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Recognizing History in Range Ecology: 100 Years of Science and Management on the Santa Rita Experimental Range

Abstract: At the centennial of the Santa Rita Experimental Range, historical analysis is called for on two levels. First, as a major site in the history *of* range ecology, the Santa Rita illuminates past successes and failures in science and management and the ways in which larger social, economic, and political factors have shaped scientific research. Second, with the turn away from equilibrium-based models in range science—a turn prompted in part by research at the Santa Rita—there is a growing need for history *in* range ecology itself. I discuss the needs, premises, and events underlying establishment of the Santa Rita in 1903. Then I examine the evolution of research and management recommendations through four major periods from 1901 to 1988, and I discuss the land swap that transferred the Santa Rita to State ownership in 1988 to 1991. Finally, I consider what effects the Santa Rita has had on rangelands and range management in the region. I argue that a static conception of the carrying capacity of Southwestern rangelands was imposed for economic and political reasons, over the objections or reservations of early range scientists at the Santa Rita, and that this may have contributed both to range depletion and to rancorous relations between public agencies and private ranchers in the twentieth century. To meet society's current demands on rangelands, the long-term, large-scale data assembled from the Santa Rita will be critically important.

Keywords: range science, range ecology, history, carrying capacity, mesquite, Frederic Clements, semiarid rangelands

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Introduction

The Santa Rita Experimental Range is 100 years old this year, providing an occasion to celebrate and to reflect. The first of many experimental ranges in the United States, the Santa Rita was founded at a time when both range science and plant ecology were in their infancy. The purpose was to conduct research that would aid in the management of Southwestern rangelands by public agencies and private ranchers, in the belief that science, coordinated by public agencies and conducted on a suitably large scale, would produce methods of restoring and conserving the vast and severely degraded rangelands of the region more quickly and effectively than a private, trial-and-error approach could. Confidence in the ability of government science to solve pressing public problems was characteristic of the era, giving birth not only to the Santa Rita but also to range science more generally and to an array of Federal agencies.

To assess a century of work on the Santa Rita, at least two questions must be answered: (1) What happened on the experimental range itself, in terms of research and recommendations for management? And (2) what effects did this work have on rangelands in the region? The historical record is abundant regarding the first question, but comparatively thin as to the second. I begin by reviewing the circumstances surrounding the creation of the Santa Rita Experimental Range. Then I use the more than 400 publications produced from the Santa Rita to define four major periods of research from 1901

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to 1988. Within each period, I examine selected documents—some published, some unpublished—to trace the evolution of research questions and management recommendations. Then I briefly discuss the period since 1988, when ownership of the range changed from Federal to Sate. Finally, I examine the evidence regarding actual management and range conditions over the past 100 years. Although the degree of influence of the Santa Rita is difficult to determine in detail, several themes and possible lessons for the future emerge nevertheless.

The overarching thesis of my argument is that a century of research at the Santa Rita indicates the need for historical analysis both *of* and *in* range ecology. Understanding the history *of* range ecology is important for the same reasons as in any discipline: to learn from past failures and successes, to recognize intellectual antecedents, and to enable critical reflection on our own ideas and practices. The history of the Santa Rita reveals that while the methods and emphases of research changed to reflect accumulating knowledge, the central questions and many management recommendations remained surprisingly consistent until very recently; it also suggests that institutional and political factors have been as important as scientific or ecological ones in shaping the knowledge that researchers produce. The importance of history *in* range ecology emerges from what has been learned in the past century, both at the Santa Rita and in other arid and semiarid settings. Whereas equilibrium-based ecological theory allowed most past researchers to neglect historical questions, current theories emphasize the potential of nonstationary climate and discrete events, interacting at various spatial and temporal scales, to cause significant and lasting ecological change. Today, with the larger social, political, and economic contexts of range management dramatically different from a century ago, there is a need both to recognize and to re-cognize history, so that the changes of the past can be properly understood and the challenges of the present and future effectively confronted.

