



Perspectives on desertification: south-western United States

Ed Fredrickson, Kris. M. Havstad, Rick Estell & Paul Hyder

*USDA-ARS, Jornada Experimental Range, P.O. Box 30003, MSC
3JER, New Mexico State University, Las Cruces, NM 88003, U.S.A.*

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Several climatic changes occurred in the northern Chihuahuan Desert and other parts of the south-west United States during the last 12,000 years leading to a markedly warmer and drier climate. Vegetation changed in response to this climatic shift. Generally, this transition was from coniferous woodland to grasslands and eventually to the present day desert scrub. Pre-Columbian inhabitants of this region adapted by changing from hunter-gatherer to primarily agrarian economics. European immigration into the south-west U.S. beginning in the mid 1500s greatly affected this region. The greatest impact occurred after the U.S. Civil War in the 1860s. Before that time land use tended to be localized near small agricultural areas, mines, and military installations. The post-war range livestock industry expanded dramatically, especially during the 1880s — a period of general abuse of arid lands in the region. Recognition of this abuse and the deteriorating productivity of the land led to greater government involvement, including establishment of experimental stations and eventually management of the public domain by governmental agencies. Fire suppression, mismanaged grazing, changing climatic conditions, loss of soil and increasing atmospheric CO₂ concentrations, mainly due to the burning of fossil fuels, are among the probable causes of continued desertification trends. Urban and rural populations, presently technologically isolated from their environment, need to better understand the dynamic nature of their environment. A greater degree of co-operation among diverse entities will be crucial.

Keywords: Chihuahuan Desert; Sonoran Desert; desertification; south-west United States

Introduction

The following quote is from the book *90 Years and 535 Miles: vegetation changes along the Mexican border* by Dr Robert Humphrey (1987): ‘The semidesert grassland has been extensively studied in an attempt to determine the changes that have, and are, taking place and the underlying reasons for this evolution. A change of climate, the prevalence and/or control of fires, and grazing by livestock are the three factors usually considered largely responsible for a gradual takeover by the scrub species. Which of these is of paramount importance is often a moot question, and the one to which greatest importance is attached frequently depends on a particular research worker’s

major interest and field of expertise. This may result in an inadvertent lack of objectivity.'

The vegetation transition to which Humphrey is referring is often termed desertification by those working in the arid and semi-arid regions of the south-west United States. Furthermore, his insight extends beyond the semi-desert grasslands and the researchers directly involved in the desertification debate. Vegetation change pervades the south-west region, and how society views this change is greatly limited by our specific interest or personal perspective. Nevertheless, these perceptions will shape our future.

The prehistoric South-west

One aspect that limits our perspective of a given situation is the time frame in which we make our observations. If we extend our viewpoint backward beyond our lifetimes and long before the historic record, it soon becomes obvious that desertification is not a phenomenon new to the South-west. Perhaps the first desertification event began during the end of the Pennsylvanian period, between 330 and 286 million years ago (mya). For the preceding 70 million years, it is generally believed that shallow seas covered much of western Texas, New Mexico, and Arizona (Sheldon, 1979; Seager, 1981; Chronic, 1983, 1987). Rooted vascular plants already occupied some regions after evolving during the Devonian period (*c.* 360 to 300 mya). The establishment of plants most certainly affected atmospheric gas concentrations, most notably by probably lowering CO₂ concentrations that perhaps led to cooling and later glaciation during the Carboniferous period (360 to 286 mya; Berner, 1997; Retallack, 1997).

With large amounts of water in glaciers and perhaps the rise of the ancestral Rocky Mountains, the seas began to shrink. During the Pennsylvanian period seas covered only south and central Arizona, southern New Mexico, and most of west Texas, while deserts prevailed in northern Arizona. During the Permian period (286 to 245 mya) west Texas and southern New Mexico were covered by a southern sea, in which formed a large barrier reef (Sheldon, 1979; Chronic, 1987). Dunes dominated the landscape of northern Arizona with intermittent submersion by western seas (Chronic, 1983). Climatic shifts probably led to several (perhaps many) desertification events.

During the 'age of the dinosaurs' (Mesozoic, 245 to 66 mya), atmospheric CO₂ concentrations were apparently greater than during the Carboniferous period, leading to warmer temperatures than we are presently experiencing (Berner, 1997). During the Jurassic period (208 to 144 mya) the Sierra Nevada were uplifted. This event, coupled with elevated temperatures, resulted in vast deserts in Arizona and New Mexico. As Chronic (1983) stated, 'dunes blew endlessly across a featureless landscape.' The Permian Sea evaporated (Sheldon, 1979), while explosive volcanism occurred in southern Arizona during this era (Chronic, 1983).

During the Cretaceous period North America began its 125 million year drift away from Europe (Axelrod *et al.*, 1991). With shifts in the tectonic plates, the climate became more moderate and more variable. Events such as the rise of the Rocky Mountains created more extreme climates (e.g. leeward dry climates and colder climates at higher elevations), which restricted the range of existing plants while providing evolutionary opportunities for newly developing species (Axelrod *et al.*, 1991). Also during this period, a massive extinction led to the end of the dinosaurs, while mammals flourished and diversified in the following Paleocene (66 to 58 mya) and Eocene (58 to 37 mya) epochs of the Cenozoic era (Chronic, 1987).

Geologically, the early Tertiary period (66 to 2 mya) was marked by the continued rise of the Rocky Mountains and the Laramide Orogeny (a period of crustal folding) throughout the South-west (Seager, 1981). Extensive volcanism occurred during the

late Eocene epoch, peaking in the Oligocene (37 to 24 mya) and continuing into the Miocene (24 to 5 mya; Seager, 1981).

