7.0 Livestock and Landscape

Introducers: Richard Hunter and William E. Doolittle

Abstract Livestock have been portrayed as a bane on the landscape of Latin America, often without fair and unbiased assessment. Here, two articles by William M. Denevan, one on cattle in Bolivia and one on sheep in New Mexico, are discussed. The findings demonstrate how objective scholarship provides more light than heat on a subject that is often contentious because it is misunderstood.

Keywords Bolivia · Cattle · Grazing · Landscape · Livestock · Historical geography · Sheep · Southwest

Introduction

William M. Denevan's greatest influence within geography and cognate disciplines has arisen from his investigations into native demographics and related environmental changes in the New World. His historical geographical research has done much to dispel "the pristine myth," a term Denevan (1992) coined to describe the belief that the New World was lightly populated and a little modified by indigenous peoples. However, he has studied more than this (as this volume attests). Furthermore, his approach has never been dogmatic in the sense of maintaining a position and gathering data in its support. The line of thought often associated with Denevan and his students is one that insists asking questions is more important than proffering answers a priori. Perhaps, this is no better seen than in his writings on livestock, particularly cattle and sheep, introduced into the Americas by Spaniards in the 1500s. Denevan wrote these articles about very different environments on two different continents, work that testifies to his breadth as well as depth of scholarship. Their early publication dates and repeated citations stand as evidence that they were both pioneering and seminal articles.

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"Cattle Ranching in the Mojos Savannas of Northeastern Bolivia" (Denevan 1963a) focuses on herding in a seasonally inundated environment. Although dealing with events of the late twentieth century, it is framed in a historical context, dating back to 1682. The article traces fluctuations in herd sizes over time, revealing the importance of political stability, markets, other products, and technology. Of particular note in this article is that we can observe Denevan's early interest in the history of population sizes, although in this case he was writing about cattle rather than people. In Mojos, he recognizes that the annual flooding is the limiting factor on cattle numbers rather than drought, disease, or any other variable. High floods kill or submerge edible grasses and sedges, with the only viable forage growing on *islas* that become trampled or cattle drown trying to reach. The piece argues – successfully – that cattle ranching, then a topic of neglect and disinterest, is worthy of geographic investigation. This article is also noteworthy in that philosophically it can be considered political ecology (e.g., Robbins 2004), albeit *sans* the dogmatic rhetoric that often accompany such studies.

"Livestock Numbers in Nineteenth-Century New Mexico, and the Problem of Gullying in the American Southwest" (Denevan 1967) focuses on sheep and environmental degradation. Arroyo-cutting was doubtless occurring throughout the Southwest for millennia, but it came to the fore in the 1880s due to the proclivity of ranchers to view environments as stable and to build their houses in valley bottoms, two very big mistakes. Ranchers typically built slightly upstream of knickpoints. With a few heavy rains and runoff events, all were lost. Word of damage caused by headward cutting spreads quickly, thanks to the nascent newspaper business (Aschmann 1982). This, in turn, leads scholars to begin exploring human impacts on the environment – specifically overgrazing. Lines were quickly drawn; some scholars argued that livestock caused gullying, while others claimed there were changes in rainfall patterns. Denevan took an open-minded and even-handed approach to the issue. He explains, "The lack of widespread gullying prior to 1870 has previously been assumed to be explainable by the absence of overgrazing and consequently a denser, protective vegetation cover, or by climatic conditions favoring alluviation rather than erosion. The historical evidence of livestock and vegetation conditions during the period 1788–1848 weakens the overgrazing argument" (Denevan 1967, 693). The evidence to which Denevan refers derives from his research into livestock numbers in the early nineteenth century that revealed how the late Spanish and early Mexican ranchers stocked the ranges of northern New Mexico with nearly as many sheep as in the late nineteenth century when widespread arroyo-cutting ensued. He notes that grazing pressure was also probably higher in the later period because ranchers often kept their sheep in enclosures to protect them from "hostile Indians" rather than allow them to graze unrestricted as was common practice in the earlier period. What Denevan uncovered was that sheep numbers in and of themselves – and overstocking, however that phenomenon is measured – are insufficient to induce arroyo-cutting in this environment. Arroyo-cutting occurred in the late nineteenth century rather than the early nineteenth century not because there were so few sheep in the earlier period but rather because arroyo-cutting is triggered by a combination of "drought, followed by several years of heavier than average summer storms, high livestock numbers, and a probably weakened vegetation cover" (Denevan 1967, 702). Subsequent investigations into

historical arroyo-cutting in New Mexico as well as global locations have reached similar conclusions (see, e.g., Jones 2015; Butzer and Helgren 2005, which also appeared in the *Annals* nearly four decades later).

This pair of articles marks Denevan as a pioneer in the field. Historical ranching and the environmental effects of such have now become a fertile research area within Latin American historical geography. Topics of subsequent studies are numerous and diverse. Some examples include livestock introductions (Doolittle 1987), the development of a Mediterranean-like agro-pastoral complex replete with transhumance (Butzer 1995), the formation of haciendas and latifundios (Aguilar-Robledo 2003; Edelman 1992), the establishment of distinctive ranching cultures (Jordan 1989; Bell 1998), the contribution of Africans (Sluyter 2012), the historical productivity gains of Colombian ranchers (Van Ausdal 2012), the expansion of cattle ranching in Brazil's Mato Grosso (Wilcox 1999), how a cultivation-to-pasture land use change may have contributed to the Little Ice Age climate anomaly (Hunter and Sluyter 2015), and the use of new technologies for understanding pastoral landscapes of the past (Hunter 2014). An interesting connection within, while illustrating the diversity of, the so-called Berkeley School of Geography (Spencer 1976) is that Denevan's study area of northern New Mexico was the same as that of Yi-Fu Tuan, a former fellow graduate student who was trained in geomorphology (a student of John Kesseli), went on to become the New Mexico state climatologist, and later gained fame as the discipline's foremost humanist geographer (e.g., Tuan 1974). New Mexico's livestock heritage has also been the focus of at least one historian who received geographic training at Berkeley (Dunmire 2013).

These two early articles connect to other research Denevan was conducting at the time as well as foreshadow his later career trajectory. In addition to his piece on cattle ranching in the Mojos savannas, Denevan also published in that same year a report on the quantity and distribution of earthworks in the Mojos that he made from low-flying aircraft (1963b). His report describes extensive landscape modifications including raised fields, causeways, mounds, and circular ditches. To explain this once highly managed landscape, he suggests "there were large populations of well-organized people" before the Jesuits arrived in the late seventeenth century (1963b, 543). Interestingly, in his article on the history of cattle in the Mojos, Denevan describes another, much more recent episode of landscape abandonment. He describes that by 1950 meat companies had acquired cheap World War II surplus aircraft, which raised the value of Mojos cattle because beef could now be transported to urban centers such as La Paz at a much lower cost than the traditional overland cattle drives. With their cattle suddenly much more valuable, many ranchers chose to round up and slaughter every animal they could find. "Because of the decrease [in cattle]," Denevan (1963a, 43) writes, "many ranches have been abandoned, thus creating a rural depopulation as both ranchers and their workers have left for the highland cities or the Santa Cruz region."

In his 1967 piece, he identifies and dispels a false belief that the Spaniards, Mexicans, and indigenous people of early nineteenth century northwestern New Mexico must have had relatively few sheep because there was little environmental degradation dating to that period. In a way, this was another kind of "pristine myth" mentality perpetuated by Anglo latecomers. Indeed, relying on documentary numerical data and chroniclers' accounts, to meticulously reconstruct livestock population sizes, is much the same

approach that Denevan subsequently used to conclude that the entire New World had a far greater pre-European human population than previously accepted. As he writes succinctly elsewhere on this topic, "The evidence is convincing" (Denevan 1992, 370).

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7.1 Cattle Ranching in the Mojos Savannas of Northeastern Bolivia

Original: Denevan, W.M. 1963. Cattle ranching in the Mojos savannas of Northeastern Bolivia. *Yearbook of the Association of Pacific Coast Geographers* 25:37–44. Reprinted by permission of the Association of Pacific Coast Geographers.

Abstract In the Mojos (Beni) savannas of Bolivian Amazonia cattle production has been the primary economy since the Jesuit missions in the late seventeenth century. For 250 years this involved the rounding up of wild cattle. Because of seasonal flooding alternating with seasonal drought the raising of cattle was difficult resulting in high mortality every year. And because of isolation marketing was limited, requiring long drives to Santa Cruz. After World War II beef companies used cheap surplus planes for flying raw meat to La Paz and Cochabamba. Most of the wild cattle were soon rounded up. Formal ranches began to be established on high ground, including houses, fencing, corals, and air strips, along with controlled breeding and conversion of vintage criollo to Cebu stock. High prices and good transport resulted in over exploitation, and cattle numbers declined from over one million in 1952 to about 350,000 in 1962. Nevertheless, Mojos continued to be the main source of beef for the capital city of La Paz.