Beginnings: Founding a Range Research Reserve

Nineteen hundred and three was the fifth year of a 6-year drought in southern Arizona. The boom and bust cycles of markets and rainfall were already painfully familiar to both ranchers and public officials in the area. Just 10 years before, the drought of 1891 to 1893 had killed scores of thousands of cattle and wiped out countless ranchers. That drought, more than the one from 1898 to 1904, helped to set in motion the factors that would eventuate in the Santa Rita Experimental Range. But it was not the only, or the first, factor.

The Hatch Act of 1887 authorized State and territorial governments to receive Federal funding for agricultural experiment stations. Lacking other resources, the University of Arizona took advantage of Hatch Act funds beginning in 1890, using them to cover operating expenses and salaries as well as agricultural research (Webb 2002: 80). A year later the Arizona Agricultural Experiment Station published its Bulletin number 2, comprising two short articles by J. W. Toumey (1890): "Arizona Range Grasses in General" and "Overstocking the Range." The latter article contained a prescient warning. In the open range, Toumey wrote (1890: 7):

> ...even the hardiest grasses when continually eaten close to the ground will, as a rule, in a few years become extinct... [W]here drought and overstocking both combine, and the grass that does not burn out from the effects of the hot sun, is continually eaten close to the ground by hungry cattle, the range is in poor condition to produce feed for the following season. The repetition of this process year after year cannot help but decrease the supply of grasses on the range.

By the time the drought broke in late summer 1893, an estimated 50 to 75 percent of southern Arizona's cattle had perished from lack of feed or water. Photographs from the time bear out Toumey's most dire scenario (fig. 1).

The undeniable ecological and economic damage of the drought helped get the attention of Congress, which in 1895 appropriated the first Federal funding expressly for range research. In the Texas high plains, Jared Smith and H. L. Bentley arranged to fence two sections of rangeland

Figure 1—Photograph taken by George Roskruge, surveyor for the General Land Office, at an unidentified southeastern Arizona location in the summer of 1891. Heavy, unconrolled grazing combined with drought produced widespread denudation of rangelands previously dominated by perennial bunchgrasses, eventually prompting Congressional action to regulate grazing on the public domain and to create experimental ranges such as the Santa Rita (courtesy of Arizona Historical Society, Tucson, AHS #45866).

for experiments funded by these monies. It was not until 5 years later, however, that the Federal government took the decisive step of reserving land from the public domain specifically for range research. President McKinley signed the order withdrawing four sections southeast of Tucson on October 10, 1900.

David Griffiths of the Arizona Agricultural Experiment Station had spent "the greater part of a week" scouting the Tucson basin for this tract of land (Griffiths 1901: 23). That it was bisected by the Southern Pacific Railroad was an advantage in his eyes, because it meant that one side of his research plot was already fenced. He enclosed 52 acres, divided it into 60 plots, and began a series of experiments. But the "small inclosure" [sic], as it came to be called, soon showed serious limitations. Even including the unfenced portion, it was too small and too uniform to represent the varied rangelands of the region. It was also lower and drier than the prime grasslands south and east of the Tucson basin. Griffiths tried to assert that the area was "a typical mesa region in every respect" (1901: 24), but it contained more creosote and cacti than perennial grasses and little topographical, climatic, or edaphic variation. "The production of forage is so small here, at best, that one is obliged to measure his pasture by square miles rather than by acres," he noted, "and the operations in range improvement must be on a correspondingly large scale" (1901: 29). Even if Griffiths' experiments in establishing forage plants had succeeded, the need for a larger research range would have remained.