The Pliocene (5 to 2 mya) was another period of extensive erosion. The Colorado River began carving through the Colorado Plateau (Chronic, 1983), and the Rio Grande became a through-flowing stream during this time (Chronic, 1987). Volcanic activity marked a period of mountain-forming in west Texas (Sheldon, 1979), and erosional debris filled intermountain valleys.

Before the uplift of the Rocky Mountains three major vegetation types covered North America. The north was covered by species characteristic of the eastern deciduous forest, west coast conifers, and east Asian species such as ginkgo and redwood. The southern regions of North America resembled the tropical and subtropical forests of present day southern Mexico and Panama. Between these two extensive vegetation types were southern New Mexico, south-east Arizona, and north-central Mexico, where a third flora better adapted to the areas's drier climates developed. This flora evolved from the two adjacent floras and generally had a woodland or scrubland appearance (Vankat, 1979; Lowe & Brown, 1994). During this time and later the south-west United States and north-central Mexico consisted of a tension zone between diverse climates, a breeding ground of diversity.

As the climate cooled due to mountain building during the late Cretaceous and much of the Tertiary periods, the northern forests spread to the south, and many of the deciduous trees disappeared, unable to adapt to the drier winters (Vankat, 1979). During this time grasses began to develop, probably as an understory species (Van Devender, 1995). Within the mid to late Tertiary period, a geologically rapid uplift of the Sierra Nevada, Cascade, and Coast Ranges occurred. The resulting rain shadow effect was responsible for the drier habitats from which arose grassland (Van Devender, 1995) and desert vegetation (Vankat, 1979). Similarly, the late Tertiary was a time when plant extinctions are believed to have been extensive (Leopold, 1967).

At least three general themes emerge during these and later periods. First, some lands became more mesic while others grew more xeric, or desertified. This shift was largely due to orographic effects on regional climates. Second, soil deposition from land degraded by erosion of the newly developed mountain regions enhanced soil attributes and increased productivity of adjoining and even distant regions. Third, the demise of some species, resulting in lower biodiversity, led to periods of increased adaptation and speciation, and ultimately greater biodiversity.

The late Pliocene and Pleistocene epochs denote the beginning of a series of reoccurring periods of glaciation, with perhaps 15 to 20 glacial periods in the last 2.4 million years. Each glacial period appeared to be about 10 times longer than interglacial periods (Imbrie & Imbrie, 1979, cited by Van Devender, 1995). Although little of the South-west was actually glaciated, vegetation species composition shifted down slope with each glacial period and moved upward with each warmer, interglacial period. About 18,000 years ago most of New Mexico, including large areas of the present desert glasslands and short grass prairie, were vegetated with montane coniferous forest, including *Pinus*, *Pseudotsuga*, and *Abies* species. The present day Chichahuan Desert, as delineated by Schmidt (1979), was then coniferous woodland (Martin, 1963; Dick-Peddie, 1993).

Between 12,000 and 11,000 years ago, the climate of the South-west began to change to warmer, drier conditions (Dick-Peddie, 1993; Lowe & Brown, 1994), a transition that some authors describe as rapid (Mehring, 1967). Another notable vegetation shift, or desertification event, occurred between 7000 and 9000 years ago (Mehring, 1967; Cole & Monger, 1994; Monger, 1995; Van Devender, 1995). The date of this transition appears to vary depending on the region being studied and perhaps by the technique used to estimate the date. But it is certain that the climate became increasingly arid. With increasing aridity, desert scrub vegetation appeared to have concomitantly increased in areas previously dominated by grasses (Monger,

1995). This transition was not unlike the vegetation shifts during the past 100 years.

Another shift leading to increased aridity occurred between 4000 and 5000 years ago, followed by a period of general cooling of 2500 years ago and a period of warming between 2500 and 800 years ago (Dick-Peddie, 1993). Between 4000 and 800 years ago, there appears to have been at least three periods when desert scrub vegetation increased in the desert grassland region (Van Devender, 1995), indicating periods of increased aridity or shifting precipitation patterns.

At the beginning of the last 12,000-year warming trend, mammals such as mastodons, sloths, camels, horses, and other megafauna roamed the South-west. By 10,000 years ago, many of these species had disappeared in a major wave of extinction with some species such as *Bison antiquus*, *Camelops* spp., *Mammuthus columbi*, and *Equus* spp. disappearing possibly as late as 8500 to 7000 years ago (Mehringer, 1967). In North America about two-thirds of large mammals became extinct (Martin, 1984).

Although explanations for these extinctions include major catastrophic events and Old Testament type floods (Grayson, 1984), the most accepted models appear to be the climatic and prehistoric overkill models. Climatic or ecological models are based on short- or long-term vegetation change and its direct effect on herbivore and predatory mammals. (See King & Saunders, 1984 and associated articles.) The overkill hypothesis asserts that both over hunting of the megafauna by prehistoric peoples and climatic changes are responsible for these extinctions. (See Martin, 1984 and associated articles.) Herbivores invariably exert a great effect on the structure and function of plant communities. The presence of the Pleistocene megafauna surely had a major impact on vegetation dynamics before the Pleistocene extinctions, as did their absence in the later 8000 to 10,000 years.

Although some believe that humans occupied the South-west more than 25,000 years ago (Wormington, 1978), earliest accepted evidence of prehistoric peoples suggests initial occupation was about 11,500 to 11,000 years ago (Haynes, 1967, 1984). While summarizing prehistoric cultures in the Chihuahuan Desert, Mallouf (1986) described the following cultural continuum. On the basis of the many kill sites of Pleistocene fauna, the first Paleo-Indian cultures were mainly that of nomadic big game hunters.

Increasing aridity at about 10,000 to 8000 years ago coincided with the beginning of the Early Archaic period, which extended to about 5000 years ago. Although little is known about these cultures, evidence suggests an economically diverse hunting and gathering lifestyle. Archaic bands maintained territories that were defined by a carrying capacity of food and the presence of water.