Keywords Cattle ranching · Bolivia · Mojos

Introduction

The Llanos de Mojos is a seasonally inundated tropical savanna occupying about 90,000 square km in the Beni Department of northeastern Bolivia. Today, the region is undeveloped, has a population of only 120,000, and remains isolated from the rest of Bolivia. Cattle ranching has dominated life in Mojos for over two centuries, but cattle have nevertheless been almost worthless until recently. However, since 1950,

as a result of the use of meat cargo planes, the Mojos savannas have become the major source of beef for La Paz, and cattle are now the most valuable product of northeastern Bolivia.

Both physically and economically, the Mojos savannas have much in common with other large grassy savannas in South America: the lower Orinoco *llanos*, the Amazon *campos*, and the vast Pantanal de Mato Grosso. All of these savannas are seasonally flooded, and all are important livestock raising areas today. Mojos, however, is somewhat unique for the severity of its annual floods, for the past neglect of ranching, and for the partly negative effects of the recent and sudden availability of major markets for beef. An examination of some of the past and present aspects of cattle ranching in the Llanos de Mojos therefore seems desirable, with an emphasis on the striking changes which have taken place since ranching was described in the late 1940s and early 1950s (Weeks 1946; Comisíon Ganadera al Beni 1953; Osborne 1956, 88–91).

Background

The Mojos savannas occupy most of the Beni basin, which is located between the Andes and the western hills of the Brazilian Highlands and is filled with thousands of feet of young sediments washed down from the Andes (Fig. 7.1). This unusually level plain ranges in elevation from roughly 1000 ft. in the south to 600 ft. in the north, and the gradient is about one foot per mile. The basin is drained by the Río Beni, Río Mamoré, and Rio Guaporé (Itenez) which along with the Río Madre de Dios join in an apex near the northern border of Bolivia to form the Rio Madeira, a major tributary of the Amazon. During high water, these rivers and their tributaries overflow, and this flooding, combined with standing rain water, results in as much as 80 percent of the savannas being under several inches to several feet of water between December and June. Rainfall averages 60–75 in. a year and is concentrated between October and May. Vegetation is directly related to relief, and the associated amount of flooding, but is also strongly influenced by burning. The lowest ground has sedges (*Cyperaceae*) where permanently wet and grasses (*Graminae*) where seasonally flooded. Higher ground subject to only brief flooding has open scrub savanna dominated by palms (*Copermicia*, *Acrocomia*) and species of *Tabebuia* and *Curatella*. Sites seldom or never flooded (*islas*), such as natural levees, low divides, and low mounds, are usually forested. Rain forest or semi-deciduous tropical forest surrounds the Llanos de Mojos on all sides. The savanna soils consist mainly of acid clay loams with hard pans and low organic content. Because of the low fertility and poor drainage of the grassy savannas, all agriculture today is confined to the better soils of the forested *islas*.

Mojos was one of the legendary El Dorados of South America but remained unexplored until an expedition reached it from Santa Cruz de la Sierra [to the south] in 1580. The Indian tribes encountered had large, palisaded villages, elaborate crafts, and a total savanna population of probably several hundred thousand. Some of the tribes adapted to the inconveniences of flooding by constructing causeways, mounds, and raised and ditched crop rows. The remnants of these pre-Spanish

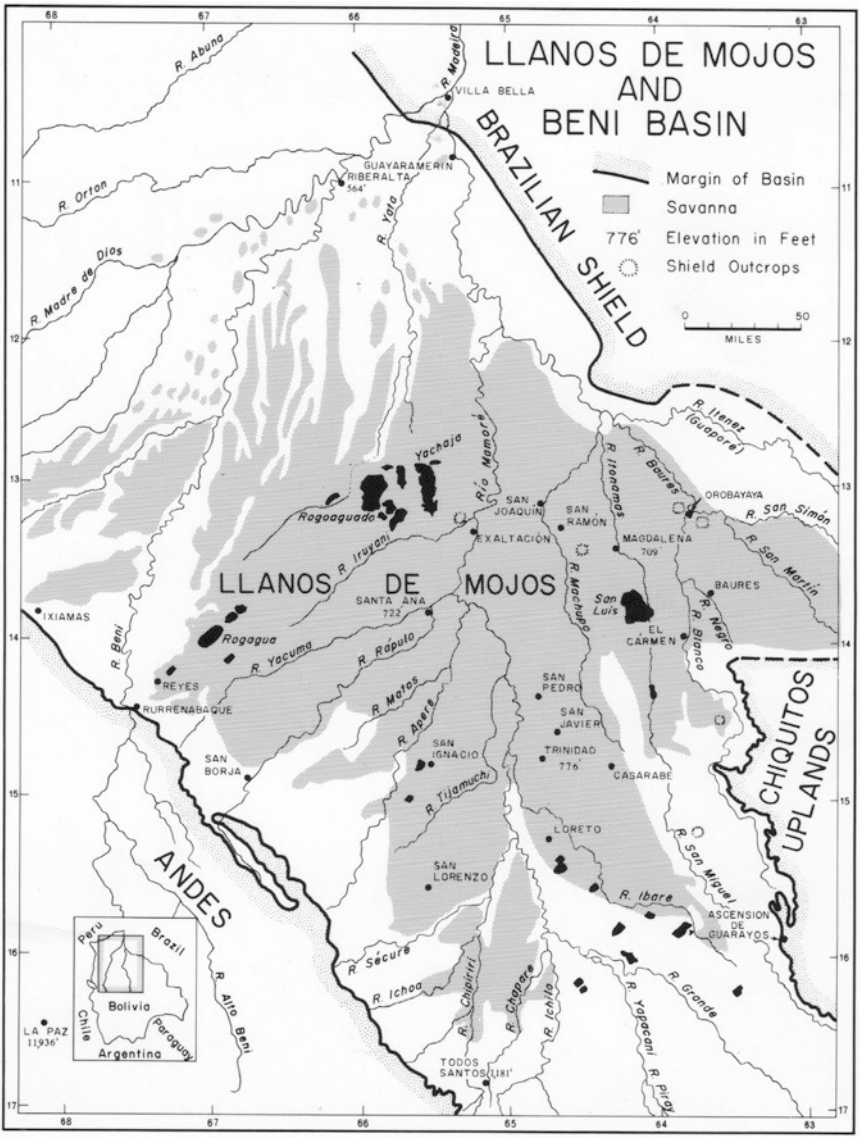

Fig. 7.1 Map of northeastern Bolivia and the Llanos de Mojos

earthworks, numbering in the tens of thousands, can still be seen but are little known (Denevan 1963). The first European settlements were Jesuit missions founded in the late seventeenth century by which time the Indians had been decimated by disease and slave raids. The Mojos missions prospered with a cotton textile industry and with large cacao and cotton plantations in the forests, but both the settlements and the economy deteriorated after the Jesuits were expelled in 1767.

History of Ranching

Cattle were introduced to Mojos by the Jesuits in 1682, when a herd of about 200 head survived a 54-day overland trip to the Loreto mission from Santa Cruz (Anonymous 1743, 456). All the missions established ranches and raised cattle for meat, milk for the Indians, and tallow for export. By 1767, there were about 55,000 cattle in 15 missions (René-Moreno 1888, 46). The Indians became excellent horsemen and *vaqueros* but seldom raised their own animals, preferring to hunt wild cattle.

Following the expulsion of the Jesuits, virtual wars of extinction were waged against livestock in Mojos. Cattle were considered part of the public domain and were treated as an unlimited natural resource to be exploited without restrictions. The present prevalence of cattle thieves in the Beni reflects the survival of this tradition. The mission cattle declined under the new curate administrators who killed them mainly for tallow, and some missions were abandoned because of the scarcity of meat and the necessity for the Indians to return to hunting wild game. Administrative reform brought protection, however, and cattle numbers increased.[1] After Bolivian independence in 1825, increasing numbers of Spaniards entered Mojos from Santa Cruz, received grants of land from the government, and established large private cattle ranches. Also, the government often paid debts and salaries by issuing letters of credit or bonds for so many thousands of head of [wild] cattle in Mojos.

The only major market for Mojos beef was in Santa Cruz, and there was a small but regular dry season movement of cattle thereto through the Chiquitos uplands. Losses from thirst, hunger, and exhaustion were very high, but the cattle initially cost little or nothing, so there was some profit. Many of the cattle were slaughtered for the preparation of *charque* (dried strips of beef) for both local consumption and export, but the majority were killed only for their tallow and hides, which were sent in long caravans of oxcarts to Santa Cruz and from there to the mining towns of the Altiplano. In the Mojos villages and ranches, the abundant tallow was used for fuel, while rawhide strips and hides found many uses.

The descriptions of the cattle industry of the nineteenth century (Keller 1875, 182–185) are reminiscent of the slaughter of the bison in the United States. Large numbers of cattle were killed in single roundups, including calves and pregnant cows, and beef loss from spoilage was high.

> The thousands of cattle which grazed on the vast plains were decimated, driven in herds to Santa Cruz, or slaughtered in the open for the sake of their fat. The carcasses were abandoned in the pampa, and the people did not even bother to select the cattle to be slaughtered (Saucedo 1942, 31).