In 1902, Alfred Potter—who would shortly become Gifford Pinchot's first Chief of Grazing—drafted a report for the proposed Santa Rita Forest Reserve, from which the experimental range would subsequently be carved (Potter 1902). In its earliest conception, the reserve was to extend from the Santa Cruz River east to Cienega Creek, and from the Southern Pacific Railroad south to Sonoita Creek, an area of 592 square miles or 379,000 acres. Potter acknowledged that only 45,000 acres of this area was "well forested," and that nearly four-fifths of it was mesa and foothills land. Most of the lower elevation, nontimber land was eventually excluded from the reserve, but on the northwest flank of the Santa Rita Mountains parts of four townships were withdrawn, giving birth to the Santa Rita Experimental Range; Griffiths termed it "the large inclosure" [sic]. President Theodore Roosevelt signed the proclamation on April 11, 1902. The boundaries expanded under subsequent executive orders, by Roosevelt in 1907, Taft in 1910, and by Coolidge twice, in 1925 and 1927. Taft's order also recognized the Santa Rita as distinct from the adjacent Forest Reserve, which had been consolidated into the Coronado National Forest 2 years before; in consequence, title to the experimental range remained with the Interior Department, rather than transferring to the Department of Agriculture. Ultimately, the Santa Rita encompassed over 53,000 acres, or more than 1,000 times the size of Griffiths' first enclosure (which was converted to military uses in 1925 and today is part of Davis-Monthan Air Force Base).

Two of Potter's observations about the Santa Rita Forest Reserve are worth noting here. First, he wrote that before the 1891 to 1893 drought, the area had "carried fully 25,000 head of cattle and horses and 5,000 sheep," and that as of 1902 these numbers had dropped to "between 7,000 and 8,000 cattle, from 1,000 to 2,000 horses, and about 4,000 sheep." These figures translate to roughly 44 head per section before 1891, and 15 to 18 head per section in 1902. Potter also described a seasonal pattern of movement within the proposed reserve, with herds concentrating in the mountains in the fall and winter and the foothills in the spring and summer.

Second, Potter reported that "the mesa lands are all covered with mesquite, to a certain extent; although over the greater part of the area the growth is very scattering and shrubby in character. The only good solid mesquite area is along close to the river bottom and in the draws coming down from the mountains." He described mesquite as "the most universally useful tree in this section," providing almost all the firewood and fence posts used in the vicinity. Since many wells at this period relied on steam pumps fueled with wood (Griffiths 1904: 35), it is possible that mesquite harvesting may have invisibly skewed later perceptions of the area's "original" vegetation.

Between March and June 1903, 27.3 miles of fence were constructed around the experimental range, at a cost of $105 per mile. For the next 12 years, no livestock would graze on some 49 sections of land, while Griffiths and his successors studied its recovery. Spanning more than 2,600 ft of elevation, the new reserve encompassed significant gradients of rainfall, temperature, soils, and vegetation. At the highest, most productive edge of the reserve, another nine sections of land were included in the experimental range but were allowed to remain in the management of settlers already established there: McCleary, MacBeath, Proctor, and Ruelas. Their pastures, ranging in size from 194 to 1,695 acres, were fenced by 1908 and served comparative purposes for the researchers, suggesting how recovery proceeded under controlled grazing.

That the founding management act of the Santa Rita Experimental Range was fencing its perimeter is emblematic of circumstances at the time. There had been livestock in the Santa Cruz Valley for 200 years, and for most of that time they had not constituted a problem, as far as we know. Limited transportation and markets, along with notorious insecurity, had largely isolated the region from outside sources of livestock, and herd growth had been determined mainly by local conditions of forage, water, disease, and predation. Only in the last quarter-century had the cattle boom flooded the region with livestock from elsewhere, brought in on foot or by railroad and financed from afar. In 1903, leases and fences were not yet in place to regulate competition for forage on Federal lands, but there was finally a political consensus that access to the range had to be controlled, and that fencing was the only practicable way to do this. Many early reports implied that fencing, in and of itself, would cause range conditions to improve; fences went up on forest lands after 1905, on State Trust lands after 1912, and on the remaining public domain after 1934. The expanded scale of the livestock industry, from local to international, entailed a contraction of the scale of the individual herd—from entire valleys or mountain ranges to defined and fenced pastures. Almost without exception, research on the Santa Rita would take this geographical innovation for granted.

Periods of Santa Rita Research

With the range fenced, David Griffiths could begin his research, initiating the stream of publications by which the Santa Rita's scientific production can be appraised. Al Medina's (1996) bibliography of Santa Rita research publications lists 452 articles spanning the period 1901 to 1988. This figure includes 18 undated leaflets and several duplicate entries; excluding these and adding one important reference omitted by Medina (see below), we have a data set of 427 articles. If we organize these chronologically, and depict the results graphically (fig. 2), several periods of research activity can be identified. This periodization is intended as a heuristic device only; there have always been multiple threads of inquiry, administration, and funding in the fabric of the Santa Rita, and the variable lag between defining, funding, conducting, and publishing research defies neat temporal separation.