The Middle Archaic period (5000 to 2500 years ago) was initially dry but became more mesic during the later half (4000 to 2500 years ago). Evidence exists for a greater diversity of tools and possessions, while stone-lined pit ovens were used to process foods such as agave.

The Late Archaic and Late Prehistoric periods (2500 to 500 years ago) are the most intensively studied and better understood periods of time. During the early part of this period the population grew substantially, and all ecological zones were used more. Yet this period of apparent prosperity ended with the reoccurrence of desert-like conditions about 2200 years ago. In conjunction with this increased aridity was apparently a reversion in many areas to the subsistence hunter-gatherer lifestyle of the Middle Archaic.

Along the Rio Grande and other water courses, however, cultures began to develop with a more sedentary lifestyle based on agriculture. By 1700 years ago people were using pithouses and ceramics. Rapid population increases were apparent by 1150 years ago in the Mimbres and Rio Grande areas. By 1000 years ago lodging shifted from pithouses to surface pueblos, some with as many as 200 rooms. Agricultural village

populations peaked around 900 years ago, followed by abandonment of the pueblos in the Mimbres area 100 years later. The pueblos of the Rio Grande cultures were not abandoned for another 200 years. Archaeological evidence reveals that these later cultures were part of an extensive trade network with cultures in Mexico and Arizona. This time period was also influenced by complex socio-economic and religious systems.

With greater detail, Gumerman & Gell-Mann (1994) describe a similar succession of cultural events generalized for the greater South-west, including the classic Hohokam and Anasazi cultures. Within these and other descriptions of the early South-west peoples, three events seem to be of primary importance. First is adoption of agriculture by peoples of the South-west at a time when adjacent peoples maintained a hunter-gatherer lifestyle. Second, the aggregation of early people into communities with complex social structures and common languages and religions marks a period of rapid social development. The final event of note is the abandonment of communities representing a large social investment. These critical periods have received a great deal of attention from archaeologists and anthropologists.

As noted by Wills (1988), adaptation of agricultural practices by hunter-gatherers was probably a response to improved resource, or food reliability during periods of decreasing environmental predictability. In contrast to nomadic hunter-gatherers to the north and east, the increasing aridity experienced in the last 10,000 to 12,000 years in the South-west led to a decline in big game and less predictable supplies of important food plants. To maintain some sense of homeostasis, these people needed to adjust their behavior while anticipating future environmental change. Agriculture must have provided a way for these people to cope with the South-west's changing environment.

In addition to a more stable food supply, the adoption of chiefly Mesoamerican agriculture allowed for a more sedentary lifestyle, increased population growth, and resulted in a greater diversity of social roles. Furthermore, these changes led to what many believe is greater economic and cultural development, which eventually resulted in aggregation into large complex communities. (See Codell *et al.*, 1994 for a more comprehensive treatment of factors leading to aggregation.) The causes of abandonment appear more complex and perhaps variable among archaeological sites. In some areas the concentration of rapidly expanding populations in a localized area meant greater dependence on local resources and eventual environmental degradation, which might explain some abandonment events. Pueblos that were intact when the Spanish arrived also may have suffered from European diseases. Most abandonment events, however, are not so easily explained. Indeed, the reasons leading to abandonment of most pueblos remain one of the South-west's greatest mysteries (Fish *et al.*, 1984).

What is known about the prehistory of the South-west is somewhat coarse and inexact. More data and methods of data interpretation are needed. Yet despite the present obscurity of the farther reaches of the past, one aspect of the desert South-west's prehistory is fairly certain: desertification is not a new phenomenon. We reside in a land that is often arid and semi-arid with frequent desertification events. These events have definitely shaped the land, its flora and fauna, and the early peoples that resided here.

The historic South-west

After being shipwrecked near present day Galveston, Texas, and spending 8 years as slaves among the nearby indigenous people, four men unintentionally set out to be the first European explorers of the South-west. Cabeza de Vaca and Estévan, a Moorish slave, and two others escaped capture in 1533 and moved west along an uncertain path. Eventually they arrived at the confluence of the Rio Grande and Rio Conchos,

where they moved south until reaching Spanish settlements in Mexico. Their stories of cities and precious metals sparked the imagination of Spaniards seeking wealth, land, and glory. The ensuing Spanish invasion significantly changed the South-west (Crouch, 1989).

Coronado's expedition into the South-west in 1540 dampened somewhat the enthusiasm of the Spaniards for pursuing the legendary Seven Cities of Cibola but did not stop the steady influx of adventurers, gold-seekers, and priests into the area. To establish a colony in the territory Don Juan de Oñate led an extensive expedition up the Camino Real in 1598. Families and livestock moved north through the 'Jornada del Muerto' (Dead Man's Journey) basin, to San Juan. Along the trail cattle ate mesquite (*Prosopis glandulosa*) beans and left a trail of seed-filled dung. The Camino Real would later become readily visible from a distance, marked by dense stands of mesquite that lined the road.

Horses also changed the lives of the indigenous peoples and had a substantial impact on the land. The nomadic Athabaskans from the north and east quickly became skillful horsemen. Horses increased their mobility, their hunting success, and their ability to raid neighboring villages and eventually European settlements. These raiding nomads prevented large-scale colonization of the South-west for some 250 years after Oñate's journey. Because of nomadic attacks, settlements were often small and localized, as was the effect of Europeans on the land (Bahre, 1995; Sheridan, 1995).

The indigenous peoples and their horses were at least somewhat responsible for the spread of mesquite, a desert scrub that has replaced large areas of desert grassland. Humans extensively used the beans for food and later fed them to their horses, resulting in the spread of mesquite seed around their campsites. Old campsites are still marked by dense stands of mesquite (York & Dick-Peddie, 1969). Furthermore, indigenous peoples, especially the Navajo, adopted many animal husbandry techniques of the Spanish.