Decrees passed to prohibit such abuses were ineffective. The herds recovered once more, however, in the years from 1870 to 1920 when many of the ranchers and their Indian *vaqueros* left the *llanos* for the booming rubber regions to the north.

[1] The *Archivo de Mojos*, Vol. 9, No. 43 (Biblioteca Nacional, Sucre) contains a 1786 circular prohibiting the killing of cattle or sale of horses "in order that they might multiply for the benefit of the province."

Cattle numbers increased to over one million by 1900, and from then until 1952 estimates vary from one to one and one-half million (Bayo 1911, 396; Suárez 1930; Chirveches 1952). Most of these cattle were feral or nearly so, ranged unfenced and uncared for, and fended for themselves against jaguars, floods, and drought; breeding was uncontrolled and pastures unimproved. Travelers often found foot movement through the *llanos* dangerous because of herds of wild bulls.[2] The American Navy Lieutenant, Lardner Gibbon, reported 60,000 wild cattle in the Loreto *pampas* in the 1850s (Gibbon 1854, 251), and 100 years later an estimated 500,000 wild cattle were reported in just the Lago Rogoaguado area of northwestern Mojos (Osborne 1956, 88). After 1950, when beef prices began rising considerably, wild cattle were rapidly rounded up. Bush pilots who had helped ranchers spot and shoot or capture wild cattle reported that few were left in 1962.

Until about 1950, there continued to be large cattle drives to Santa Cruz and from there to northern Argentina, where the stock was rested and fattened up and re-exported by railroad to La Paz. Cattle are still sold in Brazil, mainly in Guajará Mirim at the southern end of the [former] Madeira-Mamoré railroad. In 1949 Pôrto Velho at the northern end of the railroad was receiving 6000 head of cattle a year from the Beni (Osborne 1956, 90), but this number is less now that small ranches have been established along the railroad. Some Beni cattle, however, still reach the Amazon via this railroad and the Rio Madeira.

The *Estancias*

The largest ranches in the Llanos de Mojos, such as those of the firm of Suárez Hermanos (once a rubber empire), were confiscated by the government in the 1950s as part of Bolivia's land reform program. Today, the ranches average about 5000 ha and less than 3000 head of cattle; few ranches, if any, exceed 40,000 ha and 15,000 head of cattle.

Ranches have changed little from pre-aviation years, mainly because few ranchers care to invest their profits in their ranches. Surface travel is mainly by oxcart, horseback, and canoe, and only a few ranchers have a truck or jeep. Most ranches have a *trapiche* for grinding sugar cane and possibly a small lumber mill. Crops include several hectares of rice, *yuca* [manioc], plantains, and sugar cane. Ranch buildings and corrals are of palm wood and are built on *islas* of high ground not normally subject to flooding, which average 5–10 ha in size. At most, a ranch may have 200 or 300 ha of barbed-wire-fenced pasture. Only a few ranches have a *gran casa* with running water, electricity, and some degree of comfort. Usually, the owner's house has daub-and-wattle walls, a thatched roof, dirt floors, and one screened room. Most ranches have a small landing strip, and the owners live in town [or La Paz] and commute via bush plane.

[2] Col. P.H. Fawcett (1952, 235), the British explorer, commented in 1913 that "We were warned of the wild bulls, which had killed many foot travelers."

In addition to a *mayordomo*, the average ranch has half a dozen of permanent Indian *vaqueros*. Some owners will give men (*partidarios*) 20 or 30 head of cattle, and after 5–10 years, they receive a certain percentage of all the young steers. The *partidario* receives free grazing land, medical care, tools, and immunization service in addition to the initial cattle. Most of the farming on ranch property is done by *inquilinos* (tenants) who are obligated to sell produce to the rancher at the price given in the nearest town.

The typical ranch has mostly criollo cattle, whose ancestry dates back to the early colonial period. These cattle take over four years to mature, often produce calves only once every two years, and provide low quality, tough, and tasteless beef. A few ranchers have some improved breeding stock which are full or part Cebu. Only the towns and largest ranches have air fields of sufficient length to handle meat planes. The cattle are driven to the nearest airfield where a *frigorífico* (meat company) maintains corrals and a slaughter house, but no refrigeration. The cattle are butchered overnight, and the meat is flown out the next morning.

In 1962, the *frigoríficos* paid about 28 cents per kilogram for beef, carcass weight. The round-trip cost of transporting the beef to La Paz was about 9 cents per kilogram, with each plane carrying a load of supplies from the highlands and then returning with about seven and a half tons of beef (USDA 1962, 55–60). The time from slaughter to arrival in La Paz is only seven to eight hours; consequently, there is little loss from spoilage, but neither is the meat allowed to age before sale. If a plane loaded with meat is delayed in takeoff, the beef is dried. Butter, cheese, tallow, and *charque* may be shipped by boat or trail to river towns or to Brazil, and increasing numbers of cattle reach Cochabamba by river boat and then truck via the Chapare region (Todos Santos area).

The Mojos savannas have an average yearly grazing capacity of about 10 ha per head (Braun 1961). Most of the range grasses are perennial, native tussock types, including species of *Panicum*, *Paspalum*, *Sporobolus*, *Leersia*, *Axonopus*, *Tripsacum*, and *Andropogon*. Introduced grasses being grown on a few ranches include jaragua (*Hyparrhenia rufa*) and molasses grass (*Melinis minutiflora*) on high ground and *pará* grass (*Panicum purpurascens*) and Guinea grass (*Panicum maximum*) on low ground. The best pastures are found in May and June after the floods have largely receded. By August, the mature grasses are dry and fibrous and are rejected by cattle. The grasses are burned, and new shoots appear promptly without benefit of rain. These grasses must last until the November rains; however, if the rains start late, there may be a second burning, but this invariably results in a poor wet-season growth. The critical periods for cattle are (1) the end of the dry season in September and October when forage is poor and water is scarce and (2) the periods of maximum flooding between January and March, which last from a few weeks to 2 or 3 months.

The annual floods limit the potential maximum number of cattle in the Llanos de Mojos rather than drought, poor forage, or disease (aftosa, rabies, brucellosis). Edible grasses and sedges are killed or submerged during periods of high flooding, and with the main exception of the water hyacinth (*Eichomia*), forage is only available on the scattered *islas*. If forested the *islas* may have very little forage and what there is may be trampled and destroyed by herds of cattle and also by wild animals.

During flooding, thousands of cattle die from starvation, drowning, or exhaustion while attempting to swim long distances between *islas*. Near the town of Santa Ana, some of the local ranches lost 80 percent of their stock in an unusually big flood in 1959. Even during the years with low floods, such as 1962, there is a high mortality of calves, and the calf loss from all causes exceeds 50 percent annually.

Little effort is made to drive cattle out of the low savannas to areas of high ground before the start of flooding. This is partly because of long distances to sizeable areas of high ground as well as the presence of dense forests in such areas. A few ranchers do maintain barges or boats for rescuing stranded cattle during flooding and for moving as many as possible to safe areas. Ranchers talk of using bulldozers to build artificial *islas* for cattle refuges although few have done so. Nor is anything done to provide supplemental feeding during flooding. Ranchers do their best to save their cattle after a big flood strikes, but the general attitude is one of lazy optimism that each year's flood will not be bad, and there is little preparation for potential disaster.

The Impact of Aviation

Beef has been flown directly out of the Mojos savannas to the cities of the Altiplano since the end of World War II when Bolivian meat companies began acquiring cheap war planes (B-17s and C-47s).[3] By 1952 meat cargos amounted to several million kilograms a year, and today beef from Mojos is not only the main source of meat for La Paz but is also important for Cochabamba and some mining centers. In 1960, 5200 of the 7500 tons of beef marketed in La Paz came from the Mojos savannas (La Patria 1961). Suddenly, nearly worthless cattle were valuable, and it was El Dorado all over again. Cattle were slaughtered regardless of age, sex, or quality as many ranchers rounded up all the cattle they could find, drove them to the nearest suitable landing field, sold everything, and left the Beni. Town officials in Loreto reported that 15 ranches in that area alone were abandoned in the 1950s. The sell-out-and-get-rich attitude of the ranchers is partly a lack of faith in the future of Bolivia's economy and in the security of land holdings, but it also reflects the old attitude toward cattle as a resource to be exploited for its immediate worth rather than as an industry based on sustained yields and improvement of stock.

The Beni is a unique example of an area where the economic benefits of a revolutionary improvement of transportation have thus far been largely outweighed by unfavorable side effects. Today most movement to, from, and within the Beni is by plane. This movement includes not only people and beef but also rubber, Brazil nuts, vegetables, hardwood lumber, and heavy machinery. As a result of the use of meat planes, cattle declined from over one million in 1952 to about 350,000 in 1962 (Victor Vargas Monasterio, Inspector Forestal del Beni, Trinidad, September 16, 1961, pers. comm.). This decrease partly represents losses from floods and increased disease, but mainly it results from the slaughter of cattle at a faster rate than new

[3] In 1946 the Bolivian Development Corporation began flying small amounts of beef from their ranch at Reyes to La Paz (Macaulay 1946).

cattle are being raised. Because of the decrease, many ranches have been abandoned, thus creating a rural depopulation as both ranchers and their workers have left for the highland cities or the Santa Cruz region.