It is immediately clear from the graph that wildlife has been an important focus of research on the Santa Rita since the 1920s, increasingly so in recent decades. But it has rarely constituted a majority of publications, and its very consistency makes it poorly suited as a means of distinguishing periods of research effort. I defer to Krausman (this proceedings) to illuminate the place of wildlife research in the history of the Santa Rita. The history of research on Lehmann lovegrass is not as long, but otherwise similar to wildlife—recurrent but minor from the 1940s through the 1980s. I will touch upon it along the way.

1901 to 1931: Institutional Consolidation, Revegetation, and Carrying Capacity

In the first 30 years of the Santa Rita, only 19 articles were published, never more than two in any one year. This was a period of minimal funding and staffing of the range, while the larger institutional basis for range research was slowly being consolidated. Major events in this consolidation process included the transfer of the Forest Reserves to the U.S. Department of Agriculture and the formation of the Forest Service in 1905; the creation of the Office of Grazing Studies within the Forest Service in 1910, followed a year later by the subdivision of forest administration into

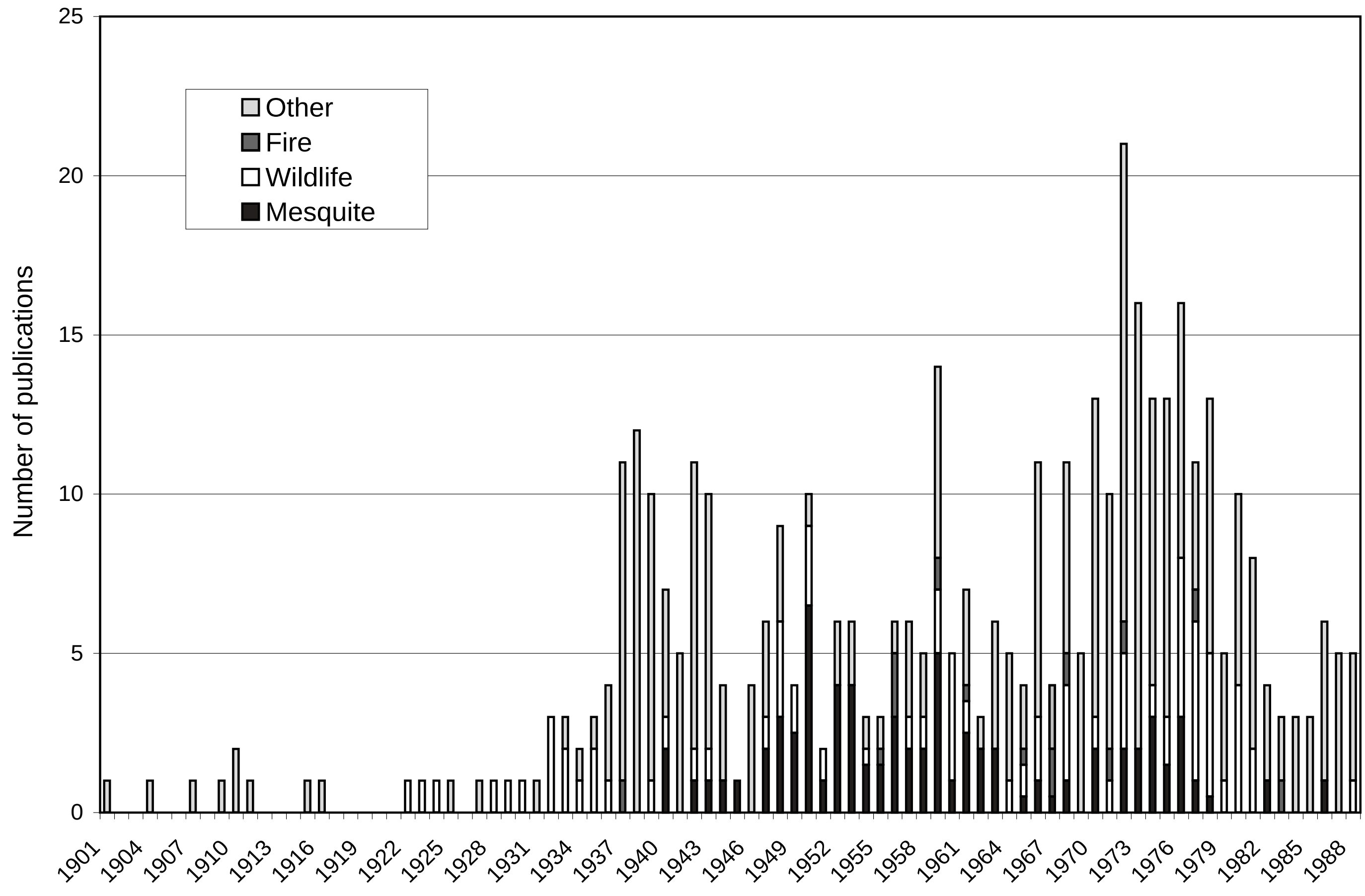

Figure 2—Annual output of publications from Santa Rita research, 1901 to 1988, organized topically. Half-units reflect publications that expressly covered two topics together (for example, mesquite and fire) (adapted from Medina 1996).

regional offices; the transfer of range research outside National Forests—including the Santa Rita Experimental Range—from the Bureau of Plant Industry to the Forest Service in 1915; the transfer of the Office of Grazing Studies from the Branch of Grazing to the Branch of Research in 1926; and finally, the creation of regional forest and range experiment stations under the McSweeney-McNary Forest Research Act of 1928 (Chapline 1944). It was this last event that created the Southwestern Forest and Range Experiment Station (SWFRES), based in Tucson, which brought increased Federal funding for range research and triggered the rise in Santa Rita publications from 1932 on.