After the annexation of Texas in 1845, President Polk offered to buy California and the New Mexico Territory (now New Mexico and Arizona) from Mexico. When Mexico refused, Polk declared war on Mexico. By 1848 the United States had extracted Arizona, New Mexico, California, and \$15 million dollars from Mexico. At this point California was considered the prize of the Mexican War, while the New Mexico Territory was merely a dangerous desert wasteland between the United States and California.

During this time impressions of the land and its vegetative condition varied widely among authors. Writing about his passage through the Jornada del Muerto in 1846, Dr Frederick Adolph Wislizenus ([1848] 1969), the physician/botanist of the Doniphan Expedition, stated, 'The wide country through which we have to travel, in the elevation of from four to five thousand feet above the sea, with dry, hard soil, tolerable grass, and an abundance of mezuite and palmillas.' Two years later, journalist John Cremony ([1868] 1983) described the same area, '... is a large desert, well supplied with grama grass in some portion, but absolutely destitute of water or shade for ninety-six miles.' Beale (1858) reported to the Secretary of War in 1858 after crossing the South-west by camel. In his report, he described the Jornada Plain as, '... a level plain, covered thickly with the most luxurious grass, and filled with wildflowers ...' He continued, 'Hundreds and hundreds of thousands of acres containing the greatest abundance of the finest grass in the world, and the richest soil are here lying vacant, and looked upon by the traveller with dread because of its want for water.' The earlier two reports describe this area as one might describe it today. Beale's description would imply that a tremendous shift to desert scrub had occurred in the last 130 years. Beale was interested in building an immigrant road through New Mexico to California, for which he was requesting \$100,000 (Beale, 1858).

Ethnologist and Boundary Commissioner John Barlett travelled from San Antonio, Texas, through El Paso, past the south-west corner of the Jornada del Muerto, and

toward what is now Gila National Forest in western New Mexico. On 28 April 1851, while camped near a lagoon along the Rio Grande north of present day Fort Seldon, he wrote in his journal (Bartlett, [1854] 1965), 'The young grass, and the deep foliage of the trees, were refreshing to our eyes, which for five months had gazed on little more than stunted mezquit bushes, and the thorny cactus.'

Colonization of the South-west was not extensive until after the United States Civil War of the 1860s. After the war soldiers were assigned to subdue raiding nomadic peoples, and large numbers of unemployed men and women were ready to seek their fortune in the West. Railroads provided an effective means to transport cattle to the lucrative markets in the East, while the West offered free grazing to whoever reached it first. To entice immigrants to the Mesilla Valley, lawyer, politician, and newspaper editor Albert Fountain wrote in a bulletin that the Jornada Plain was treeless and waterless but covered with rich, nutritious grass. He further claimed that profits from grazing sheep or cattle should average 30% annually (Fountain, 1885, as cited by Buffington & Herbel, 1965).

Since little land was suitable for farming, most of the people that moved into the area raised livestock. According to U.S. Census Reports for New Mexico, cattle numbers increased from 41,117 in 1870 to 153,746 in 1880 (Table 1). During this same period, sheep numbers increased from 619,438 to 2,088,831. By 1885, others estimated that 800,000 cattle and 5,000,000 sheep were present (Bancroft, [1889] 1962). Later estimates by the Bureau of Agricultural Economics placed cattle numbers at 158,000, 545,000, and 1,065,000 for the years 1850, 1880, and 1886, respectively (Stewart, 1936). Estimates for 1900 were 843,000 cattle and 3,535,000 sheep (Cockerill, 1959). Although livestock numbers escalated later, the magnitude of the increase was similar in southern Arizona (Bahre, 1991).

Because of differences between government and industry estimates, the accuracy of these reports is difficult to determine. For example, estimated sheep numbers for 1883 in the Auditor's Report to the United States Public Lands Commission were 1,757,948, while the Proceedings for the First National Convention of Cattlemen reported 3,960,000, and on 10 July 1883 the New Mexico Review reported 25,000,000 sheep in New Mexico (Bancroft, [1889] 1962). While cattlemen might benefit by under reporting herd size to government sources, they might also benefit from overestimating sheep numbers. The more organized cattlemen perceived nomadic shepherds as a threat because they both competed for the same public forage. By overestimating sheep numbers they may have justified their actions, being sometimes violent (Sampson, 1923) against sheep producers, while favorably affecting public and government opinion.

Differences in government estimates may reflect a difference in perception of western rangelands. In the 1880s excessive grazing appeared to be a major problem to only a few. Yet in the 1930s problems of grazing seemed obvious to many (Stewart, 1936), and the seemingly low numbers were challenged more often.

Table 1. *Estimated livestock numbers for New Mexico, 1870–1885*†*

	1870	1880	1882	1883	1884	1885
Horses‡	11,174	24,620	17,370	28,112		
Cattle	41,117	153,746	267,200	471,121	1,000,000	800,000
Sheep	619,438	2,088,831	1,339,718	1,757,948	1,000,000	5,000,000

*From Bancroft (1889).

†1870 and 1880 estimates are from U.S. Census Reports; other estimates are from other government and industry reports.

‡Includes horses, mules, and asses.

Part of the problem was the perception of the West held by policy-makers in the East. The Homestead Act of 1862 gave settlers 65 ha if they occupied the land for 5 years. Alternatively, they could purchase land for \$3.88 per ha after residing on the claim for 6 months. Although 65 ha was enough land for a farm in the eastern United States, it was grossly inadequate for pastoralism in the arid lands of the West. In 1879 John Wesley Powell, Director of the United States Geological Survey, recommended that allotments be increased beyond 65 ha (Powell, 1879). Despite the recommendation of men such as Powell, allotments were not increased until 1909, when the Enlarged Homestead Act was passed. This act permitted settlement of 130 ha, which again was an adequate amount of land in many areas of the West. Consequently, many tracts were sold to large mining and livestock interests (Stoddart *et al.*, 1975), often in a degraded condition.