In the Mojos savannas, meat is now too expensive for most local people, whereas formerly the poorest Indian family had several or could shoot cattle without fear of recrimination. Absentee ownership has increased as most owners now commute between town and ranch by bush plane. The large towns of the Beni, especially the capital, Trinidad, have increased in size and prosperity, but numerous small towns have deteriorated. Also, there has been a decline in both overland and water transport; oxcart and cattle trails are less used, and the large paddle-wheel steamers that once plied the Beni, Mamoré, and Guaporé rivers are now hulks rusting on the banks. The dominance of air transport can continue, despite high gasoline costs, as long as there are cheap airplanes and government subsidies available. Once these benefits come to an end, river transport and connecting roads will once more become important. Possibly by that time navigable waters of the Beni rivers will be connected by good roads to the highland cities.[4]

Conclusion

The history of cattle in northeastern Bolivia has been one of neglect, disinterest, and exploitation. These attitudes reflect the relatively minor economic importance that cattle long had due to the lack of a readily accessible market. However, cattle ranching has continued to be neglected and, in some respects, has declined since the booming of beef prices with the use of planes to fly meat to the highlands. Prosperity did not immediately result in major changes in traditional methods of raising cattle. The situation contrasts significantly with ranching in other New World savannas, most of which have not experienced extreme isolation. Ranching in these areas has been more progressive than in Mojos, and where some beef is now flown to market as in the Orinoco llanos, the overall effects have been favorable.

Recently, the Bolivian government, United States, and United Nations technicians and individual ranchers have been endeavoring to stabilize and modernize ranching in the Mojos savannas by introducing foreign breeding stock, artificial insemination, disease control, fencing, new pasture grasses, and experimental stations. By 1963, cattle ranching seemed to be recovering, or rather, true cattle ranching seemed to be developing and replacing what can be realistically described as the hunting of semi-wild cattle.

[4] Roads are planned which will eventually connect (1) Cochabamba with Puerto Villarroel on the Río Ichilo, the most navigable of the upper tributaries of the Río Mamoré; and (2) either Reyes or San Borja in the southwestern *llanos* with La Paz via the Alto Beni region.

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7.2 Livestock Numbers in Nineteenth-Century New Mexico, and the Problem of Gullying in the Southwest

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Abstract In the 1880s, intensive accelerated erosion began producing large gullies throughout the Southwestern United States. This modern arroyo cutting was originally attributed to deterioration of the protective vegetation cover because of below normal rainfall and overgrazing by excessive numbers of livestock (4,000,000 sheep in New Mexico in 1880). However, recent studies have stressed the greater importance of increased high intensity rainfall. Additional perspective is provided by an examination of livestock numbers in the upper Rio Grande region of New Mexico during the 19th century, particularly during the Mexican period when the ranges were heavily stocked with sheep (possibly 3,000,000 head in the 1820s), but with little or no gullying. The incomplete record of livestock numbers in relation to climate and gullying backs up the climatic argument but also gives some new support to the older view that overgrazing was a major contributive factor causing severe modern gullying.

Keywords Ranching · Rio Grande · Erosion · Overgrazing

[5] Grateful acknowledgment is made to the late Erhard Rostlund, in whose last seminar this study was first begun, and to Yi-Fu Tuan, Andrew H. Clark, James J. Parsons, and Ernst Antevs who made valuable comments on various drafts of the paper.

Introduction

The subject of arroyo cutting or gullying in the American Southwest, on which there is considerable literature, has recently received an excellent review by Tuan (1966). Modern (post mid-nineteenth century) gullies were initially attributed to accelerated erosion caused by overgrazing and consequent impairment of the vegetation cover. However, the discovery of prehistoric gullies has led to the formation of two different and conflicting theories: the Bryan-Antevs model associates arroyo cutting with drought and poor vegetation cover and arroyo filling with higher rainfall and an improved vegetation cover. The more recent Martin-Schoenwetter model, on the other hand, associates gullying with increased summer high-intensity rainfall when there may actually be a greater annual rainfall and an increased vegetation cover.[6]

On the basis of field work and historical studies of the Chaco, Puerco, and Tesuque canyons in New Mexico, Tuan presents evidence to support the Martin-Schoenwetter theory. In addition, Tuan points out that there is not as close a relation between modern arroyo cutting and overgrazing as had previously been thought. In some areas of New Mexico, gullying began before the rapid increase in sheep numbers in the 1870s (from 619,000 in 1870 to nearly 4000,000 by 1880).[7] Some gullies reached a state of equilibrium before conservation measures begun, and in other areas, gullying continued after conservation measures had been initiated. Also, modern gullies have been reported in areas where there apparently has been little or no grazing.[8]

An examination of livestock numbers, especially of sheep, in relation to vegetation, climate, and gullying in New Mexico prior to 1870 throws additional light on the suggested secondary role of overgrazing in causing accelerated gullying. The main purpose of this paper is to present evidence that the ranges of the upper Rio Grande region of New Mexico (Fig. 7.2) may have been nearly as heavily stocked, but without serious erosion, in the late Spanish-early Mexican period, as during the late nineteenth century when intensive and widespread gullying occurred.[9]

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[6] For a discussion of these two models and for references, see Tuan (1966, 583–584, footnote 2).

[7] Gordon (1883, 994) For 1880, 3,938,831 sheep and only 347,936 cattle were reported (includes entire Navaho Reservation stock); horses and mules were not reported.

[8] Dellenbaugh (1912), Gregory (1917, 132), and Peterson (1950, 421). Of interest would be a comparison of the history of erosion on the overgrazed and seriously eroded Navajo Reservation with that of the Apache Reservations where sheep and goat raising have not been important but climate generally has been comparable.

[9] The United States Department of Agriculture in 1937 reported that 75 percent of the drainage basin of the upper Rio Grande in New Mexico had experienced moderate to advanced accelerated erosion, and that "every large and practically every small valley of the watershed has been channeled from 50 to 100 percent of its length" by vertical-walled arroyos as much as 300 ft. wide and 30 or more ft. deep. See Cooperrider and Hendricks (1937, 2, 11–12).

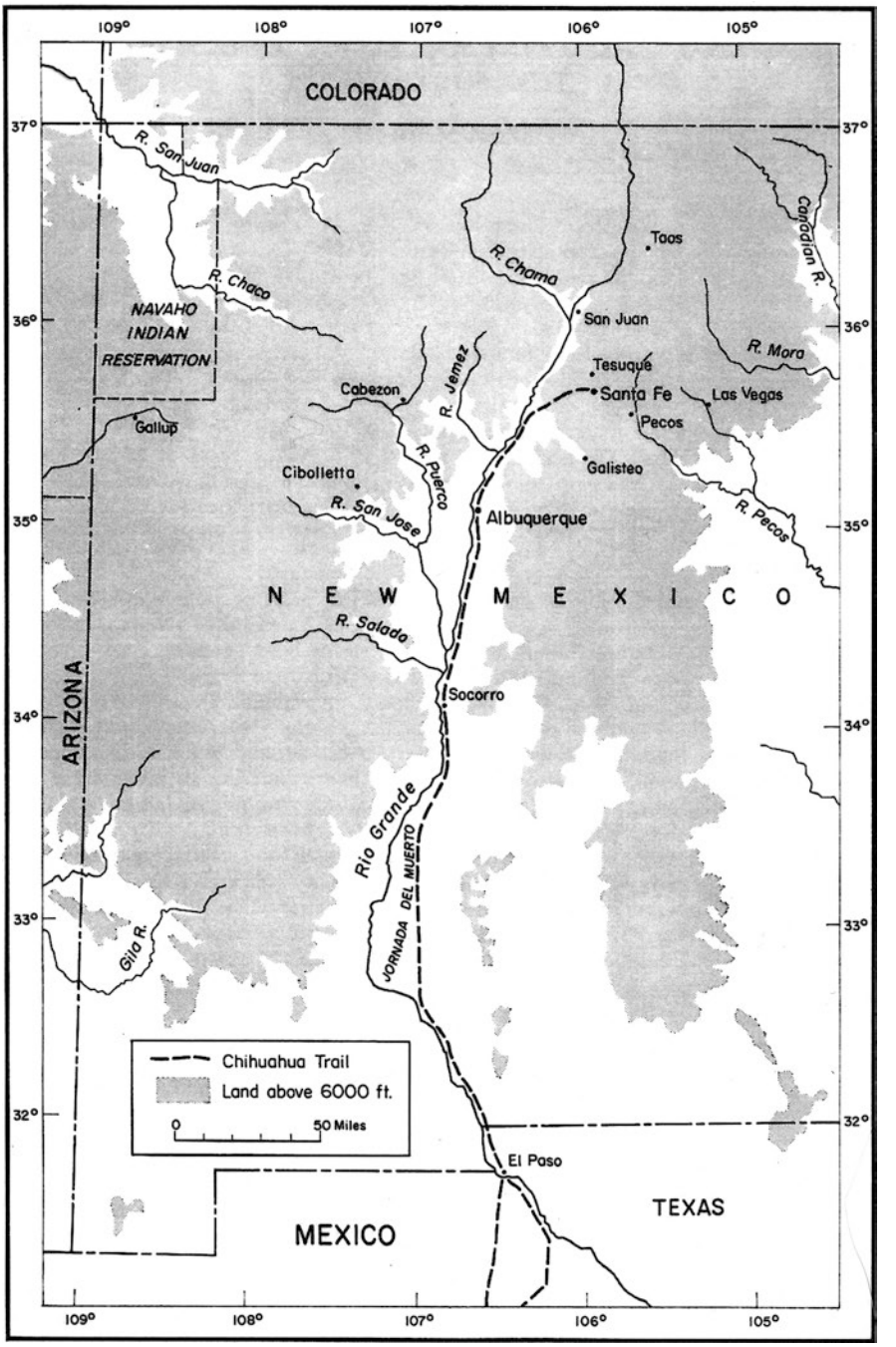

Fig. 7.2 Location map of the upper Rio Grande region of New Mexico

Modern Gullying[10]

