Conservancy easement often include specific protections for vulnerable plant and animal communities. The Montana Land Reliance is a state-wide land trust which emphasizes open space and agriculture, as well as wildlife and fisheries habitat. Local land trusts write easements to maintain traditional land uses which contribute to the character of the community.

Estate Planning for Ranchers

Gregory V. Gadarian, J.D.[1]

I. GENERAL ESTATE AND GIFT TAX CONCEPTS

A. An annual exclusion is provided for gifts of $10,000 (or less) per donee.
B. A lifetime exemption of $600,000 is provided for gifts or bequests that are not deductible.
C. Deductible bequests are bequests to a surviving spouse or a charity.
D. Estate tax rates.
  1. The estate tax rates begin at 37% for estates in excess of $600,000 and increase to 55% for estates in excess of $3,000,000.
  2. A special 5% surtax is imposed on estates of $10,000,000 to $21,040,000.
E. A generation skipping transfer tax (GST Tax) applies to transfers to grandchildren. The GST tax rate is 55%. A $1 million lifetime exemption is provided for the GST tax.

II. BASIC PLANNING TECHNIQUES.

A. Utilizing the Credit Exemption Amount.
  1. Avoid "I Love You" wills.
  2. Credit is for $192,800.
B. Special Rules for Ranchers and Small Business Owners.
  1. Special Use Valuation allows property to be valued as a ranch or business property. However, value can only be reduced by $750,000 under this rule.
  2. Rule applies if property continues to be used for ranching by a qualified heir.
  3. Installment payment of estate taxes is allowed for businesses (including ranches). Installment period is 1 for 5 years. Amortizing principal over next 10 years.
C. Bypass Trusts.
  1. $600,000 is placed in trust for benefit of the surviving spouse.
  2. Income and principal can be sprinkled to family members.
  3. Surviving spouse can serve as trustee.
  4. Remainder passes estate tax free to children on death of surviving spouse.
D. QTIP Trusts.
  1. Trust qualifies for marital deduction.
  2. Assets pass to children on death of surviving spouse.
  3. Used frequently in second marriages.

  4. Election out of QTIP treatment allows postmortem planning.

III. ADVANCED PLANNING CONCEPTS

A. The Traditional Corporate Freeze.
  1. Parents hold preferred stock and give common stock to children.

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[1] Attorney, Tucson AZ.

2. The appreciation in the value of the business is reflected in the common stock. The value of the preferred stock is frozen.

3. This type of planning was restricted by the 1987 and 1988 Tax Acts.

B. The Testamentary Freeze.

1. Parents hold common and preferred stock in the business.

2. Preferred stock is left to surviving spouse.

3. Common stock is left to children (or in a generation skipping trust).

4. Appreciation in value of family business after death of first spouse escapes estate taxation on death of surviving spouse.

C. Minority Discount.

1. Property is valued for estate tax purposes at the amount a willing buyer would pay a willing seller.

2. Valuation will reflect the fact that the decedent held a controlling interest or minority interest in the business.

3. The parents' interests should be restructured so that each holds a minority interest in the business.

D. Family Limited Partnerships.

1. Gifts or bequests are subject to tax on the "value" of the property transferred.

2. Limited partnership interests are traditionally subject to discounts for lack of marketability and lack of control.

3. Transferring assets to a family limited partnership allows the discounts for lack of marketability and lack of control to be applied to assets such as real estate, stocks, bonds and other securities.

E. GRATS and GRUTS

1. Trusts which provide an annuity or unitrust payment to the grantor for a term of years and the remainder to the Grantor's children (or other individual) are GRATS and GRUTS respectively.

2. The value of the gift of the remainder is a present value calculation.

3. If the assets in the trust earn more than the IRS table assumes, then the difference escapes estate tax and gift tax.

F. Charitable Remainder Trusts.

1. Similar to GRATS and GRUTS with an annuity or unitrust amount being paid to the grantor and the remainder to a charity.

2. Tax benefits are (I) a current income tax deduction and (ii) avoidance of gain on the transfer of assets to the CRT.

G. Generation Skipping Transfers

1. The GST tax provides for a $1,000,000 exemption for each taxpayer.

2. The parents should leave the assets in trust for their children The children cam serve as trustees. Upon the children's deaths the property is <u>not</u> subject to estate tax and passes in trust or outright to the grandchildren.

H. Life Insurance Trusts.

1. Proceeds of life insurance payable to the trustee of a life insurance trust are not subject to estate tax or income tax on the insured's death.

2. The proceeds may be used to purchase assets from the insured's estate.

3. The life insurance trust can also be set up to hold the assets as a generation skipping trust.

I. Defective Trusts.

1 . The creator of a trust or the beneficiary will be subject to tax on trust income if certain types of "defects" are used in drafting the trust agreement.

2. A Defective Grantor Trust causes the creator to pay tax on trust income even if the income is accumulated in the trust for the benefit of the creator's children.
By paying the tax on the income the creator is in effect making additional tax-free gifts to the trust.

3. A Defective 678 Trust causes a beneficiary to be taxed on the trust income even if the income is accumulated in the trust. Most beneficiaries will have a lower tax rate than the trust so this defect reduces income taxes.

J. Recent Tax Law Changes.

1. Income tax rates for individuals are 39.6% on ordinary income. The rates for capital gain caps out at 28%.
2. Income tax rates for trusts hits 39.6% at $7,900
3. No alternative minimum tax for gifts to charities of appreciated property.

K. Legislative Proposals.

1. Increase in lifetime exemption from $600,000 to $750,000.
2. Indexing of lifetime exemption.
3. Indexing of annual exclusion.
4. Special treatment for small businesses.

Land Management Partnerships: a Panel Discussion

Ann Moote, Session Moderator [1]

INTRODUCTION TO THE PANEL

Land management partnerships are organized groups of individuals and organizations working together to address land use, natural resource, or environmental issues at the local level. Partners may include government agencies, nonprofit organizations, professional societies, corporations, landowners, and private citizens. Frequently, these people or organizations have not previously worked together. Often they are traditional adversaries. They form a partnership when one or more individuals or groups identifies a problem or need that they cannot address alone because they lack adequate funding, skills, jurisdiction over the resource, or land ownership.

Partnerships are said to enhance land use and natural resource management by drawing expertise and input from a wide range of individuals and groups who live in and intimately know the resource base and the local economy. Getting more people involved in a project increases the likelihood that it will be accepted and maintained over the long term. Working through issues with a diverse group of individuals and organizations, partnership groups often come up with creative and desirable projects. Furthermore, by pooling resources of several organizations, agencies, and individuals, partnerships can achieve greater volunteer involvement and a broader base of financial support.

DISCUSSION (SUMMARY)

Although a new concept in the United States, community-based conservation has had a longer history in other countries, particularly in the developing world. In developing countries, almost all conservation efforts are focused on the people living close to protected areas. Research has shown that conservation projects that ignore local patterns of resource use or tenure relationships tend to fail, as do those that depend on outside expertise. Yet in the U.S., conservation efforts traditionally have ignored local residents and relied exclusively on agencies or private conservation groups to manage the resources.

This is changing, however. With the advent of ecosystem management and increasing restrictions on public lands access and use, communities adjacent to public lands have become less willing to let outsiders make public land management decisions for those lands. New concepts, like holistic resource management and coordinated resource management, also have united many grassland communities around their resource base. Local communities are fighting for equal consideration in land management decisions that effect them.

As described by discussants and illustrated in the Sonoita and Cascabel cases, successful partnerships share some common characteristics. They are characterized by broad membership; a common guideline for partnership groups is "involve everyone." Working together, the participants generate a commonly shared vision for natural resources and local communities that helps build long-term support and can improve project implementation. Communication is the primary tool used to solve problems and reach agreements. Decisions are typically made collaboratively or by consensus, to ensure everyone's needs and concerns have been addressed. Through the process

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[1] Water Resources Research Center, University of Arizona, Tucson AZ.

of group decision-making, partnerships increase individual members' levels of responsibility, involvement, and commitment.

Not all partnerships are successful, however. Discussants in this session identified several reasons partnership groups have fallen apart, including: a history of extreme, unresolved conflict among key interests; lack of a clear purpose; unrealistic goals or deadlines; failing to include key interests and decision-makers; major inequity of power or benefits; and forming the group too late--after projects or proposals are already developed. All discussants considered communication--keeping everyone up-to-date and maintaining dialogue among partners--critical to building trust and a sense of community. In Cascabel, the Management Committee addressed some of these potential problems by setting a definite deadline, agreeing on a policy of limited consensus, and keeping the partnership "open, but not too open." The Sonoita Valley Planning Partnership keeps lines of communication open by mailing minutes of meetings to a large list of interested people, and accepts written comments as well as input during meetings.