Two pressing issues dominated the research of this period: (1) how to restore forage plants decimated by the cattle boom, and (2) how to measure range resources for management and administration. Griffiths (1901, 1904, 1907) and J. J. Thornber (1910) tested hundreds of native and nonnative plant species in hopes of finding economical ways of artificially establishing cover and forage on bare or nearly bare ground. Most failed altogether, and even those that showed some success were failures in economical terms. Building up berms of soil to slow runoff and capture seed was also attempted at the small enclosure, but the structures often blew out in floods and did not result in enough grass to justify the costs. "Much more satisfactory results have thus far been obtained by husbanding the native vegetation and grazing well within the capacity of the land to maintain stock" than by any other methods, Griffiths (1910: 13) concluded. This recommendation against overgrazing has been a consistent refrain from Santa Rita researchers ever since, although far less simple than it appears.

Determining carrying capacities was central to the research of this period because it linked environmental and ecological factors to political and economic imperatives. It was of "the utmost importance," according to Griffiths' boss, because "This knowledge determines the rental and sale value of range lands and should also determine the size of the minimum lease or homestead for range purposes…" (W. J. Spillman, in the preface to Griffiths 1904). If fencing and leasing were to work as planned, carrying capacity had to be a coherent concept that public officials could apply, measure, and enforce. Furthermore, the capacity of any given piece of range had to be more or less static, both for administrative efficiency and so that ranchers and their financial backers could build leases into their business plans and credit instruments. Griffiths recognized these constraints, and he delivered carrying capacity estimates as best he could, as did Wooton (1916). Following Smith's (1899) example from Texas, both were inclined to define carrying capacity by reference to forage production in poor (in other words, drought) years. In 1904, Griffiths recommended 37 acres per animal unit (AU) (or about 17 AU per section) for the Santa Rita generally, and 50 to 100 acres per AU (about 6 to 13 AU per section) for lower or more degraded ranges; in 1910 he revised the Santa Rita estimate to 32 AU per section. Wooton concurred with the latter, higher figure.