Before proceeding to the history of sheep in New Mexico during the early to middle nineteenth century, it must be emphasized that there is evidence for only very localized gullying during the same period. Bryan dated arroyo cutting throughout the Southwest by examining early travelers' accounts and talking with old-time ranchers, and he was able to document a post-1880 initiation of severe erosion in most areas. A good example of the historical record of trenching of a stream channel is that for the Rio Chaco in northwestern New Mexico. Lt. J.H. Simpson on a military reconnaissance in 1849 wrote that "The Rio Chaco, near our camp, has a width of eight ft. and a depth of one and a half" (Simpson and McNitt 1964, 42). The channel in this area in 1925 was 20–30 ft. deep and 150–450 ft. wide. Channel trenching of the Tesuque Valley probably began about 1880, which is when accelerated erosion began in the nearby Santa Fe area (Miller and Wendorf 1958). Many other examples could be given (Bryan 1925; Thornthwaite et al. 1942, 102–104).

In all the Southwest, the only stream for which pre-1850 arroyo trenching is well documented is the Rio Puerco in New Mexico.[11] In crossing the Rio Puerco above Cabezon in 1849, Simpson reported the channel to be 30 ft. wide with vertical banks 20–30 ft. high, which had to be cut down so the Army could get its artillery across (Simpson and McNitt 1964, 29). This and other mentions of arroyos by Simpson and other travelers led Bryan, Leopold, and Tuan to conclude that discontinuous trenches existed before 1850 in many parts of the Rio Puerco Valley and its tributaries, but that they did not become continuous until after 1880.

Early American travelers reported that the plant cover in the Rio Puerco Valley in the 1840s was mostly poor (Leopold 1951a, 301–305). For example, Lt. J.W. Abert, who was with General Kearny in 1846, wrote that for the Rio Puerco 48 miles above its junction with the Rio Grande "... the valley, deep with sand, only nourishes artemisias, yucca, and cacti" (Abert 1962, 95). This was supposedly an excellent grazing area in the late eighteenth century, with 10,000 head of cattle and sheep in the 1760s and was the location of a much-disputed land grant (Twitchell 1914, 41–42). However, the Mexicans abandoned the upper Puerco in 1823 because of pressure from Navajo raiders and apparently no longer took their herds to the area (Bryan 1928). Abert wrote:

> At Albuquerque we were cautioned by people against the dangers we would run before reaching Cibolletta, as the war trail of the Navajos runs through the valley of the Puerco;

[10] Following the usage by Antevs, the words "arroyo" and "gully" are used here as geomorphic terms for wide, flat-floored and deep, vertical-walled channels, old as well as modern, in the southwestern United States. Desert washes, which are also flat floored and steep walled, differ from arroyos by being eroded mainly in gravel and independently of vegetation condition (Antevs 1952, 375).

[11] Leopold cited early travelers who reported gullies elsewhere in New Mexico and Arizona, but the descriptions are vague as to the size and nature of the gullies. Many, especially in New Mexico, apparently were desert washes rather than true arroyos (Leopold 1951a). For a description and history of the Rio Puerco Valley see Widdison (1959).

> and the Mexicans advised us to travel with great circumspection, and not to make any fires at night (1962, 73).

On the other hand, the Navajo themselves may have grazed their own large flocks in this area after 1823 and thereby maintained pressure on the plant cover. Quite possibly, however, the discontinuous gullying of the Puerco before 1850 was primarily associated with localized climatic conditions which favored trenching.

To what degree did extensive irrigation works retard accelerated runoff and erosion? Reagan suggested that many small irrigation diversion works on the tributary streams in the old Hopi Pueblo areas retarded for centuries what would otherwise have been rapid runoff (Reagan 1924, 283–285). The density of some of the areas of Hopi settlement is evidenced, for example, along Laguna Creek in Arizona where there are ruins of 202 villages. The Spaniards and Mexicans apparently irrigated much more than did the Indians, and their dams and diversions on the tributaries of the upper Rio Grande may have offset increased runoff caused by overgrazing. An estimated 30,000 acres of land were irrigated in the Rio Grande Valley prior to 1846 (Thomas 1948, 37). There are numerous references to the large irrigation systems around individual Mexican settlements; Abert, for example, related how he and his group got entangled in a labyrinth of water-filled irrigation canals (*acequias*) at the mouth of the Rio Jemez and required help to get out (Abert 1962, 71.[12] Whether either Indian or Spanish-Mexican diversion works alone, retarded arroyo cutting is questionable, but they may have had some effect and might be further studied with this in mind. Actually, it is more likely that abandonment of irrigation works did not precede and cause gully erosion but followed erosion. Cooperrider and Hendricks felt this to be true in the upper Rio Grande watershed where many irrigation works were abandoned in the 1890s (Cooperrider and Hendricks 1937, 14–18; Widdison 1959, 273–276). Bryan even concluded that Pueblo migrations in the fourteenth century were a result of the natural arroyo cutting of the late thirteenth century which destroyed the Indian methods of floodwater farming (Bryan 1941).

The lack of widespread gullying prior to 1870 has previously been assumed to be explainable by the absence of overgrazing and consequently a denser, protective vegetation cover, or by climatic conditions favoring alluviation rather than erosion. The historical evidence of livestock and vegetation conditions during the period 1788–1848 weakens the overgrazing argument. Nineteenth-century chroniclers and travelers in New Mexico reported individual herds and annual exports of sheep numbering in the hundreds of thousands, even millions, during the early part of the century when arroyo cutting was either absent or very localized. Of the many studies made of accelerated erosion and overgrazing in the Southwest, apparently none consider the possibility that the ranges may have been heavily stocked well before the period of severe modern gully erosion.

[12] For a good description of the Mexican irrigation systems in New Mexico see Davis (1857, 195–200).

The remainder of this paper will examine the evidence for large numbers of livestock in New Mexico before the American take over and then relates this evidence to the problem of gullying in the Southwest.

Sheep in Early New Mexico

Prior to the Civil War, the upper Rio Grande region of New Mexico contained far greater numbers of livestock, predominantly sheep, than any other part of southwestern North America, and the region is the major exception to the generalization that the southwestern ranges were not heavily stocked until about 1880. However, there were also some large ranches in parts of southern Arizona in the early nineteenth century, and the Navajos in Arizona and New Mexico had very large herds of sheep even before the tribe was defeated and placed in a reservation in 1868.[13]

The upper Rio Grande Valley lies mainly between 4000- and 7000-ft. elevation and is fringed on the north, west, and east by mountains rising to between 8000 and 14,000 ft. On the margins of the valley, however, there are wide plains, tablelands, and tributary valleys. The climate is semi-arid with generally between 10 and 20 in. of rainfall, but there is considerable variation from year to year and from area to area. The vegetation consists mainly of grasses and xerophytic shrubs.

Almost all the Spanish and Mexican settlements in New Mexico were confined to the Rio Grande basin, mainly between Taos in the north and Socorro in the south. Most of the towns were near the Rio Grande and were linked together by the Camino Real or Chihuahua Trail leading into Mexico. Hostile Indians hampered occupation of the upland valleys to the east and west and to the south lay desert – the Jornada del Muerto. Numerous towns or inhabited places were founded before New Mexico became a part of the United States in 1848, the first being San Gabriel (later San Juan) which was established by Juan de Oñate in 1598. Many of the early settlements, which included missions and large haciendas, were short-lived, but some still exist.

The years 1788–1848, which include the closing years of Spanish rule and the period of Mexican control of New Mexico, saw a great flourishing of the sheep industry in New Mexico. Sheep were brought into the region in 1598 by Oñate and thereafter multiplied in the missions and then dominated the *ranchero* economy after the missions declined at the end of the eighteenth century.[14] However, almost continual warfare with the Pueblo, Navajo, Apache, and Comanche Indians kept

[13] Large sheep haciendas around Tucson and Tubac, broken up by Apaches in the 1830s, were mentioned by Haskett (1936, 9). The Navahos were reported to have had 500,000 head of sheep in 1846, mainly in large herds, according to Luomala (1938, 56); based on an Indian Bureau Report. There were 30,000 sheep in the Hopi pueblos as early as 1779, according to Father Escalante as reported by Towne and Wentworth (1945, 163).