These larger interests used other tactics to obtain public land as well. One method included 'grazing out' so-called squatters by overgrazing land claimed by newcomers. As stated by Stewart (1936), the 1880s and 1890s were 'largely the story of struggle between the big owner and the little owner, with the 'rustler' an unrecognized but inevitable ally of the small owner.' Bentley (1898) described the struggle between cattlemen and newcomers to the range, called nesters: 'It was really a fight over a crust, however. The best grass was gone, and with every class of stock a drag on the market at the lowest prices ...'

A severe winter in 1885–1886 in parts of New Mexico and a sequence of drought years during 1886, 1891–1894, and 1901–1904 ended the cattle boom in this area. Many cattle died of starvation, while rangelands were left severely overgrazed. The loss of their livestock strongly influenced livestock grower perceptions of the range resource. Wooton (1908) cited a 1905 Public Lands Commission report that surveyed 118 stockmen from New Mexico. Of those surveyed, 102 producers believed that the carrying capacity of their ranges was diminished, while 16 reported an increased carrying capacity. Of the producers that said their carrying capacity was reduced, 69 believed the reduction was due to overgrazing and 33 attributed the reduction to drought. Regardless of the cause, little incentive was offered to improve the range. As Wooton (1908) noted, 'The lack of legal control acts detrimentally on the range in two ways. Those men who, for their own benefit or from more altruistic motives, might care for and improve the range they are using, dare not do so for the fear that their labor may only bring them competitors; hence there is no inducement for the desirable kind of occupant to do what he otherwise would do gladly. For those individuals who are carelessly or consciously ruining the ranges there is no possibility of censure, much less punishment, since they have no definite legal authority and consequently no definite responsibility.' The situation, in part, is what Hardin (1968) would later describe as 'the tragedy of the commons.'

The early 1900s experienced the first real conservation movement of the era. Congress had previously set aside Yellowstone National Park in 1872 as 'a park or pleasuring ground for the benefit and enjoyment of the people.' By 1877, Carl Schurz, Secretary of the Interior, proposed a system in which the public owned forested land but timber was harvested by private individuals. He also proposed a public land commission and repeal of ineffectual laws. But as Clawson & Held (1957) concluded, 'The general public was quiescent, as yet unaware or unconcerned with the waste and disposal of the public land.' Consequently, few legal changes were enacted.

As of 1891, few people were aware that an act authorized by the President to set aside forest reserves was passed by Congress during its closing days. Some even doubted that Congress knew it had done so (Clawson & Held, 1957). Two years later President Harrison withdrew 5.3 million ha for national forest purposes. Later, prompted by the visionary leadership of Gifford Pinchot, President Roosevelt added 13.4 million ha to the national forest in 1905 and another 12.1 million ha in 1906. The withdrawals so angered Congress that it passed legislation prohibiting further

withdrawals without its consent. Just before signing the act, Roosevelt established 21 more national forests.

The first national forest reserves in the South-west were established in 1902 and signify the first efforts to conserve range and forest resources in the region. These efforts included both grazing control and fire suppression (Bahre, 1995). Yet large tracts of land, chiefly the less valuable arid lands, were not protected.

Rangeland research arose because of federal policy for newly established national forests and their administration. Just before 1901 the Bureau of Plant Industry began to study forage plant techniques, reseeding, and grazing practices. In 1903 the Santa Rita Range Reserve was established near Tucson to protect a large area of native range from grazing. That same year the Carnegie Institute established the Desert Laboratory in Tucson for fundamental studies of desert plants (Chapline *et al.*, 1944). State agricultural experiment stations established by the Hatch Act of 1887 also began to show interest in rangeland research. An example is the work of Robert Forbes examining the impact of grazing on watersheds in Arizona (Forbes, 1901).

The Santa Rita Range Reserve was expanded in 1909, and the Jornada Range Reserve near Las Cruces, New Mexico, was established in 1912. Both stations were reassigned to the United States Forest Service in 1915. Established research, however, was discontinued at the Santa Rita Range and greatly curtailed at the Jornada Range in 1917 to maximize livestock production for World War I.

In New Mexico cattle numbers were at an all time high (Fig. 1). Unfortunately the years 1916–1919 were also drought years. During this time areas of the Jornada Reserve suffered moderate to heavy overuse but apparently recovered to pre-drought conditions with the rains of 1919 and 1920 (Forsling, as quoted by Ares, 1974).

Research in itself did not end overgrazing on the public domain, especially on lands not administered by the Forest Service. Instead, research found that more work needed to be done. But the legal framework at that time was inadequate to meet the