Commitment and trust were said to be critical to effective group processes. Discussants stressed that all participants need to make a long-term, personal commitment. In Sonoita, for example, all meetings are held on weekends, not weekdays when agency and organization representatives would paid for meeting while self-employed people lose a day's work.

Often, community members have been frustrated by past experiences and are leery of investing their time and energy in these efforts. Participation and confidence often must be earned, primarily by allowing sufficient time for partners to become acquainted on a personal level and discover areas of agreement. Therefore, partnerships should tackle issues they can agree upon first, leaving the contentious ones until they have developed some mutual trust. For example, the Cascabel Management Committee agreed to avoid highly contentious issues like fire and grazing management on private lands, but moved forward with planning for several other resource issues.

Both of the partnership groups discussed avoided private property rights issues by explicitly limiting themselves to discussion of public land management. During the discussion, some participants mentioned the tendency of private landowners to "hide behind private property rights" and avoid partnering. Private property owners expressed a fear that increasing government regulation and environmental zealotry will limit their use of their land. They agreed, however, that with property rights come responsibilities.

Consensus is another highly contentious issue for partnerships. Many people insist that consensus decision-making is the only way to ensure that everyone's needs and concerns are addressed. Offering another perspective, Eric Schwennesen stressed the difference between common or collective agreement and consensus, describing consensus as "a way to brow-beat minority opinion into submission." Other participants expressed the concern that consensus gives any one individual veto power.

The appropriate role for traditional decision-makers (i.e., agencies, powerful interest groups) in partnerships was also discussed. Agency representatives, in particular, may be viewed as arrogant, led by their "agency culture" to believe they are the sole experts, and by bureaucratic rigidity to believe they should be the sole decision-makers in public land management planning. Discussants emphasized that agency representatives need to "separate themselves from their uniforms" as much as possible. While still representing their agency and bound by some laws, they also need to present themselves as individuals, with respect for other individuals.

Finally, reliable funding was mentioned as a critical factor in the success or failure of a partnership effort. Both partnership groups presented here were funded by agency and interest group participants. In general, however, government funding can only be expected in the short term. Luther Propst noted that identifying innovative, long-term funding sources is one of the greatest challenges partnership groups face.

As communities rally around their local public lands, agencies and traditional powers are slowly becoming more willing to share decision-making with them. In this session, presenters described how the Bureau of Land Management is sharing its planning authority, and The Nature Conservancy has evolved from a "command-and-control" type organization to one that can share control. The results are innovative partnerships characterized by broad-based local participation that utilize and build on local knowledge to develop better land management plans.

Strategies for Creating Successful Partnerships[1]

Luther Propst[2]

Here are some suggestions for park and refuge managers who want to build partnerships with the communities and landowners on their borders:

Know thy Neighbor. Take the time to get to know local leaders. Working relationships with community members are best developed outside of hearing rooms or council chambers. Don't just host an annual open house for the community--have lunch regularly with community leaders, give them VIP tours of the park or refuge, or join them on a hunting, hiking, or fishing trip. Be sure to interact not just with elected officials, but with everyone involved in local decision-making: bankers, developers, environmental advocates, landowners, journalists, land-use planners, and business owners. Make sure you're visible before threats arise.

Become a Member of the Community. Developing good relationships with gateway communities requires a full-time commitment to the well-being of the community. You won't get results if you're only willing to tackle issues of importance to your park or refuge. Instead, participate in the whole range of issues affecting the community. Get involved in the community as well--join a neighborhood association, coach a Little League team, volunteer on community projects, join the Rotary, or become an active member of a church. If possible, develop employee housing in the community rather than behind the park boundary.

Get Involved Early and Often. Effective participation in a community's decision-making process requires early and ongoing involvement. The best opportunity to influence decision-making occurs well before proposals are made public. This principle works both ways: Don't expect to be invited to a community's preliminary planning sessions if you don't include local leaders in your own.

Be a Team Player. As a member of the community, you are entitled to participate in local decision-making processes and express concerns and opinions. Accept that you are one of many who are trying to shape and influence decisions. Constructive participation in community decision-making will only enhance your role as a legitimate member of the community.

Build Coalitions. Having a well-organized and thoughtful constituency is the best way to ensure that local government listens to park or refuge concerns. A coalition of individuals or groups working toward a common goal can be extremely effective in influencing decisions. Involving too many is always better than leaving someone out. Establish partnerships between divergent interest groups--an alliance between a downtown merchants association and a local "Friends of the Refuge" group, for example, can have a powerful impact on local decisions. Do so before you need to--a proactive group is typically more effective than one that organizes in response to a specific threat.

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[1] Many thanks to Gil Lusk, director of the National Park Service's employee training programs, for assistance in preparing these strategies which are excerpted from *Balancing Nature and Commerce in America's Favorite Towns* (tentative working title) by Jim Howe, Luther Propst, and Ed McMahon.

[2] Sonoran Institute, Tucson, AZ.

Develop a Strategy. Don't just go blindly into partnerships or community relations: Have a strategy and tangible goals in mind. Understand both the concerns most important to you and those where compromise can be sought. Instead of opposing projects, try to come up with modifications that would allow you to support them or with alternatives that allow you to present your concerns in a positive light.

Don't Get Ruffled by Criticism. Some members of the community will not appreciate your views. Expect criticism and accept it without getting defensive. Resist the temptation to fire back. It's important to maintain an open dialogue not only with those who share your views, but with individuals and groups who may oppose you. At the same time, know which relationships will lead to fruitful partnerships and which will simply keep the lines of communication open.

Understand the Full Range of Growth Management Strategies. Many local officials are unaware or suspicious of growth management tools. To ease doubts about growth management, every protected area manager should be familiar with the complete spectrum of public and private land-use techniques--conservation easements, agricultural districts, cluster development, floodplain regulations, zoning, etc.--and how they apply in your state or locality.

Lead by Example. Wherever possible, protected area managers should set the example for new development. If a new park or refuge building is under consideration, involve the community in determining its location and scale. Then design a new facility that serves as a model for other projects in the community. Utilize architecture that blends in with the landscape, outside lighting that keeps night skies dark, landscaping that makes use of native plants, and conservation-minded plumbing and lighting. (Older buildings can be retrofitted, too.) Use interpretive signs and brochures to make sure the public knows what's been done.

Demonstrate the Link Between Resource Protection and Economic Vitality. Local leaders are more likely to pay attention to environmental concerns if they can be linked to economic vitality. Develop data that demonstrate how your protected area contributes to the local economy through increased property values, tourism, sales tax revenue, local purchases, or jobs. A local college can help carry out this research. Also, wherever possible, hire from the community and purchase products and services from local businesses.

Empowering Land Management Partnerships

Eric Schwennesen[1]

In the small African kingdom of Lesotho a few years ago, I had a chance to witness firsthand some of the whimsy that occurs when modern technology meets practical culture. The mainly agrarian kingdom was about to receive the gift of a new international airport.

As is often the case with new technology, there was to be some care and feeding of this gift, and local officials spent many long days explaining to the villagers in the surrounding region how beautiful!, important!, beneficial!, this new airport would be.

And just to make sure, nearly one half million dollars was spent to put a very formidable fence around the whole thing. Well, the money spent was enough to scare nearly everybody away (is any of this starting to sound familiar?) And it really was important to keep this airport running smoothly.

Well, even before the new airport had a chance to start operations a "breach" in the security fence spilled cattle all over the runways. Frantic investigations finally turned up the dangerous lunatic who had sabotaged the massive project: a 12-year-old boy with a $2 pair or pliers.

He was a herdboy, an important responsibility in Africa. One morning he found his track blocked by a very formidable fence, found it to be an impediment to his progress ... and solved his problem with an elegant simplicity that I can only admire today.

The lesson, in case it has escaped you, is that enforced partnerships, regardless of intention, don't work. They have a fatal weakness; anyone with a philosophical $2 pair of pliers can ruin them. It happens all the time; anyone care to guess how much money and effort has been built into massive projects, only to be defeated by "pliers?" That's what lawyers do.

This all sounds defeatist, so can I suggest or demonstrate a better way?

Yes I can.