[14] At least three-fourths of the New Mexicans derived part or all of their income directly or indirectly from sheep in the view of historian Hallenbeck (1950, 299).

New Mexico in constant turmoil that prevented large-scale ranching, except locally, for much of the time until after the Civil War. A brief golden age of relative peace and prosperity followed the governorship of Juan Bautista de Anza, 1778–1788, when the main hostile Indian groups were subdued. Anza's successor, Fernando de la Concha, was very interested in promoting the raising of sheep as evidenced by correspondence in 1789 requesting that the exporting and slaughtering of female sheep be prohibited in order to increase the size of the small New Mexican herds (Bloom 1927).

With substantial military protection, there was less danger from Indians on the open range, and sheep numbers greatly increased from 1788 until Mexican independence in 1821. The Mexican government, however, was not able to give adequate military support to the New Mexican settlements; the Indians again became uncontrollable, and partly as a result, sheep raising began to decline by the 1830s.[15] A low point was reached after the United States took over New Mexico in 1848.[16]Apaches and Navajos dominated the ranges and stole tens of thousands of sheep until defeated by the US Army after the Civil War. Then, following the entry of railroads into the West, sheep numbers in New Mexico boomed from several hundred thousand to a peak of between four and five million in the 1880s.

The soil erosion survey by Cooperrider and Hendricks mentioned only one figure for livestock numbers in the vicinity of the upper Rio Grande settlements during the Spanish and Mexican periods. This is 240,000 sheep and goats in 1827. The following comment was made:

> such large numbers of animals, if the ranges adequately supported them, indicate a higher grazing capacity and a vastly better condition of the ranges close to these settlements during the early years of the nineteenth century than now exist (Cooperrider and Hendricks 1937, 28).

There is evidence, however, that there were far more than sheep in New Mexico at times during the early nineteenth century. The figure of 240,00 sheep in New Mexico comes from a livestock census included in a report in 1849 by Don José Escudero, a lawyer and statistician. But Escudero made the further comment that:

> …we can assert without doubt that even this document has not set forth the real rural wealth of New Mexico. It would be curious and extremely interesting to have before us a report of the numerous herds of sheep which annually have gone out of New Mexico for cities as far distant as Mexico City, and which still continue to go out in spite of the small price they bring (Carroll and Haggard 1942, 40).

At the other extreme, the historian Hallenbeck recently estimated that:

> … the average sheep population of New Mexico during the period 1790 to 1820 was about 3,000,000 head, with an annual increase of some 800,000 to be slaughtered or sold outside the province (Hallenbeck 1950, 299).

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[15] After 1830, "the herds declined eighty percent," according to historian Fergusson (1936, 104). Also, Gregg (1954, 134–135) and Abert (1962, 52).

[16] There were 380,000 sheep in New Mexico in 1850 and 830,000 in 1860, on the basis of official counts and estimates according to Coan (1925, 365).

My efforts to verify such a large figure, or any other figure, have only been partly successful. In original sources, there are just a few mentions of livestock numbers, and these vary greatly and are generally incomplete. Many secondary sources fail to give adequate references. For example, several writers on both the history of New Mexico and the history of sheep in America refer to the statement by Charles Lummis of Governor Bartolomé Baca owning 2,000,000 sheep and Governor Francisco Chávez owning 1,000,000 sheep during the early Mexican period (Lummis 1893, 19). Lummis, however, writing in the 1880s, gave no sources and was probably passing on local, possibly exaggerated tradition. The evidence for large numbers of sheep in New Mexico in the first half of the nineteenth century is mainly in the form of contemporary estimates. The strength of this evidence lies in the relatively large number of known estimates rather than in the accuracy of any particular one or in the reliability of any particular source.

During the Spanish and Mexican periods, there was, surprisingly, little mention of stock numbers in New Mexico by local writers. There were, however, many general references to the importance of sheep raising. For example, in 1832 the Mexican official Don Antonio Barreiro wrote:

> The thousands of sheep raised in this territory have no parallel anywhere else in the republic. This livestock increases from day to day in an incredible manner (Carroll and Haggard 1942, 103).

Most of the early livestock estimates available are from accounts by American travelers and are for the Mexican period from 1821 to 1848. The estimates can be grouped into three categories: (1) holdings by single owners, generally wealthy families referred to as *ricos*; (2) exports to Mexico and California; and (3) Indian thefts.

The first detailed description of New Mexico by an American, that of Z.M. Pike in 1807, tells us little about the Spanish economy but does report a single herd of 20,000 sheep (Pike 1889, 263). Herds of 80,000 in 1825 were mentioned in an account of the travels of a Dr. Willard, and herds of 40,000 were reported by Abert.[17] Of possibly greater reliability are the comments by J. Gregg who spent considerable time in New Mexico between 1831 and 1839. He noted that: [18]

> Nothing, perhaps, has been more systematically attended to in New Mexico than the raising of sheep. When the territory was at the zenith of its prosperity, *ranchos* were to be met with upon the borders of every stream, and in the vicinity of every mountain where water was to be had … in former times there were extensive proprietors who had their *ranchos* scattered

[17] Anonymous (1962, 242): "where farmers have six or eight thousand horses or mules, forty thousand cattle, and twice as many sheep." This is the only mention encountered of sizable numbers of other livestock besides sheep. For New Mexico as a whole, for most of the nineteenth century, sheep probably comprised 80–90 percent of the livestock total, in contrast to less than 50 percent in 1965; Abert (1962, 52).

[18] Gregg (1954, 133–334). A single proprietor owning "as many as three hundred thousand sheep" in the 1830s was mentioned by Davis (1857, 204); the source probably was Gregg, although Davis did live in New Mexico himself for several years.

> over half the province, in some cases amounting to from three to five hundred thousand head of sheep (Gregg 1954, 133–134).

Sheep on the hoof and wool products were the principal items of trade with Mexico. For over 200 years, commerce over the Chihuahua Trail was considerable and much more important for New Mexico than was the much-publicized activity on the Santa Fe Trail. Each fall, and sometimes also in the spring, large caravans or *conductus* left Albuquerque and Santa Fe for Chihuahua and Sonora. Often over 1000 people were involved as well as an armed escort and large numbers of loaded wagons and livestock. For the New Mexicans, this was the big event of the year, the only social and commercial contact with the outside world. Commercial records for these *conductas* should give an indication of sheep numbers in early New Mexico, but apparently few such records still exist. Moorhead, who has made a study of the Chihuahua Trail, recognized that the chief trade items were wool blankets and sheep, but the only official figure presented from the Spanish and Mexican archives is a report by Governor Chacón of a drive of 18,784 sheep from Santa Fe to Chihuahua in 1800 (Moorhead 1958, 45). In 1803, Governor Chacón reported that from 25,000 to 26,000 sheep were driven annually to (Nueva) Vizcaya (Bloom 1927, footnote 33). For the same period, Pike mentioned a single drive of 15,000 sheep to Mexico (1807) and an annual total of 30,000 to Mexico City, Biscay (Nueva Vizcaya), Sonora, and Sinaloa (Pike 1895, 305). Much larger totals, however, were reported in later years.

Gregg wrote in 1844 that:

> Between ten and twenty years ago, about 200,000 head were annually driven to the southern markets; indeed, it is that, during the most flourishing times, as many 500,000 were exported in one year (Gregg 1954, 133–134).[19]

Support is given to such large exports in the 1880 census where there are references to the son of Colonel Manuel Chávez saying that his father in 1839 took 75,000 sheep to Mexico and other ranchers a total of 225,000 and to people who "popularly reported" that in 1840 500,000 sheep were taken to Mexico, including 300,000 by one owner (Gordon 1883, 989). Such large numbers, if correct, probably could not have been taken south in the one or two annual *conductas*. Hallenbeck maintained that only a few sheep were ever taken on the annual *conductus* since the sheep traveled too slowly. He said that the total of 300,000 in 1839 was broken down into numerous herds of about 15,000 each (Hallenbeck 1950, 313).[20] This seems reasonable, and Indians seldom attacked movements of such size.

Further evidence of large numbers of sheep in early New Mexico comes from estimates in the 1880 census of 551,000 head of sheep being exported to California between 1852 and 1857, including 200,000 in 1856 (Gordon 1883, 992). Another

[19] Also, see Davis (1857, 204); again, his source was probably Gregg.

[20] Hallenbeck (1950, 313); no sources given. A contemporary report (1832) of the size of sheep drives into Mexico was provided by Don Antonio Barreiro: "There are some men who have contracts in Durango to deliver annually fifteen thousand sheep …"; Carroll and Haggard (1942, 109).

estimate gave a total of 376,000 in 1858.[21] In 1854, the US Boundary Commissioner John Bartlett, on the basis of reports by Assistant US Marshals, stated that Indians had stolen 450,000 head of sheep from the Rio Grande settlements between 1846 and 1850 (Bartlett 1854, 385–386). All of these figures are for a period in New Mexico when livestock raising was supposedly at its lowest ebb.