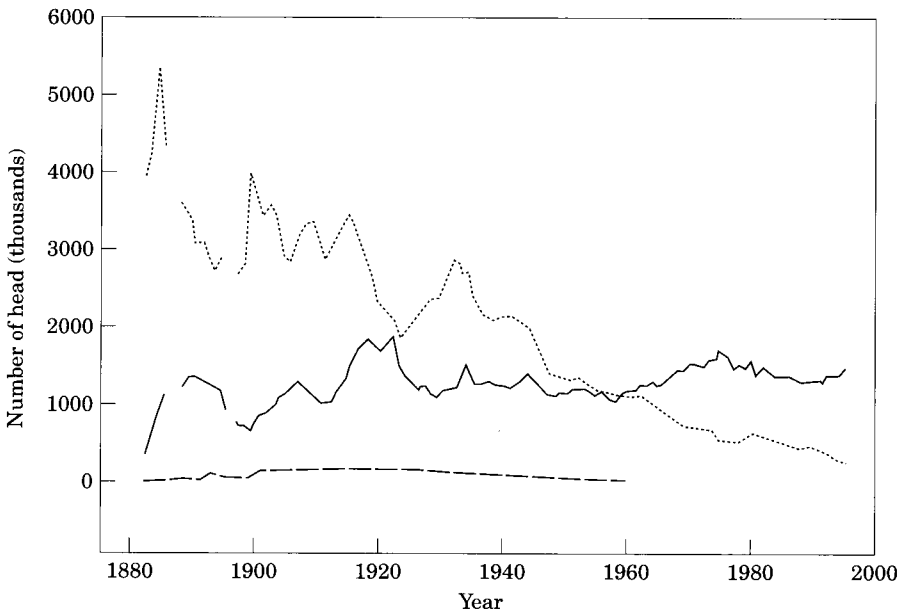


Figure 1. Estimates of sheep (·····), cattle (—) and horse (---) populations in New Mexico. Data provided from Wooten (1908) was used for years 1880 to 1900, data from Cockerill (1959) for years 1900 to 1959, with data for remaining years provided by the United States Department of Agriculture, Agricultural Statistics Service.

challenge. In part due to the persistence of the ranching industry, during the 1920s Congress introduced a series of bills that eventually led to the 1934 Taylor Grazing Act. This act created grazing districts and required the issuance of permits for private use of public lands. Administration of these lands was placed under the Department of the Interior because it promised both low grazing fees and low administration costs. These promises later hampered efforts by the department to obtain appropriations to properly perform its duties (Clawson & Held, 1957).

Before the 1940s, management of public lands was largely custodial. Although range ecology was studied, much of the research was designed to improve forage management. Major research thrusts involved development of carrying capacity recommendations, drought management strategies, and animal management systems, including methods of improving livestock distribution. Governmentally-sanctioned programs were established to help livestock producers maximize forage use. Some programs sought to eliminate livestock predators, while others were intended to lessen the competition for grass by other herbivores. As a result, free-ranging grizzly bears and Mexican gray wolves are no longer found in the South-west. Programs using strychnine-laced baits reduced prairie dogs to a few very small populations.

Possibly because of a change in perception, in the 1940s a more intense management style emerged and survived for more than 30 years, elicited by the seemingly irreversible transition of grasslands to non-forage woody species (Buffington & Herbel, 1965; Ares, 1974; Bahre, 1991). During this 30-year interval many rangeland inventories were conducted and improvements made. Improvements were aimed at increasing forage production and stabilizing the soil in seriously degraded areas.

Beginning in the 1930s new plants were introduced with hope of finding species that would germinate and establish easily. Among the most successful were the lovegrasses from South Africa, including Lehmann lovegrass (*Eragrostis lehmanniana*). Later this grass would be viewed with some uncertainty because it tended to expand beyond seeded areas into native ranges, often replacing native species (Anable *et al.*, 1992), especially in areas damaged by grazing or drought (Robinette, 1992). Furthermore, the success of these seeding practices is often quite low, and rarely are these approaches economically feasible with the current types of land use (Sherwood, 1994).

Other improvement methods that were employed included use of herbicides and heavy equipment. These methods are typically expensive and have a limited effective life (Gibbens *et al.*, 1992). Rangeland assessments were also conducted during this era, but recently the value of even these is being challenged (National Research Council, 1994).

Drought was the pre-eminent event for much of the South-west during the 1950s. The drought of 1951–1956 was the most severe drought recorded during a 350-year period. In the Chihuahuan Desert grass cover was severely reduced, while shrubs such as mesquite readily established after the drought. The resulting transition from grass to desert scrub occurred both on land grazed and not grazed by livestock (Herbel & Gibbens, 1996).

The formation of the Society for Range Management in 1948 elicited a change in emphasis in the scientific literature. According to Tobey (1981), research shifted from examining grassland ecology to addressing technological concerns of an era of intense range management. This research emphasis did not change significantly until during the late 1960s and early 1970s. People such as Van Dyne (1969) and others advocated the use of ecosystem concepts for research and management of natural resources, suggesting a change in emphasis from the organismic level to the integration of all the living and non-living factors of the environment.

This emphasis on the integrated whole was a major turning point for resource management. Such an emphasis would eventually force us to consider the complexities of our environment and our interactions with it. We would eventually learn that there

are no 'quick fixes' to the land degradation of the past and that every action had its consequences, sometimes a cascade of consequences.

Van Dyne (1969) suggested that one impetus for this shift was the work of Rachael Carlson, who made us keenly aware of the dangers of unwise pesticide use. Furthermore, because of the efforts of Van Dyne and his colleagues, the International Biological Program was established for the collaborative study of ecosystems. Much was learned from this program about the grasslands of the South-west, eventually leading to a clearer understanding of desertification processes.

Another critical factor occurring in unison with a shift in research priorities, albeit gradually, was a change in the human demography of the South-west. Until the 1950s human populations were typically rural, with small urban concentrations. Soon after parity was reached in the 1950s, urban populations became a dominant force in the South-west (Figs 2 and 3). As urban populations rose, land use shifted toward increased recreation and other non-consumptive uses. This situation led to the Multiple Use Act of 1962, which provided for uses other than grazing, logging, and mining. Later, public concerns about the condition of public lands led to more land use laws.

Conflicts between rural agriculturists and urban environmentalists were common, especially in the court system. Frequently land management agencies were caught in the middle of this battle. Ranchers voiced concerns such as prior rights (Hage, 1989), while environmental groups expressed their rights as citizens (Cooperrider & Wilcove, 1995).

This historic period represents a time, like other times, in which previous events unleash a cascade of events that ultimately affect current conditions. The Spanish reintroduction of the horse is one such incident. The horse greatly affected the nomadic peoples, the lives of sedentary agriculturists, rate of the Spanish conquest, and finally the occupation of the South-west by the United States. It is conceivable that if horses were not reintroduced, more Spaniards may have colonized the South-west and occupation by the United States might have been prevented or delayed.