1. Instead of starting with a project ("what this country really needs is ...") start with a common goal, not a vague, everybody-knows-it-anyway statement, but a detailed written goal that recognizes every serious wish of every participant. The goal becomes the guiding force for everything that happens later and cannot tolerate consensus! Either every participant supports the stated goal, or more effort has to be made to have the goal include further needs. It is not a workable goal until every participant supports it. (See paragraph one: "enforce partnerships.")

2. No uniforms. A workable partnership at any level has no need of corporate identity of agency mystique. By the same reasoning, there can be no "experts." Participants are individuals with individuals' need for recognition, and if one individual has special knowledge that is pertinent, so do all others who participate.

3. Be inclusive, not exclusive. We have evolved into a society that treats severely anyone who came in late." I'm still trying to understand why! Probably it's a throwback to school days and tardy bells, but it's a very silly reason to exclude someone who really cares, from participating in the management of a better future. I have had the fortune of seeing the inclusive approach and its consequences in extraordinary places. Rest assured that anyone who really wants to be involved, does have something important to contribute.

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[1] Rancher, Winkleman AZ.

4. Land management partnerships should not be made to "follow regulations." To do so places the group's goals in an inferior position to policy and bureaucracy and in that case, don't bother. Start over with a group that includes the policy writers. See point #1. By my reckoning, the "right way" to manage land has not been invented yet.

5. The previous points all call for that rarest of commodities, trust. About two-thirds of the audience will now curl their lips in derision ... which does not change my statement in any way. In my experience our land management groups have tried hard to broker trust without realizing that you can't broker it; you have to earn it. When you do earn it, the whole management equation changes.

6. I'd like to list a few brief examples which are nearby and will happily welcome you into their management partnerships.

- Clay Riggs Ranch, Sunizona, Arizona
- Double Check Ranch, Winkleman, Arizona
- The 20:1 Group, Austin, Nevada
- Rancho Mababi, Cucarachi, Sonora
- Adams Ranch, Texas Canyon, Arizona
- Wheeler Ranch, Globe Arizona
- Holder Ranch, Eagle Creek, Arizona

There are many other such partnerships, and I haven't bothered even to mention the much larger progress being made overseas.

Thank you.

The Sonoita Valley Planning Partnership

Karen M. Simms[1]

INTRODUCTION

The Sonoita Valley Planning Partnership (SVPP) is a voluntary association of agencies (federal, state, and local), organized groups and individuals who share a common interest in the future of public land resources in the Sonoita Valley. Participating individuals have come from a variety of communities including Sonoita, Elgin, Patagonia, Huachuca City, Sierra Vista, Nogales, Tucson, and Phoenix among others. Participation has also come from representatives of organized groups including hiking clubs, conservation organizations, off-highway vehicle clubs, mountain bike clubs, bird-dog clubs, and grazing and mining interests. Agency representation has come from BLM, Nogales and Sierra Vista Ranger Districts of the Forest Service, Natural Resource Conservation Service, U.S. Geological Survey, Arizona Game and Fish Department, Arizona State Land Department, Arizona Department of Water Resources, Pima County Parks and Recreation and Planning/Flood Control, and Santa Cruz County. Participation in the SVPP is completely open. Anyone can participate and they can join at any time. Those who are unable to attend the monthly meetings are invited to participate by reviewing meeting minutes and providing written or phone comments.

The (SVPP) was conceived as a way for the community (private, public, government, local, non-local, etc.) to come together to achieve community oriented resolutions to local and national issues affecting public lands within the Sonoita Valley. This in turn has increased awareness, communication, understanding, trust and support for each other. It has also helped us look at the valley as a whole and what we want and need in the future.

BACKGROUND

In 1988, The BLM acquired the public lands on the Empire-Cienega Resource Conservation Area (RCA) through a land exchange. These lands located in north-eastern Santa Cruz County and southeastern Pima County, Arizona, hold extremely high social, cultural, and resource values for the local and national public. These values include a critical watershed which is important to Tucson for flood control and aquifer recharge, a site on the National Register of Historic Places, endangered species, extensive riparian areas, broad expanses of native grasslands, outstanding wildlife habitat, scenic open space and high potential for dispersed recreation. The BLM is mandated to complete long-term land use planning to guide management of the 45,000 acres of public land within the Empire-Cienega RCA.

After several false starts on developing a plan for the RCA, the BLM decided to take a new approach which would involve greater public participation in all aspects of planning and which would also improve communication and coordination with surrounding public and private landowners. This desire for a new approach led to creation of the SVPP.

In January of 1995, the BLM brought together representatives from federal, state, and local agencies with interest in the Sonoita Area to discuss the idea of forming a partnership to work with the community on public land issues. There was strong interest from all participants. This meeting was followed by a community potluck in April 1995. Agencies and groups were invited to put up displays of their activities in the Sonoita Area, and tours were given to various sites in the Valley.

[1] Bureau of Land Management, Tucson AZ Field Office

Participants filled out a questionnaire on their concerns for the future of the Sonoita Valley. In July 1995, the SVPP put on a community workshop to review the results of the questionnaire and to generate other issues related to the Sonoita Valley. The participants decided to deal only with issues related to public lands. Three working groups were created at the workshop to address issues relating to wildlife-vegetation, water-minerals, and people. The groups met monthly. In December 1995, the groups gave a joint presentation on their accomplishments on issues, visions and goals. They also decided to merge the water-minerals and wildlife-vegetation groups into the natural resources working group and to continue to meet monthly. In September 1996, the groups gave another joint presentation on accomplishments and decided to have all working groups meet together for the time being to finalize objectives and work on management recommendations. Although working with the BLM on planning for the Empire-Cienega has been a driving force behind the direction of SVPP. The working groups have also provided input into several BLM and USFS projects.

SVPP ACCOMPLISHMENTS

To date the SVPP has accomplished the following:

- Created vision statements relating to open space, water, healthy diverse grasslands and traditional uses for the Sonoita Valley that broadly define what future conditions the community would like to maintain or reach in this valley.

- Raised a variety of issues concerning public lands within the Sonoita Valley.

- Formed three working groups to address issues relating to:
  People (cultural/historical resources, recreation, land uses, economics etc.),
  Water/Minerals (water quality and supply, mineral use and impacts, etc.),
  Wildlife/Vegetation (wildlife populations and habitat, endangered species, grasslands, grazing, etc.).

- Developed goals for vegetation, wildlife, water, watershed, cultural resources, recreation, open space, traditional uses, and stewardship of resources.

- Drafted specific, measurable objectives for upland and riparian vegetation, watershed, wildlife, cultural resources, and recreation.

- Made preliminary recommendations on use of prescribed fire, off-highway vehicle designations, management of antelope habitat, and management of special recreation permit areas.

SVPP FUTURE

The SVPP has already accomplished a great deal. The direction that that group takes in the future is up to all of the participants. The working groups have decided to meet jointly for the time being while finalizing objectives and working on management recommendations. By meeting together, the groups can more effectively address the different views of the participants in relation to specific issues. Some of the tasks that the group will be working on include:

- Finalizing objectives
- Developing management recommendations to achieve objectives and solve issues

- Preparing a final report of accomplishments
- Working with BLM to finish Land Use Plan for Empire-Cienega
- Continuing to provide input on implementation of plans
- Continuing to provide input on specific issues/topics relating to public lands in Sonoita Valley as they arise

Components of Success

There are several indicators of the success of the SVPP approach so far: a high level of participation has been maintained in the working groups, new participants have continued to join, communication has increased between the participants on a variety of levels, there has been increased interest and involvement in management activities by the agencies, and the local community has started up the Sonoita Crossroads Community Forum which is dealing with many issues which complement those being dealt with by SVPP.

BLM has achieved a better understanding of the importance of the valley to everyone; of community values, of present and future needs and concerns; how public lands are important to sustaining the desired community and character of the valley, and how the solutions to our problems today lie in the strength of our community in the future.

Some of the components of success include:

- Have an open process, don't keep anyone out, invite detractors in
- Use an outside 'neutral' facilitator at least until trust is there
- Initially, get everyone acquainted in a non-confrontational, recreational (fun) atmosphere
- Keep communication going throughout the process (minutes)
- Keep commitment going (funding, level of involvement)-don't back burner it
- Have an education component with technical specialists
- Respect diverse views
- Seek common ground
- Nurture partnerships

Trouble In Tortuga! A Rangeland Conflict Simulation Exercise: Simulation Materials and Evaluation Report

Kirk Emerson, Hal Movius, and Garri Dryden[1]

INTRODUCTION

During the spring of 1996 a group of scholars from the University of Arizona and professional mediators from Tucson formed the Environmental Dispute Resolution Interest Group (ENDRIG) to promote the study and practice of environmental conflict resolution. One of the group's early projects was to design a simulation game that would model a distinctly southwestern environmental conflict and would help explore ways toward resolving the conflict.