The Navajos and Apaches stole a great number of sheep from the Mexican and New Mexican ranchers. A typical example of their impact was given by Abert in 1846:

> This morning we received notice of an incursion of the Navajos, a few miles below us [south of Albuquerque]. The *pastores* left their flocks and fled, while a large body of Indians, rushing down from the mountains, where they had secreted themselves during the night, devastated the whole valley, killing all the human kind they met, and sweeping off the flocks and herds of the Mexicans. No less than 5,000 sheep were carried off within twenty miles of the great city of Albuquerque (Abert 1962, 96).

Gregg also had an interesting comment on the sheep raiding activities of the Indians:

> Indeed, the Indians have been heard to observe, that they would long before this have destroyed every sheep in the country, but that they prefer leaving a few behind for breeding purposes, in order that their Mexican shepherds may raise them new supplies (Gregg 1954, 135)!

The well-documented hostility and sheep raiding activities of the Indians have led several recent writers to assume that livestock in New Mexico was kept close to the settlements, and therefore, that livestock numbers were never large in early New Mexico. Leopold in his vegetation study of Southwestern watersheds in the nineteenth century said that "--- until well past the middle of the nineteenth century extensive grazing had been prevented by frequent raids of hostile Indians" (Leopold 1951a, 295). Cooperrider and Hendricks (1937, 29) wrote that "frequent raids of marauding plains lndians restricted the areas on which the flocks could graze with safety".

If such restrictions were really severe, then there could not have been very large numbers of sheep in New Mexico. However, stock numbers undoubtedly fluctuated greatly from time to time, increasing when more peaceful Indian relations allowed movement onto the interior ranges. The Indians were much less of a problem in the late Spanish and early Mexican periods than they were after about 1830; nevertheless, there are numerous counts of herds seen far from settlements by American travelers even in the 1830s and 1840s when the Navajos were particularly troublesome. Abert in 1846 reported large flocks of sheep, cattle, horses, and goats between the Moro (Mora) and Pecos rivers well to the east of Santa Fe (Abert 1962, 37–41). Gregg, for the 1830s, wrote:

> Even upon the arid and desert plains, and many miles away from brook or pond, immense flocks were driven out to pasture and only taken to water once in two or three days (Gregg 1954, 133).

[21] Richardson and Rister (1934, 371); no source given; Gordon (1883, 992) however, said that the export of sheep from New Mexico to the Pacific Coast was terminated in 1858.

Furthermore, the Indians seldom dared to attack the main settlements and large ranches, so the large numbers of stock they stole must have been obtained mainly from Mexican herds on the open range.

How many sheep, then, were there in New Mexico at their most flourishing times between 1788 and 1848? Figures range from 240,000 in 1827, the only official total, but a discredited one, to the undocumented 3,000,000 estimated by Hallenback as the annual average from 1790 to 1820. Reported sizes of individual holdings range up to 2,000,000 given by Lummis, and reports of annual exports to Mexico vary from 30,000 in 1803 according to Pike to 200,000 to 5,00,000 given by Gregg and others for the Mexican period. In this writer's opinion, the evidence for peak numbers approaching 3,000,000 in the 1820s seems to be good. Additional support comes from the tenth US Census in 1880, in which there is an excellent report on livestock by Gordon, who made a detailed survey of the range in New Mexico in order to describe forage and water and stock numbers by county. Many people who were alive or whose parents were alive during the Mexican period were interviewed, and on this basis Gordon stated that:

> … the tradition is that importations with the different settlers and the natural increase had fully stocked the present New Mexico with sheep long before 1800, and that stock numbered as many from 1825 to 1835 as in 1880 [nearly 4,000,000] (Gordon 1883, 986).

The available evidence, admittedly based mainly on estimates and tradition prior to 1850, suggests that for New Mexico there was a general increase of sheep to between two and three million between 1820 and 1835, a general decrease associated with greater Indian hostility from about 1835–1850 (380,000), then a slight increase until 1870 619,000, and then a very rapid increase until 1880 (3,938,831). The peak number of sheep in New Mexico reached possibly 5,000,000 in the late 1880s, but the total has subsequently been well under 4,000,000 partly because of extensive range deterioration and partly because of much larger numbers of cattle.[22]

Most of the New Mexican sheep were owned by a few *ricos* who divided their herds into flocks of several thousand and ranged them over large areas. The main pre-1848 concentrations seemed to have been in the area Of the Rio San Jose and lower Rio Puerco, around Albuquerque, and the area between Santa Fe and Calisteo. These were still important ranges in 1880; however, with the Indians under military control, many herds were taken into the more remote plateaus and mountain valleys in the northeast and northwest (Gordon 1883, 986–992). The New Mexican ranges were clearly heavily stocked in the 1880s, and livestock numbers at that time were significantly greater than the estimated 2,000,000–3,000,000 sheep during the early Mexican period. In the 1880s, however, sheep were grazed over a much larger area than they generally were prior to the Civil War, and consequently, the grazing pressure in terms of sheep per unit of land probably was as great, although less extensive, in the earlier period as it was during the period of accelerated erosion in the 1880s and after.

[22] In 1965 there were 969,000 sheep, 1,106,000 cattle, and 43,000 horses and mules in New Mexico according to the U.S. Department of Commerce (1965, 674).

Were there really several million head of sheep in New Mexico for much of the period between 1788 and 1848? The variety of evidence presented here suggests that there were, but the evidence is mainly in the form of unreliable estimates and is not conclusive. Probably, the only means of further verification would be from a thorough examination of the Spanish and Mexican Archives of New Mexico and northern Mexico, which heretofore have revealed very little data on sheep numbers.[23]

Grazing Pressure

The years of high livestock numbers during the early nineteenth century were not necessarily years of overgrazing and vegetation deterioration which might have contributed to heavy runoff and gullying. Range condition, or carrying capacity, at a given time varies with rainfall, history of previous use, kind of management, and type of animals. In general, a higher range carrying capacity could be expected in the 1820s and 1830s when rainfall was above normal than during the 1870s and 1880s when rainfall was below normal. Locally, of course, there may have been greater or lesser grazing pressure during any given period. Hence, the desirability of examining the history of specific valleys. Unfortunately, localized rainfall, livestock, and vegetation data are lacking for individual valleys for most of the nineteenth century.

How much were livestock restricted in early New Mexico? Unrestricted grazing on the open range is generally much less detrimental to the vegetation cover than is grazing of stock in fenced-in or otherwise limited areas. A good example of this is the situation on the Navajo lands in northwest New Mexico and northeast Arizona. In 1846, the Navajos were reported to have had about 500,000 head of sheep, mainly in large herds ranging over vast areas. After the Navajos were defeated and placed on a reservation in 1868, each individual was given two sheep, for a total of about 15,000. The new pattern was one of thousands of small family herds, all with restricted ranges. Sheep and goats increased to 700,000 by 1880 (Underhill 1956, 163),[24] which was not too many more than in 1846, but the range damage that occurred after 1880 was tremendous and was probably more a result of many small restricted herds than the total number of stock on the reservation ranges. In the Rio Grande Valley, however, there was no such restriction in 1880,

[23] The periodic reports of the different Spanish governors contain some data on sheep numbers and sheep exports to Mexico, as in the previously mentioned reports of Governor Chacón for 1800 and 1803. Twitchell (1914, Vols. 1, 2) lists and describes documents in the Spanish Archives of New Mexico, but there is no indication of significant data on sheep numbers. The possibility of finding official data on sheep during the critical Mexican period seems unpromising. Also, unfortunately, the United States commercial agents in Santa Fe apparently never reported on such matters as livestock (M.L. Moorhead, pers. comm.).

[24] Underhill (1956, 163). Navaho sheep numbers reached a peak of 1,370,554 in 1931 according to Luomala (1938, 57).

except for some fencing by new American cattlemen in Colfax County in the northeast.

The 1880 census reports that most of the sheep herds were still in the hands of a few Mexican families who ranged their stock widely over the state (Gordon 1883, 992). Actually, there seems to have been much more restriction and concentration of livestock in New Mexico before 1848, because of hostile Indians, than there was during the first decades after the Civil War.

Was the grazing pressure exerted by sheep and cattle in the Southwest in the nineteenth century actually significantly greater than the pressure exerted earlier by native grazing fauna? There were vast numbers of pronghorn antelope and also buffalo, deer, elk, and other herbivores which may well have equaled or surpassed the peak domesticated stock numerically.[25] On the other hand, grazing pressure by sheep, in particular, is much greater than that of wild game. Furthermore, people interfere with the natural safety valves of migration and large-scale die-off by limiting movement, by supplementary feeding, and by destruction of predators. However, until it is demonstrated otherwise, we must grant the possibility that long before European livestock appeared in the Southwest there was periodic overgrazing by wild animals which may have contributed to excessive runoff and, as result, gullying.