Recent history demonstrates the importance of citizen involvement in evoking land use changes. During the cattle boom of the 1880s, despite the warnings of land degradation by respected public officials, public interest was low and land degradation

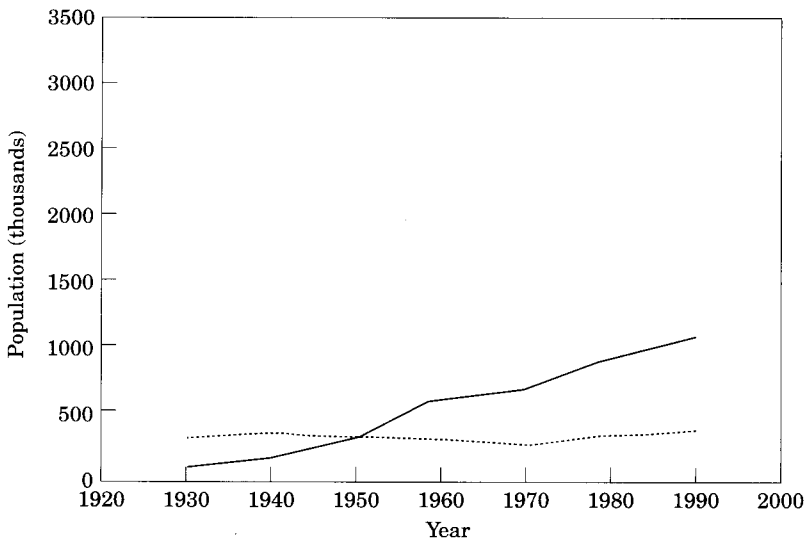


Figure 2. Urban (—) and rural (...) populations in New Mexico. Data provided by the U.S. Department of Commerce, Bureau of the Census.

proceeded at a phenomenal rate. Once public interests were aroused in the early 1900s, changes began. Ranching interests concerned about further erosion of the forage base brought about the regulations of the Taylor Grazing Act. Urban populations in the 1960s and 1970s, interested in recreation and land quality issues, were responsible for the Multiple Use Act and later laws to improve human interactions with the land.

Present and future

Currently in New Mexico cattle numbers are greater than the historic average, but in combination with the large decline in sheep numbers, total livestock numbers expressed as animal units are well below the historic average (Figs 1 and 4). Livestock operators have more management options than in the past. When applied properly, these options have helped producers reduce their potential to damage both ecosystem condition and integrity. Other management options have dramatically improved the efficiency of converting plant materials into high quality protein.

Difficulties have arisen when prices offered to beef producers have fallen below a point that makes implementing new technologies economically feasible. This problem may persist in the short-term as livestock producers compete on the global market. Because of rapid increases in national and global populations (Fig. 5), demands for livestock products will likely increase in the long-term. Methods that provide incentives to use ecologically sound livestock management practices are being proposed. These methods have great potential for improving grazing technologies and management strategies.

Grazing issues remain a public concern, but the effects of rapid population growth and urbanization are becoming a major problem that may surpass grazing in importance in the coming decade. The rapid increase in urban populations has placed increased stress on the environment. Recreational activities have damaged large areas of land, and that damage will require both time and money to repair. Increased water requirements for growing cities have significantly lowered water-tables in some areas, threatening riparian habitat and associated species as well as agricultural potential.

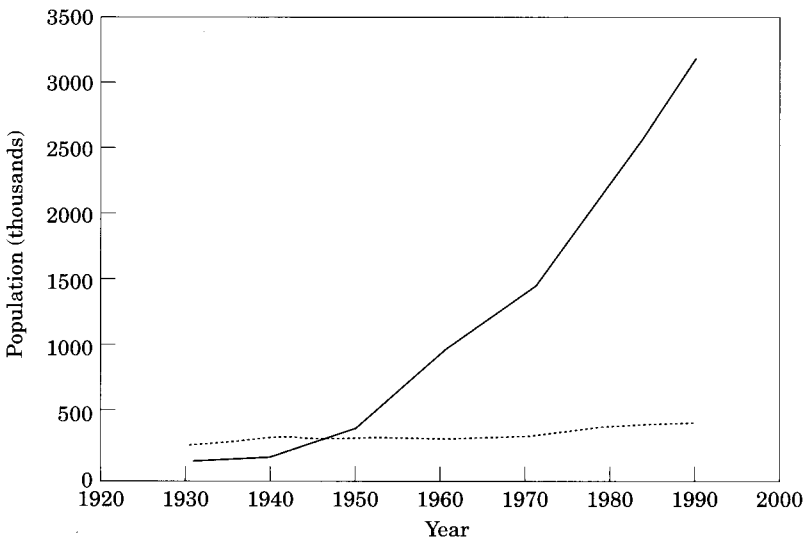


Figure 3. Urban (—) and rural (...) populations for Arizona. Data provided by the U.S. Department of Commerce, Bureau of the Census.

Agricultural potential also declines steadily as rangelands and irrigated fields are replaced by strip malls and housing developments. Agricultural water rights are being purchased to fuel continuing urban growth, leaving plowed fields not covered by concrete to be eroded by wind and water. These and other problems that have resulted from increased population growth have not been adequately addressed in the Southwest. Land use laws are seemingly ineffective or insufficient to contend with these critical issues.

The transition of grasslands to shrublands in the arid South-west during the last 120 years is apparent (Buffington & Herbel, 1965; Hastings & Turner, 1965; Humphrey, 1987; Bahre, 1991), but the causes of the transition are sometimes hotly debated.