During the ensuing summer, Kirk Emerson, Coordinator of the Environmental Conflict Resolution Program at the University of Arizona's Udall Center for Studies in Public Policy, developed an initial version of the game. The result, *Trouble in Tortuga!*, is a group interaction intended to resolve a simulated rangeland conflict in the small community of Tortuga, a factitious mining-and-ranching town (in a setting similar to that of southeastern Arizona, or other western landscapes).

While completely fabricated, the situation presented in the game was based on facts and events from actual disputes that had occurred in locales not far from Tucson. The simulation was designed to involve a cast of seven characters from Tortuga--two ranchers, a planner, an environmentalist, two government agency representatives, and a developer--brought together with a facilitator to try to sort out the trouble brewing in Tortuga. Here is a digest of the scenario:

It all begins when Ed Middleton's widow, owner of the 640-acre X-Bar ranch, dies and leaves the ranch to her children. The three Middleton kids, not interested themselves in working the X-Bar, are determined to sell the ranch to the highest bidder. Developer Sydney Stone is eager to snap up the estate to build 400 clustered homes.

Neighboring rancher Gil Sinespina also wants to buy the X-Bar--and its grazing rights to 15,000 acres in the adjacent San Cristobal National Forest--but he doesn't have the cash. Meanwhile, Sinespina has been told by the Forest Service that his own grazing allotments on the public land are being reduced because of a recent drought in the area.

Local firebrand Corey Flintlock, an activist with SAGE (Save the Arid Grassland Environment) wants to keep both cattle and condos out of the area to protect the grasslands and the habitat of the rare Gray Hawk.

And while county planner Brady Euclid worries about the impact of the proposed clustered development on the small community of Tortuga--water, sewage, schools, and police--she frets even more about what some other developer--Blake Worstcase, for example--might do if Stone walks away or is driven away from the deal. So what to do in Tortuga?

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[1] Udall Center for Studies in Public Policy, The University of Arizona, Tucson AZ

In September 1996, ENDRIG held a trial-run of the exercise to assess whether the simulation was substantively realistic and procedurally efficient. With a few modifications, a final version was then generated for use at a session at "The Future of Arid Grasslands" conference held in October 1996. Several Arizona residents volunteered to step into the seven character roles, many of which contrasted sharply with the players' real-life identities: a rancher played a U.S. Forest Service ranger, an environmentalist became a rancher, and so on. The Udall Center's Kirk Emerson and Hal Movius, a graduate student at the Center, facilitated the two-hour simulation.

The simulation was intended to elicit the complex, interrelated issues concerning the use and disposition of rangeland and to demonstrate the potential for alternative approaches to conflict resolution. Another goal of the simulation was to provide a learning experience for the real stakeholders, the participants, by providing a venue in which they could interact with each other from an alternative vantage point. For most of the participants, this was their first such experience--acting out a role to portray and promote a view different than, if not contrary to, their own. And for many, it was a real eye opener.

Following the simulation, Jim Walsh, President-elect of the Arizona Dispute Resolution Association (ADRA) and a former state legislator, moderated a panel discussion where the participants discussed the issues again, this time from their real-life perspectives. While the simulation and discussion did not completely resolve the trouble in Tortuga, it did help the participants, who approached the conflict from disparate viewpoints, move closer to resolving some of the issues.

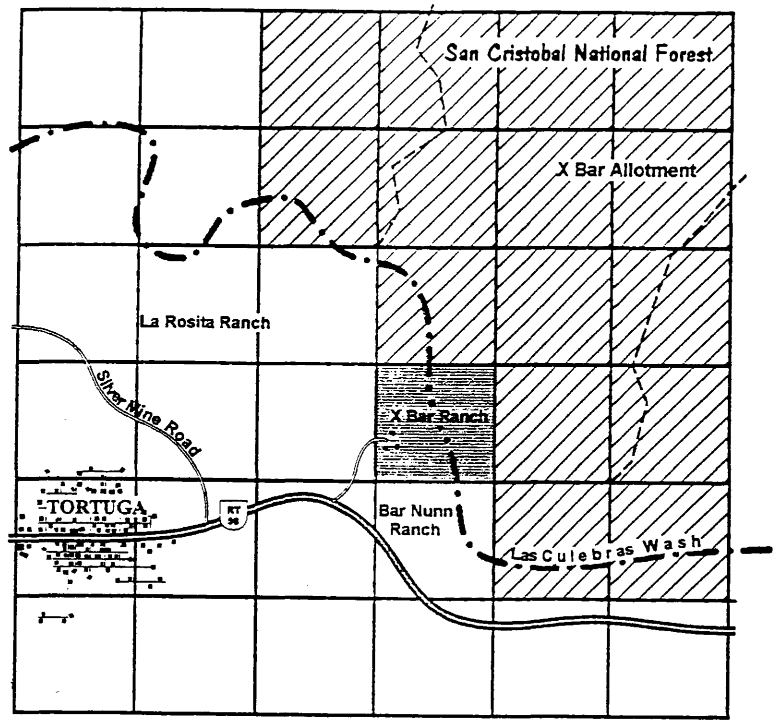
This report includes several items:

- Part I: The simulation exercise, *Trouble in Tortuga!*, including a complete set of instructions, briefing documents, maps, and background materials;

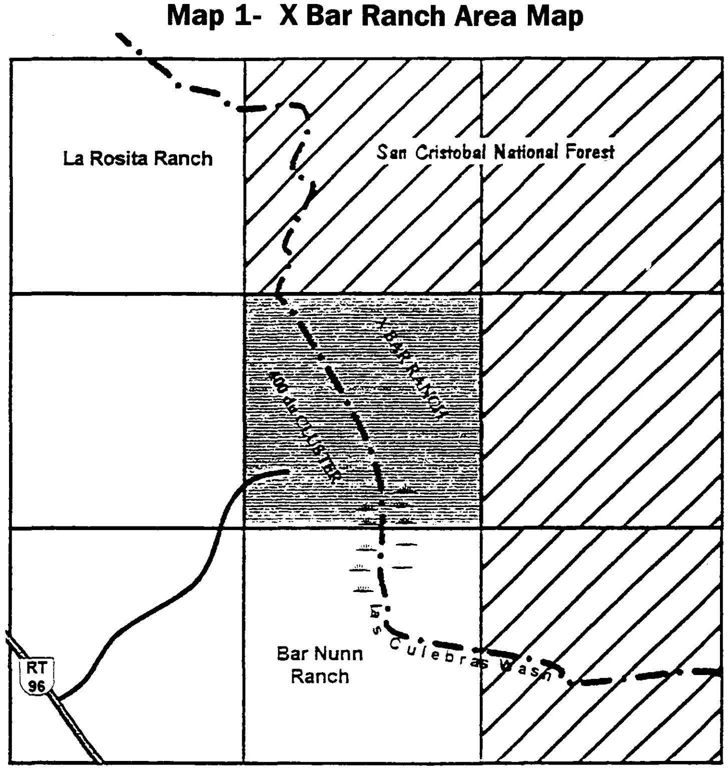
- Part II: A report and products of the simulation session conducted October 12, 1996, at "The Future of Arid Grasslands" conference, including a summary of comments made by panelists following the simulation, with an evaluation and summary of lessons learned; and an

Trouble in Tortuga! is still a work in progress. Its developers (ENDRIG members Bryce Appleton, Garri Dryden, Kirk Emerson, David Fuller, Dale Keyes, Hal Movius, Larry Robertson, and Ann Yellott) will be refining the exercise over time to use in different contexts and with different audiences and participants.

For more information about *Trouble in Tortuga!*, the Udall Center's Environmental Conflict Resolution Program, or the Tucson-based Environmental Dispute Resolution Interest Group (ENDRIG), contact Kirk Emerson, Udall Center for Studies in Public Policy, The University of Arizona, 803/811 East First Street, Tucson, AZ 85719, Tel. (520) 621-7189, Fax (520) 621-9234, email address <emersonk@u.arizona.edu>.