Vegetation Cover and Climate during the Nineteenth Century

If, as the above evidence suggests, much of New Mexico was nearly as heavily stocked in the 1820s as in the 1880s, with little arroyo cutting in the earlier period, then strong support would be given to arguments that rainfall conditions were very important factors in causing the arroyo cutting that began in the 1880s. The vegetation and climatic conditions that preceded and accompanied the recent accelerated erosion therefore need to be placed in contrast with climate and associated vegetation cover and arroyo conditions earlier in the nineteenth century.

In view of the intense overgrazing and range deterioration in the latter part of the nineteenth century throughout the Southwest, many people have assumed that vegetation conditions were uniformly better in the middle of the century and before. L.B. Leopold, however, maintained that this is an unwarranted assumption. On the basis of examinations of a large number of diaries and field notes of members of early American exploring parties, he concluded that in Arizona and New Mexico a good vegetation cover "was originally attained only in selected localities," particularly southeastern and southcentral Arizona and southwestern New Mexico (Leopold 1951a, 295). For the upper Rio Grande basin, poor grazing was reported for the most part, but some sections of the Rio Puerco Valley were good. Leopold suggested that "even before 1850, climatic factors had already initiated a tendency toward decreased vegetation" (Leopold 1951a, 305). During the 1840s, when most of the reports were made, rainfall was subnormal; furthermore, whereas sheep numbers declined considerably in the 1840s and 1850s, the poverty of the vegetation

[25] For a discussion of this theme for the Great Plains and for pertinent references, see Clark (1956).

might be partly explained by failure to recover from overgrazing in the 1820s and 1830s.[26] Vegetation descriptions before 1840 are generally much more enthusiastic than later ones. For example, Antonio Barreiro in 1832 said that "for the most part [the country] is composed of immense plains and delightful valleys covered with extremely abundant pasture" (Carroll and Haggard 1942, 21). However, some consideration must be given to the tendency of Spaniards and Mexicans from semi-arid environments to be more favorably impressed by the vegetation of New Mexico than were Americans from the humid East.[27]

Although the character of the vegetation cover of New Mexico at different periods of the nineteenth century is not completely clear, the general climatic sequence is fairly distinct. For the upper Rio Grande region, there are incomplete climatic records back to 1850 for several towns, including Albuquerque, Las Vegas, Santa Fe, and Socorro.[28] Prior to 1850, the best evidence is from dendrochronology studies which provide sequences of relative precipitation for a large number of sites throughout the Southwest.[29] For the Southwest as a whole, rainfall was subnormal for most of the second half of the nineteenth century. The New Mexican stations recorded well below average rainfall for 14 out of the 17 years between 1857 and 1873, followed by short periods of high intensity rainfall (especially 1876 and 1878), as well as several dry years (especially 1879, 1880, 1882, and 1889).[30]

There was also a marked drought in New Mexico from the mid-l840s to the early 1850s, followed by a large number of heavy rain storms between 1859 and 1856,[31] but with little or no accelerated erosion reported; sheep numbers were very low at this time. From the mid-1820s to the early 1840s, rainfall was above normal, and vegetation conditions were reported good. Livestock numbers were high, but there was little or no arroyo cutting.

Moving further back into the early nineteenth century, the relationships in New Mexico are less clear. Tree ring growth indicates near normal rainfall from 1790 to 1817; however, there was below normal rainfall from 1818 to 1823 (except for 1821), and apparently there were large numbers of sheep by the end of this period, On the other hand, this drought does not seem to have been prolonged or intense,

[26] The causes of reported poor stands of grass between 1843 and 1881 were poor soils, locally dry climates, and overgrazing, in the opinion of Antevs (1952, 378). In areas heavily grazed in the 1880s and after, recovery of the vegetation has often been quite slow, even where there has been protection and adequate rainfall.

[27] For a discussion of this theme, see Tuan and Everard (1964, 271–274).

[28] U.S. Weather Bureau, USDA (1932–1933, sections 27, 28, 29). Also, see Thornthwaite et al. (1942, footnote 10, figures 14 and 15).

[29] See Schulman (1956, especially figure 34) and Fritts et al. (1964, especially figures 8 and 9).

[30] For long-term stations in New Mexico, Leopold pointed out a significantly greater number of heavy rains in the second half of the nineteenth century than during the first half of the twentieth century (Leopold 1951b, 350). Following Leopold, high intensity rains are those with 1.00 inch or more of rain in 24 hours, and moderate intensity rains are those with 0.50–0.99 inch in 24 hours.

[31] Of the ninety maximum 24-hour storms at Santa Fe from 1849 to 1938, seventeen occurred from 1853 to 1856, sixteen in the 1770s, and only five in the 1880s (Thornthwaite et al. 1942, footnote 10, figure 14).

and Mexican livestock numbers probably did not reach their maximum until the following 10 years when rainfall was well above normal. Actually, judging from tree ring growth, none of the droughts of the nineteenth century appear to have been severe compared with those of earlier centuries such as the "great drought" of the thirteenth century, which some authorities have associated with major arroyo cutting.

The nineteenth century pattern that emerges, then, is one of:

1. Higher than average rainfall and high livestock numbers, with little or no arroyo cutting
2. Drought and low livestock numbers, with little or no arroyo cutting
3. High intensity rainfall, low livestock numbers, and little or no erosion
4. Drought followed by several years of heavier than average summer storms, high livestock numbers, a probably weakened vegetation cover, and intense arroyo cutting

Obviously, with adequate rainfall, the vegetation cover in a semi-arid region may be sufficiently improved that it can support considerable grazing pressure without being so damaged that severe sheet erosion occurs. However, the same vegetation cover may be of little value in preventing gullying during periods of high intensity rains with large and rapid runoff. But with vegetation cover impaired by drought or overgrazing, even greater runoff and gullying could be expected from heavy rains or only moderate rains.

The lack of widespread gullying in the mid-1850s, in spite of preceding drought and in spite of even more frequent high intensity rains than in the 1880s, might be explained by the lack of grazing pressure on the vegetation in the 1850s. If so, then the gullying of the 1880s could be as caused by a combination of overgrazing and climatic conditions. Furthermore, in the 1820s, moderate and high intensity rains must have been infrequent. Therefore, if prehistoric gullying is to be explained by an increase in high intensity summer rains, as suggested by the Martin-Schoenwetter model, then such rains were probably more intense and more frequent than the heavier rains of the second half of the nineteenth century. However, these are very tentative conclusions in view of the availability of quantitative rainfall data for only a few stations prior to 1880 and for none before 1850. Also, no consideration has been given to the little studied possibility of a lag between the time of occurrence of gully initiating events and the actual time of rapid enlargement of gullies.

Conclusion

Formerly, it was generally agreed that neither the drought nor the heavy storms of the post-Civil war period were intense enough alone to have caused the severe arroyo cutting which occurred (Thornthwaite et al. 1942, 46; Antevs 1952, 384). However, recent studies, especially those stressing the importance of high intensity rainfall, seem to minimize the role of overgrazing. The livestock record presented

here backs up the climatic argument but also gives some new support to the impoverished vegetation theory.

In spite of the apparent large numbers of sheep in New Mexico before 1850, arroyo cutting did not widely occur, in contrast to the situation in the 1880s. Additional backing is thus given to arguments that climatic conditions were responsible for modern gullying. There is no conflict with either of the climatic theories previously mentioned. The lack of gullying in the 1820s and 1830s when sheep numbers were relatively high can be attributed to higher than average annual rainfall and a vegetation cover that was in substantially better overall condition than it was in the 1880s when overstocking followed a period of subnormal rainfall. In other words, modern gullying may have been the result of more frequent high intensity summer rains, as suggested by the Martin-Schoenwetter model and supported by Tuan's evidence. Actually, all three factors of overgrazing, drought, and high intensity rainfall were to some extent operative and influential in the intensive gullying that took place in the latter part of the nineteenth century. If volume of runoff is the most critical factor, then certainly the state of the vegetation cover, which may be strongly influenced by both grazing pressure and rainfall, is important for its ability to retard or accelerate runoff. The lack of major gullying in the 1850s, when there were both below average rainfall and numerous high intensity storms, but when livestock numbers were very low, would suggest that the similar climatic conditions in the 1870s–1880s would not have caused gullying or at least severe gullying, without the aid of an impoverished vegetation cover caused by overgrazing by large numbers of livestock. Storms of only moderate intensity were probably much more damaging than they would have been otherwise.

As is so often true, modifications of the physical environment involve a number of complex natural and human factors. However, besides recognizing and describing these factors, every effort should be made to place them in proper perspective as to the major or minor roles they play, and geographers should be particularly concerned with sorting out man's role.

Examinations of the historical evidence of climate, vegetation, and gullying by Bryan, Thornthwaite, Antevs, Martin, Schoenwetter, Leopold, Tuan, and others have led to changing theories emphasizing overgrazing, or drought, or high intensity rains. The added perspective of livestock population history, uncertain as it is, suggests that probably neither one factor alone nor another but rather the combination of certain climatic events and overgrazing by livestock brought about severe modern gullying in the American southwest.

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