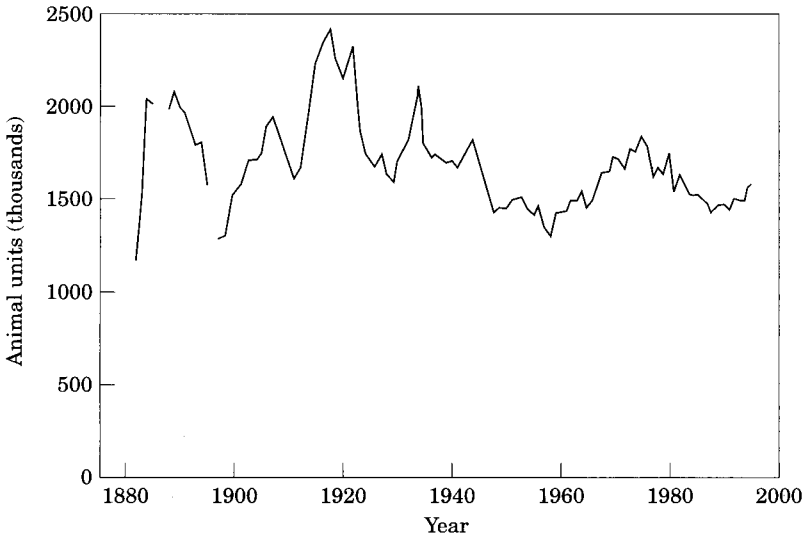


Figure 4. Sheep and cattle populations in New Mexico expressed as animal unit equivalents (AU: 1 cow and calf). A conversion of five sheep per AU was used.

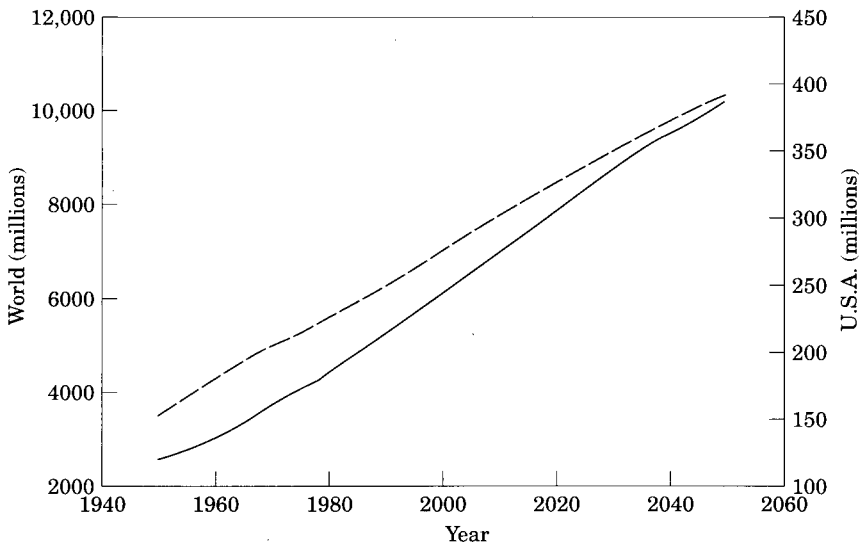


Figure 5. United States (---) and world (—) populations, and population projections. Data provided by the U.S. Department of Agriculture, Economic Research Service.

Although the debate has served to polarize concerned parties, a growing faction has abandoned the debate to seek solutions. These people are from the ranching, environmental, land management, and scientific communities, among others. These people will undoubtedly be responsible for a great deal of positive change.

One question that should be addressed is how efficiently is the scientific community helping those in search of solutions to perceived ecological problems? These are solutions that will hopefully minimize our role in land degradation while promoting regenerative ecosystem properties. Perhaps as scientists we have not been as helpful as we should be. Some of us have vigorously entered the debate in ways that further polarize it. Furthermore we have offered false possibilities of sustainability that in a dynamic system such as the arid and semi-arid areas of the South-west are marginally probable in the short-term. In the long-term the cost of sustaining any activity or ecosystem attribute may be exceedingly expensive once the conditions that supported its initial existence have changed. Can we afford the loss in credibility that accompanies the offer of such promises? Perhaps we can offer society more by helping develop methods to adapt to the changes that are inevitable.

As scientists, we have difficulty communicating what we know to the public that directly or indirectly employs us. In college we are trained to write and speak with other scientists but are insufficiently prepared to communicate complex ideas to a concerned public. Possibly because of this weakness we have become unnecessarily reliant on metaphors to express complex ideas.

One such metaphor is 'ecosystem health,' an expression that West *et al.* (1994) wrote is heavily value-laden. Therefore, interpretation of its meaning can be variable, reducing our ability to accurately communicate. Further, the term suggests that ecosystems inherently have an optimal condition. If indeed optimality is an ecosystem characteristic, then it is transient at best. Ecosystems do not appear to be stagnant, nor are the conditions that perpetuate the dynamic nature of the system (Johnson & Mayeux, 1992). If so, it may be advantageous to address the dynamic features of the system, rather than ephemeral characteristics. Dynamic traits are likely to be more meaningful. By resisting the urge to substitute metaphors for substance, we more accurately communicate how we believe ecosystems function and more effectively help the public we serve.

With the aid of a president, the engineering community in the 1960s greatly excited the American public about the possibilities of space exploration. These engineers maintained this excitement by providing the American public with a unified vision of the future, complete with moon landings, space stations, and visits to Mars. As a consequence, the public has rallied behind their cause, and their achievements are substantial.

If we expect ecological conditions to improve in the future, we must also offer the public a unified vision of the future, one that excites, has significant milestones by which to judge our achievements, and respects the right of individuals while rewarding innovation. We must also seek new mechanisms to educate the public. This is especially important since history has shown us that the world is constantly changing, and we can suitably adapt to these changes only if we have a concerned and informed public.

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