Map 1- X Bar Ranch Area Map



Map 2 - X Bar Ranch Estates - Conceptual Land Use Plan

Maps compiled by Gary Dryden. Scale: 1 inch = 1/2 mile

Part I SIMULATION EXERCISE

General Instructions to Organizers & Facilitators

1) The *Trouble in Tortuga!* simulation exercise is designed to involve seven participants, each assuming the role of a character (rancher, developer, planner, environmentalist, etc.), and one or two facilitators. Ideally, each of the seven participants will play a character different than their own real-life situation. The cast of characters to be played by the participants includes:

- Brady Euclid, County Planner
- Corey Flintlock, Coordinator, Save the Arid Grassland Environment
- Toby Nunn, Rancher, Bar Nunn Ranch
- Gil Sinespina, Rancher, La Rosita Ranch
- Sidney Stone, Developer, Sierra Grande
- Jo(e) Waterstone, State Game and Fish Commission
- Pat Wright, San Cristobal District Ranger, U.S. Forest Service

2) The recommended room arrangement for the simulation exercise is a roundtable format for 9 or 10 persons (participants and facilitators)--with name plates for each character--and additional seating around the room for observers.

3) The recommended duration for the exercise is two 90-minute sessions--with a 15-minute break between sessions--followed by a 30-minute discussion and assessment by the participants of what they learned from the simulation exercise. The 90-minute sessions are meant to simulate two half-day sessions, ostensibly held on consecutive Saturdays, with the break simulating the intervening week.

A note: Obviously, the format of this exercise can be varied--with durations ranging from one-hour to full-day sessions, and with more or fewer characters--depending on the interests or constraints of the organizers and participants.

4) Each participant should receive, in advance of the simulation exercise, a copy of the "Background and Setting" statement, his or her character's "Confidential Instructions," and both maps.

5) Each facilitator should receive and review all materials, including the "Confidential Instructions" for facilitators and those for all characters.

6) The facilitator should talk to each participant to see if they have any questions about their character and about the general format and process for the simulation exercise. Each participant should be encouraged to learn as much as possible about the type of character they will be playing, about his or her job or career/livelihood, and about what perspectives that character might realistically bring to the table. As appropriate (and without getting too corny), the participants should feel free to use props (maps, charts, books) or articles of clothing (such as, hats, jackets, vests) or whatever else might help them portray and project the "image" of their character.

7) Immediately prior to the simulation exercise, the facilitator should meet with the other participants (as a group) for a brief discussion about the how the simulation will begin and proceed (i.e., the facilitator will begin the simulation with a brief overview, each participant will then go in turn to present his or her position and interests, and then the discussion will continue whereby each person must raise his or her hand to be recognized by the facilitator before talking).

8) After the final session of the exercise, the facilitator should lead a discussion with the participants to solicit their comments about the simulation exercise and their roles in it, as well as any insights or lessons they might have learned from playing their respective characters.

Background and Setting

Ed Middleton's widow died last year, leaving the fate of the X-Bar Ranch in the hands of the executors of the estate. The Middletons' three children were all in agreement: no one had an interest in ranching, and everyone had an interest in selling the ranch to the highest bidder. Moreover, since partial payment of inheritance taxes by the Middletons falls due in six months, there is pressure to sell soon.

Located just past the old mining town of Tortuga in the foothills adjacent to the San Cristobal National Forest, the X-Bar includes one section (640 acres) of private deeded land and a 15,000-acre grazing allotment in the national forest (see Map 1).

Elena Sinespina and Toby Nunn own the ranches on either side of the Middleton property. Third generation ranchers, Toby and Elena were disappointed when none of the Middleton kids wanted to continue the tradition. Las Culebras Wash snakes through all three ranches, and for many years all three ranching families jointly managed fencing and flooding problems, droughts, and drops in cattle prices. When Ed Middleton died 10 years ago, Elena's son Gil gladly agreed to manage the X-Bar. Gil has made it known that he would like to buy the X-Bar, but it seems unlikely that he will be able on his own to come up with the money to do so.

The community of Tortuga was established in 1871 by Basque silver miners. When the mines played out at the turn of the century, the town was virtually abandoned, left to serve as the local gathering place for the area's ranching community. Decades later an eccentric geology professor purchased the town site and began rehabilitating some of the old buildings. By the mid-1960s young professionals from the nearby city of Sierra Grande were moving to Tortuga in search of a small community lifestyle, renovating the old homes and businesses. There are now 1,500 residents, and it is apparent that there will be a growing market for housing in Tortuga, particularly for commuters traveling west to Sierra Grande.

Sydney Stone, a developer from Sierra Grande, has secured an option to purchase the X-Bar Ranch from the Middletons, conditioned on securing certain zoning approvals. Rather than subdivide the 640 acres into 160 lots at the current four-acre zoning, Stone has proposed a cluster development of 400 homes on one 200-acre portion of the site with shared infrastructure and minimal site coverage (see Map 2). He has indicated that the northeast portion across Las Culebras Wash would continue as grazing land and that he would keep the Forest Service allotment.

But several related events have complicated the picture. Pat Wright, the San Cristobal District Ranger for the U.S. Forest Service, just made an administrative decision to reduce the grazing allotments on the Las Culebras Management Area. After reading the production utilization survey and watching the effects of the recent drought, Wright decided to reduce permanently the grazing allotments on all the area ranches by one-third (from 12 to 8 head per section). At a preliminary public scoping hearing, the area ranchers declared that they would appeal the reduction, and if denied, would pursue it in federal district court.

Wright's action has partly mollified an environmental group called SAGE (Save the Arid Grassland Environment) which has repeatedly asserted that not enough has been done to protect the riparian habitat along Las Culebras Wash (home to the rare Gray Hawk). SAGE has argued that the habitat is being destroyed by overgrazing, and its leader, Corey Flintlock, has been preparing to sue the Forest Service. Flintlock's first reaction to the reduction in grazing allotments was supportive, though guarded.

Brady Euclid, the County Planner, has been very worried about all of this. For one thing, Stone's proposed development clearly violates the area's recently completed comprehensive plan, which specifically calls for residential growth and expanded urban infrastructure on the west side of town toward Sierra Grande. Last month, Euclid approached the county planning board with a proposal to bring the parties together to carefully review Stone's plan. Stone's option runs out in one month and the zoning board is scheduled to discuss the proposed zoning change in two weeks. If Stone walks away, the estate might accept a fall-back offer by Blake Worstcase to buy the land outright and subdivide it into 160 ranchettes.

In response to Euclid's request, and worried about the increasingly confrontational atmosphere in Tortuga, the planning board has retained two facilitators from an out-of-state conflict-resolution firm to convene the major stakeholders. The board hopes that the stakeholders can develop a mutually agreeable solution which can inform the zoning board's decision in two weeks. With time short, the facilitators quickly interviewed the parties privately and generated a proposed agenda for a series of meetings which was reviewed by all parties and revised as needed. The parties have agreed to participate in two day-long meetings to be held a week apart. A representative from the State Game and Fish Commission, Jo(e) Waterstone, has also been asked to participate, based on the facilitators' interest in assuring that all stakeholders be at the table.

Confidential Instructions for Brady Euclid, County Planner

You have spent three years developing a very thoughtful, prudent comprehensive plan for the county. Now some people seem ready to throw all that hard work and careful planning out the window at the first sign of quick cash. It is annoying that after all the public meetings and long hours of revisions, people seem ready to abandon the plan.

Sidney Stone's development as it currently stands will throw everything out of whack. Locating such a large development on the east side of Tortuga is totally inconsistent with the county plan. For one thing, traffic through town on Route 96 would be a disaster. But you also have a personal interest in redirecting the development. As a member of ROR (Recreational Off-Roaders), you want to preserve public access through the X-Bar Ranch, since the old mining trails up in the mountains are just incredible. With private development of that land, off-road access will likely be closed off. For both reasons, new development ought to be sited on the west side of Tortuga.

Stone's proposal does have some appeal, though. The increase in tax ratables to the community will be significant. The County Board of Supervisors--particularly board chairperson Frances Townelder--supports the plan. And cluster development has the potential for saving more open space. However, there has got to be a reduction in the total number of units being proposed, given the fiscal and transportation impacts. The increase in ratables may not pay for all the new infrastructure needs that the development may require. At the very least, you want to be sure to negotiate the terms of any subdivision plan approval to cover some of these impacts. You need Stone to agree to underwrite such things as traffic lights, road widenings, water conservation measures, and public facilities. This may not be the appropriate forum for such negotiations, but you won't be endorsing the zoning change without some contingent agreement.

Confidential Instructions for Corey Flintlock, Coordinator, Save the Arid Grassland Environment (SAGE)

Saving the state's arid grasslands is not an easy mission, but someone's got to do it. For years you have witnessed the slow destruction of delicate grassland environs by overgrazing, development, and ineffective regulatory practices. Las Culebras Wash is a breeding ground for the rare and beautiful Gray Hawk, as well as for other threatened riparian species. You have built SAGE into an effective regional lobbying group, recently recognized by larger environmental organizations for its dedication and hard work.

News of Sidney Stone's proposed development has presented some interesting possibilities. If Stone can be persuaded to give up ranching altogether, maybe SAGE can help to retire the grazing allotment. That would reduce the impact on the critical riparian habitat on the X-Bar Ranch (as long as La Culebra Wash could be sufficiently buffered from the housing). Maybe you can interest Stone in some tax breaks in exchange for easements? "La Preserva de Las Culebras" sounds nice.

But SAGE is facing serious budget problems; preparation for the lawsuit has been expensive. SAGE would have to look elsewhere for any funds that might be needed to compensate Stone. Perhaps the U.S. Forest Service or the State Game and Fish Commission have resources they can bring to bear?

Another constraint is that your membership is divided. Some SAGE members are now strongly opposed to the housing development on principle; these "Open Spacers" will be very wary if you appear to cut a deal with Stone that sacrifices open space to preserve the Wash. On the other hand, there are strong wildlife preservationists in SAGE who place the riparian habitat as the very first priority and would be willing to compromise on responsible development as long as the riparian habitat were preserved in its entirety. The key is building a coalition: if the Forest Service and State Game and Fish Commission will support a deal you make, it would certainly go over easier with your more diehard constituents.

Confidential Instructions for Toby Nunn, Rancher

You inherited the Bar Nunn from your father, and have faithfully been ranching for the last 40 years. You, the Middletons, and the Sinespinas have been neighbors for along time, and it seems such a shame that the Middleton kids are selling. But you can't blame them too much--it is getting harder and harder to live this way. With the U.S. Forest Service threatening to reduce your grazing allotment, it's hard to see how anyone can survive, except by increasing the herd. Gil Sinespina is young and enthusiastic, and is organizing the ranchers to fight the allotment reduction legally.

You would like to stay in ranching if possible, and it makes you glad to see that there are good people with fight left in them. But you have other worries, too. The last year has not been an easy one for you personally. You had a bout with cancer that was pretty scary. You haven't felt as vigorous since. And you have a daughter who leaves for college next year. Now that the X-Bar is being sold, you have seriously considered selling the Bar Nunn. Last month you were secretly approached by a representative from Blake Worstcase's office, a nice young person. A price was mentioned; it was a lot of money. At this point, you have to consider the idea of taking it. Financial security has never been as important as it is now. And with the Middletons selling, it's not like you would be the only one. But you haven't mentioned this to anyone besides your spouse. If people around town found out, all hell would break loose!

But you feel torn. Your decision to sell would affect other ranchers in the area; especially Gil. Before you got this offer, you had agreed to work with Gil to approach Sidney Stone to purchase the X-Bar allotment. Purchasing the allotment might be a way of keeping ranching alive in Tortuga without jeopardizing your financial security. With a daughter to school and your strength no longer what it used to be, you are sitting on the fence. You want to support Gil and the other ranchers in their fight against the allotment reduction, and help them and yourself to stay financially secure. But you have to look out for your family first. Don't let anyone make any rules at this meeting that might hurt the value of your land.

Confidential Instructions for Gil Sinespina, Rancher

Cattle ranching sure isn't what it used to be. Your grandfather started up La Rosita Ranch nearly 60 years ago. For the past ten years--ever since Ed Middleton died--you have managed the X-Bar, and it's a beautiful old place. Such a shame that the Middleton kids are selling out. And the timing couldn't be worse! With cattle prices dropping, the only way to survive seems to be to sell more cattle, which means increasing the herd.

If district ranger Pat Wright's plan to drastically reduce grazing allotments goes through, you'll have to reduce the herd. How in the world can anyone expect you to make a decent living again as a rancher if this happens? This reduction must not go through! To make sure it doesn't, you have organized the district ranchers and retained an attorney to fight the reduction tooth-and-nail if necessary.

But adding to your headache is this crazy new development proposal, which you adamantly oppose. A massive new influx of residents to Tortuga will bring nothing but trouble. They will ask for a new school, a new library--all those expensive improvements that city folks insist on. Your taxes will skyrocket! And most importantly, there will be recreational demands placed on the San Cristobal National Forest, threatening the continued practice of grazing on that prime piece of public land.

But you have come up with a plan of your own. You and your neighbor Toby Nunn--always a good friend in a pinch--have agreed to approach Sydney Stone with a proposal to buy 100 acres of the X-Bar Ranch at the full per-acre price paid to the Middleton estate. In exchange, you are prepared to support Stone's plan (especially if fewer cluster units are planned). This way you and Toby can qualify to buy the old X-Bar allotment. While you only need 40 acres to qualify, you would like some of this land to include Las Culebras Wash as a water source for your cattle.

Confidential Instructions for Sydney Stone, Sierra Grande Developer

You and your investors have been patiently eyeing this area for years now. With the Middletons selling, your ship has come in. Tortuga is rustic in a way that people seem to like. With Sierra Grande growing at a fast clip, there is bound to be demand for units out here, though it might take awhile to cultivate. For now you are content to start with a cluster development of more affordable units for cost-conscious commuters, while holding on to the prime portion of the site, up on the east side of Las Culebras Wash. Later, once Tortuga has caught on, you'll build even more profitably in the foothills to accommodate the growing demand. The short-term cluster development will be profitable, especially at 400 units, but you know that the return is adequate for your investors at 225. Naturally, you are wary of sharing your long-term plans with anyone in Tortuga right now. But you would like to protect that foothills acreage against any easements or other restrictions that might hamper your ability to develop it later. On the other hand, your investors will want their return sooner than later. And without the zoning change approval, they are likely to pull out.

You are somewhat puzzled by the hostile response from some quarters regarding your modest plan. You don't have a reputation for tackiness and ruthlessness like some developers. You have completed preliminary environmental surveys which suggest that there is adequate groundwater on site to serve 400 homes (although there might be a significant drawdown during extended dry periods). You are aware that Blake Worstcase is waiting in the wings. But no one could want the whole site covered with ranchettes! That would just devalue everyone's land. The County Board of Supervisors--particularly board chairperson Frances Townelder--realizes this and supports your plan. At this meeting you've got to get the other people behind your plan and make them see that clustering can be attractive and low impact. This meeting is crucial to getting a good outcome at the zoning board meeting in two weeks. Try to get as many units zoned as possible. The more demand you can create now, the more that prime foothills land will be worth later. But you may have to cut some kind of a deal (e.g., water conservation, maybe a greywater system, greater building setbacks from the wash, or a last resort, reduce the number of units).

Confidential Instructions for Jo(e) Waterstone, State Game and Fish Commission

As an official project coordinator of the Commission, you received a call last week inviting you to attend some sort of discussion meeting regarding a new development planned in Tortuga. Apparently the situation in Tortuga is messy with lawsuits in the wings. The facilitators of the meeting felt that your participation might be important.

Your board has been interested in extending its non-game species protection program, particularly in arid grassland environments. The Gray Hawk has been included in the commission's draft list of wildlife of special concern.

However, the board has been reluctant to spend any of the State Heritage Fund money until a statewide plan prioritizing sites for acquisition is in place. This won't happen until early next year. Nonetheless, several parties from around the state have been asking the Commission to purchase conservation easements with proceeds from the Heritage Fund.

If there were a plan that adequately protected the critical habitat for the Gray Hawk, there is a good chance that your board would approve funds for easement acquisition in next year's plan. You have worked with the environmental group, Save the Arid Grassland Environment (SAGE), before and have found them pretty reasonable, although there is a radical element in their membership that is a concern, especially if SAGE were to become the enforcer of the easements. You need to talk with Corey Flintlock to be sure the SAGE membership is on board for any collaborative agreement.

Confidential Instructions for Pat Wright, U.S. Forest Service District Ranger

You have worked hard to be responsive and responsible, and all you seem to get are complaints and threats. First, the environmental group, Save the Arid Grassland Environment (SAGE), and now the ranchers. There are good people in Tortuga, but trying to please everyone without giving away the store just seems impossible at this point. The Forest Service's "Multiple Use" policy requires you to try to accommodate often conflicting demands--recreational, environmental, commercial, and so on. But it is far from clear how you are supposed to accomplish this when people are so polarized.

Last year's production-utilization survey clearly shows the carrying capacity of the range has been exceeded for too long; most importantly, Las Culebras Wash had been badly overgrazed. Reducing grazing is the right thing to do, particularly along the wash. People may holler for a while, but these are changing times and sometimes collective needs outweigh individual rights. As your old mentor used to say, "The forest doesn't know what district it's in." With SAGE's suit in the wind, the time has never been better to implement sound forest management practices that protect the long-term health of the ecosystem.

Nevertheless, the reality is that it will be a hard fight to reduce the allotments. When push comes to shove, you can't be sure how your boss will respond. Political pressures are real. And years of litigation will leave no one better off. At this point, maybe you could agree to some kind of delayed or phased-in reduction, or at the very least, an immediate plan to preserve and remediate Las Culebras Wash. Anything's better than legal stalemates and hostile notes on your windshield.

Confidential Instructions To the Facilitators

Based on your background as a professional conflict mediator, you have been asked to try to facilitate a resolution to the trouble brewing in Tortuga. You have managed to get all parties involved in the dispute (with the exception of the Middleton siblings) to agree to hold a discussion. As agreed by all parties, the discussion will be held on two consecutive Saturdays (simulated by two 90-minute sessions in the exercise) with a week's reflection (simulated by the 15-minute break) between each session.

As facilitator, you ostensibly have met privately with each participant prior to the discussion and have asked each character to express his or her concerns and views of the conflict (this is done simply by reading through the "Background and Setting" statement and "Confidential Instructions" for each character; but before the simulation begins and before the participants assume their respective character roles, you should have a brief meeting as a group just to review how the exercise will proceed).

Goals

As facilitator, you have six goals for the discussion:

1) Make sure that each party is given a chance to speak and have his or her concerns acknowledged by other parties.

2) Keep the parties committed to working toward a solution that everyone can live with.

3) Acknowledge institutional and legal constraints that might exist, but keep the parties focused on an interest-based solution.

4) Help the parties generate several possible alternative options before focusing on any one option for too long.

5) Identify and seek to generate objectively any technical information that may be needed regarding either the assumptions on which different plans are based, or the implications of proposed plans.

6) Remind the parties as necessary that failing to reach an acceptable solution may lead to an outcome that is less satisfactory to all.

Format

You should open the meeting by welcoming the each character and reminding all of the ground rules (ostensibly agreed to in an earlier meeting). Then proceed to review each parties major interests (as a kind of summary of the previous hypothetical meeting) and go around the table one-by-one to have each character affirm or elaborate further upon your opening remarks.

In the ensuing open discussion (and remember to enforce to rule about speaking-in-turn), focus initially on your first three goals, establishing an atmosphere of tolerance and cooperation; reviewing with each party its interests and concerns; and attempting to generate improvements or alternatives that might lead to a recommendation to the board that all parties can endorse. Then concentrate on goals four and five, helping the parties to envision alternatives and documenting any technical information that might be needed to assist them in assessing the viability of those alternatives.

At the end of the first Saturday meeting (i.e., the first 90-minute session) you should summarize what has been accomplished and encourage the parties to keep working on possible solutions during the week's (i.e., the 15-minute) break. Halfway through the break, you should circulate to each party a copy of the news flash you have just received from the *Tortuga Times* (see News Flash!).

At the beginning of the subsequent Saturday meeting (the second 90-minute session), you may want to provide any technical information that had been requested at the previous meeting (such information can be invented at your discretion to continue the simulation). Next, you should then survey reactions to the news flash, and help the parties to renew their efforts to jointly solve the problem at hand.

At the end of the second meeting, you should briefly summarize the progress that has been made. If agreement has been reached, document and announce its provisions in detail. If no agreement has been reached, carefully review the points of agreement and disagreement regarding different options that were discussed, and survey participants for what their likely next step(s) will be.

In either case, this short summary process should lead quickly to a 30-minute debriefing of the game, in which the participants (no longer playing their character roles now) provide an assessment of the simulation exercise, how it might relate to their real-life situations, and what they might have learned from the process.

News Flash!

Tortuga Times

Today's Climate: Troubled • Tomorrow's Outlook: Hopeful

Developer Offers to Buy Local Ranch

by Sam Storybored

Land developer Blake Worstcase has reportedly offered a substantial sum to Tortuga rancher Toby Nunn to purchase the Bar Nunn ranch.

Worstcase intends to turn the ranch into 160 four-acre ranchettes.

Neither Worstcase nor Nunn were available for comment today, but one source close to the deal was quoted as saying, "Toby's a good man, but Blake is making it awfully hard to say no. It's a big chunk of money."

Frances Townelder, chairperson of the County Board of Supervisors, commented, "If Sydney Stone's option expires, Worstcase will buy the X-Bar too. Then we'll be looking at over 300 ranchettes and the end of the ranching in Tortuga as we know it."

PART II EVALUATION REPORT

Overview

Trouble in Tortuga! was designed as a simulation to model rangeland conflict issues, to conflict processes, and procedural and substantive tools for working toward solutions to these conflicts. It was also designed to give both the participants and audience a chance to see how perspectives and priorities can differ in important ways, and how dialogue and creative solutions can be possible even when conflict is complex and impassioned.

The exercise presented at "The Future of Arid Grasslands" conference took place in two one-hour sessions, separated by a lunch break. The participants in the exercise included Candace Allen, U.S. Forest Service district ranger from Nogales; Jeff Burgess, environmentalist from Tempe; Jim Chilton, rancher from Arivaca; Becky Jordan, Arizona state representative from Phoenix; Rod Mondt, with The Wildlands Project in Tucson; Joe Parsons, rancher from Tucson; Dave Walker from Arizona Game and Fish Commission in Phoenix; and Kirk Emerson and Hal Movius from the Udall Center (see "Cast of Characters").

At the outset, the facilitators outlined ground rules for the discussion, and solicited introductions from the participants. The goal during this first stage of the process was to separate the verbal positions taken by the parties from the implicit interests and concerns driving them. Some of the interests that emerged included protecting ranchers' livelihoods, ensuring continued access to forest lands, minimizing traffic through town, and providing development investors with an adequate profit (see Table 1). It soon became clear that the short-term issues around the development project and allotment permits were connected to longer term planning and land use issues.

During the second stage of the process there was lively discussion as the group generated a list of issues for consideration. These issues were recorded in the form of open-ended questions, leaving many solutions possible and respecting the needs of each participant. Such issues included the number of homes to be built by the developer, ownership of the X-Bar grazing permit, avoiding "leapfrog" develop, protecting the Gray Hawk, and preserving open spaces (see Table 2).

After lunch a "News Flash!" was distributed to the participants and audience. This late-breaking bulletin made settlement more desirable for all the parties, and stimulated further discussion about tools and options for achieving solutions that would meet key interests. These tools included setbacks from Las Culebras Wash to protect the Gray Hawk, grassbanking practices among the ranchers, a development zoning change, and the use of easements and tax credits (see Table 3). Possible packages of tools began to take shape in the form of "options" as the session closed (see Table 4). Had there been more time, several packages might have been generated for evaluation by the parties.

Cast of Characters

PARTICIPANTS	APPEARING AS
Candace Allen U.S. Forest Service District Ranger (Nogales)	Brady Euclid County Planner
Jeff Burgess Environmentalist (Tempe)	Gil Sinespina Rancher, La Rosita Ranch
Jim Chilton Rancher (Arivaca)	Joe Waterstone State Game and Fish Commission
Becky Jordan AZ State Representative (Phoenix)	Corey Flintlock Save the Arid Grassland Environment
Rod Mondt The Wildlands Project (Tucson)	Sydney Stone Developer, Sierra Grande
Joe Parsons .. Rancher (Tucson)	Pat Wright District Ranger, San Cristobal National Forest
Dave Walker AZ Game and Fish Commission (Phoenix)	Toby Nunn Rancher, Bar Nunn Ranch
Kirk Emerson and Hal Movius Udall Center (Tucson)	Facilitators

Brady Euclid, County Planner

- Development needs to be on the west side--minimize traffic through town
- How will improvements be financed? (e.g., help from developer?)
- Access to forest should continue

Corey Flintlock, Coordinator, Save the Arid Grassland Environment (SAGE)

- Preserve riparian area
- Maintain some flexibility
- open spacers
- preservationists
- Protect ranching

Toby Nunn, Rancher

- Increase the herd?
- Ensure financial security

Gil Sinespina, Rancher

- Need to keep herd large; oppose allotment reduction
- Increased taxes due to development?
- Conflict with recreationists?

Sydney Stone, Developer

- Equitable and classy development (i.e., less densely zoned)
- Encourage compatible growth (i.e., maintain open space)
- Make adequate profit for investors
- Acquire zoning change

Joe Watterston, Arizona Game and Fish Commission

- Implement multiple-use policy
- Protect Gray Hawk (e.g., via easement)

Pat Wright, U.S. District Ranger

- Prevent overgrazing and other use of wash area
- Reduce allotment? (i.e., from 12 to 8)
- Implement multiple-use policy
- Work more closely with permittees

Table 1. Summary of Character Interests

1. What is the number and design of homes that will be built by the developer?
2. How will the income and lifestyle of ranchers in Tortuga be preserved?
3. Who will hold the X-Bar Ranch grazing permit?
4. How can the relationship between the U.S. Forest Service and Tortuga residents be improved?
5. How will adequate water flow for other water users be ensured by the developer?
6. How can the present zoning issue be tied to a larger planning process in Tortuga?
7. How will residents' property rights be protected?
8. How will the Gray Hawk habitat be preserved and monitored?
9. How will multiple-use-policy requirements be met?
10. How will Tortuga create wise land-management practices, given probable future growth?
11. How can "leapfrog" development practices be avoided?
12. How will open spaces be preserved?
13. How many head of cattle per acre will be allowed on U.S. Forest Service land?

Table 2. Summary of Major Issues (Who?/What?/When?/How?)

Grassbanks
Easements
Setbacks
Management plan--buyout option
Purchase/lease of X-Bar Ranch grazing allotment
Sydney Stone to lease/purchase Bar Nunn Ranch with easements
Education
Tax credits
Water rights
Offer to Toby Nunn
Allotment reduction
Zoning change (density)
Heritage fund decisions
Save the Arid Grassland Environment (SAGE)lawsuit
Fencing costs/monitoring

Table 3 Summary of Tools for Generating Solutions

1. Stone buys Bar Nunn Ranch
   - maintains grazing on eastern portion
   - provides setback
   - requires assurance of no loss of future development
   - leases option on west side of X-Bar
   - maintains access to forest
   - fenced-in cluster
   - no fence on corridor

Allotment reduction is decreased?
Allotment is shared?
Some infrastructure costs are shared (by developer)

Table 4. Summary of Options

Following the process, the participants were given a chance to describe their experience during the simulation. A panel discussion ensued on rangeland reform, chaired by Jim Walsh, a Phoenix attorney, mediator, and former Arizona state legislator. The following summaries encapsulate the reactions of the panelists to the simulation and key points made during their presentations. Written statements prepared by the several of the panelists are provided in the Appendix.

Facilitator Kirk Emerson began by noting the complexity of grasslands disputes, emphasizing the interconnectedness of public and private lands and institutions. Her associate, Hal Movius, the session's other facilitator, described the facilitation process, outlining the four steps of identifying interests, framing issues, generating tools and options, and bundling these tools and options into packages which would allow parties to make trade-offs across issues depending on their interests.

Joe Parsons introduced himself as a rancher and said he could speak "from the heart" about many of the issues addressed in the simulation. He said he found it easy to play the role of a U.S. Forest Service district ranger because he has worked with them and understands the pressures they face from their offices. He added, however, that he is regulated every day by nine different agencies, and often has to wait to make even simple repairs on his own land until all of the paperwork has been completed which sometimes takes months. He described himself as an environmentalist who cared about doing the right thing and emphasized the need for communication and education between disputants, so that stereotypes are reduced. He complained that the media "tears us [ranchers] apart" leading to an impression among the public that all ranchers overgraze. According to statistics he presented, six percent of the country's population was involved in agriculture in 1980, whereas today that figure is less than two percent. He reiterated that communication and the development of one-to-one relationships is critical if rangeland conflict is to be reduced.

Jeff Burgess, an environmentalist from the Phoenix area, agreed with Parsons that there is a need for communication, and for parties to "treat each other as people." He also cautioned that not all conflicts can have purely win-win solutions, and stated that in his view, some kind of reform was inevitable, and that it would mean "fewer cows in fewer places." He emphasized the need for equity in settling disputes with land owners, including ranchers, as part of a fair reform process. He then read aloud a proposed grazing-reform act that he had authored (see Appendix).

Dave Walker, an Arizona Game and Fish Commission official, followed by saying that it had been difficult to step into unfamiliar shoes, and that he felt Jim Chilton had done very well playing a State Fish and Game Commission representative. He also described the powerlessness he felt playing a rancher (see Appendix for Walker's submitted statement).

State Representative Becky Jordan mentioned the importance of conservation partnerships, adding that legislation to further them was badly needed. She also described the helplessness that environmentalists feel because of the funding shortages they face and competing constituencies they must serve (see Appendix for Jordan's submitted statement).

Candace Allen, a district ranger with the U.S. Forest Service, recalled a real-life example of a five-million-dollar deal falling apart because of a lengthy regulatory process, and described the dilemma she feels every day "trying to decide which laws to obey" when not enough funding is being apportioned by Congress for enforcement. She said she had come to the session "with open ears, not solutions," and concurred that "personal integrity and communication are important" in building relationships that can generate short- and long-term solutions.

Environmental advocate Rod Mondt described the need "for open places and a love of open places" in the lives of citizens. He described himself as "one of the chosen poor" who had grown up on a sugar-beet farm, and was as passionate as ranchers about preserving wildlands. He agreed with Joe Parsons that the media is a source of falsehoods and therefore a stumbling block to partnerships. He added that in his view, large-scale changes were inevitable because of geographic and historical trends.

Jim Chilton began by stating that for a rancher, "every day is Earth Day." He described the wells, troughs, and salt licks that he had implemented on his ranch to promote wildlife development and preservation. He described overgrazing as "a cruel myth" and emphasized that both environmentalists and ranchers have a passion against "ranchetting." He noted that "cowboys are like bears and lions," needing a rangeland preserve. He showed dramatic photographs from 1959 and 1996, illustrating in his view that "the Forest Service policy of range rotation works!" He closed by saying that if ranchers were forced to, they would sell their land for development, but that this was a last resort (see Appendix for Chilton's submitted statement).

LESSONS LEARNED

It is hoped that *Trouble in Tortuga!* can be used in a variety of contexts with a variety of participants and audiences to illustrate the substantive issues and complex dynamics that characterize rangeland conflict and problem-solving. The designers of the simulation wish to make it clear that this is very much a work in progress, from which different lessons and ideas might be drawn in coming months and years.

From the presentation at "The Future of Arid Grasslands" conference, several lessons emerged from both participant and audience comments about what might be done in the future to enhance the usefulness of the simulation exercise.

First, it seemed that breaking the session into two parts, separated by a lunch break, diminished some of the momentum that had been generated by the first session. In the future the simulation probably should be played without a significant break in the action (i.e., two 90-minute sessions separated by a 15-minute break).

Second, it is clear that while enacting an unfamiliar role is essential to the exercise, it can be a difficult task. This is especially the case when one's point-of-view actually clashes with the role one must enact, and when there is a large amount of technical information to be learned. *Trouble in Tortuga!* requires that participants have some familiarity with rangeland and planning issues in order to produce a more effective and realistic exercise. Participants should be encouraged to read through the materials in advance and to "inhabit" their roles as much as possible in preparation for the exercise, so that they can be both passionate and well-informed as participants.

Third, modeling both conflict and the resolution of conflict can be competing aims when time is limited. The scenario could be used effectively for either, but perhaps not both aims. Because the scenario does not clearly specify negotiation parameters (such as issues, options, and alternatives to agreement for each party), the simulation is perhaps most useful as a tool for introducing participants to issues and conflicts relating to western development: ranching, planning, multiple land-use policies, and environmental protection. Uncovering the interdependence of these issues is a major lesson that should be emphasized during debriefing.

Fourth, it is important to carefully explain the process that will be used during the simulation to both participants and audiences. Modeling a complex conflict and describing tools for its possible resolution are challenging tasks, made even more difficult when there are significant time constraints. Having a clear procedural template to work from can illustrate for participants and audiences where the process is at any point, and where it might go as discussion develops.

Finally, it is clear that more dialogue is needed between the "real-life" participants in rangeland conflict, all of whom in their own words lamented the absence of opportunities for face-to-face communication in a neutral setting regarding the difficult issues which comprise "rangeland conflict." In the future, perhaps simulations like *Trouble in Tortuga!* can be used as training exercises in the context of longer interventions that are designed to help different western constituencies to grapple with and resolve the choices they collectively face.

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