Griffiths' reports contain numerous remarks, however, that suggest he had doubts about the concept of carrying capacity when applied "in a region where the seasons, the altitude, the slope, and the rainfall are so variable" (1904: 32). Not only did productivity vary across space and time, it was also "exceedingly difficult to decide which species are and which are not forage plants," because, if necessary, cattle would eat almost everything (1904: 25). Even in the absence of grazing, the composition of vegetation did not display stability:

> …differences in vegetation, comparing one year with another, are very striking… In the large field, even with similar rainfall, there occurs an ascendency [sic] of one plant one year and another plant another year… So far as known, no one has ever offered an explanation for these yearly variations of annual vegetation (1910: 15).

Griffiths also discerned longer term vegetation changes taking place, specifically an increase in mesquite and other shrubs, and he attributed these changes to fire suppression, not grazing. There is no evidence that his doubts diminished over time; indeed, his 1910 carrying capacity estimates were even more cautiously expressed than those of 1904. Likewise, his assertion that 3 years of complete rest would restore degraded Southwestern rangelands "approximately to their original productivity" (1910: 13) seems forced, because it conflicts with many of his other observations. He noted, for instance, that 2 consecutive years of good summer rainfall were needed for significant establishment of perennial grasses—something that occurred only once in his 10 years of research in the area.

Griffiths appears to have arrived in Arizona with few preconceptions about the desert and no scientific theories to attack or defend, allowing his curiosity wide latitude. He conducted surveys of ranchers, traveled and photographed extensively in the region, and generally let his observations lead him where they would. In these respects he stands in sharp contrast to the other major figure of this period, Frederic Clements, who arrived in Tucson in 1917 to work at the Carnegie's Institution's Desert Lab on Tumamoc Hill (also founded in 1903). Clements came with a heavy investment in a powerful theory—his own—and a determination to make it work in the Southwest and, indeed, everywhere.

Clements installed vegetation plots on the Santa Rita (Bowers 1990: 40), and he also drew on the work of Griffiths and other Santa Rita researchers for his 1920 book, *Plant Indicators*, which included numerous photographs from the range. The aim of the book was to demonstrate the practical uses of his famous theory—published as *Plant Succession* 4 years earlier (Clements 1916)—in managing the rangelands of the American West. The profound influence of "Clementsian" theory on range science is widely acknowledged to this day (National Research Council 1994; Society for Range Management 1995). But both *Plant Indicators* and Clements' role in Santa Rita history have virtually disappeared from memory, as evidenced by omission from Medina's bibliography. His practical recommendations for managing livestock in the Southwest have also been largely forgotten, even though they anticipated many future developments in semiarid range management. The debates about Clements' role in range science and ecology have focused on the theory of plant communities and succession, but I would argue that the central practical issue was, again, carrying capacity.

Clements suffered from none of Griffiths' doubts about the theoretical coherence of carrying capacity, but he defined it differently and was perhaps more naive than Griffiths about how it would be used in practice. Specifically, he did not construe carrying capacities as static, and apparently he didn't see why anyone would.

> No other factor produces such rapid and striking changes in carrying capacity as does rainfall. The difference in the total yield of the same range in two successive years of dissimilar rainfall may be greater than 100 per cent, and in the wet and dry phase of the same cycle it may be even greater (1920: 292).

Clements believed that some longer "cycle" existed, probably linked to sun spot activity, which might eventually render this variability tractable for science and management. But his practical recommendation was unequivocal:

> It is evident that the maximum production can not have a fixed or average value… A degree of grazing which would be disastrous in a drought period would fall far short of adequate utilization during a wet one (1920: 296).

His book exhaustively classified and described Western rangelands, but he nowhere offered numerical estimates of acres per animal or animals per section.

> It is imperative that the ranchman be prepared to reduce the pressure upon his range as the dry phase of the climatic cycle approaches and that he be ready to take full advantage of the excess carrying capacity of the wet phase. In fact, the whole system of improvement must be focused upon the destructive effect of overgrazing in dry years and the possibility of greater utilization and of successful sowing and planting during wet years (1920: 311).

Clements also suggested that carrying capacity was a function not just of a given range and its condition but also of management. He criticized both overstocking and stocking year around (1920: 297). Making reference to wild herbivores such as bison, he linked secondary succession to long periods of rest following heavy grazing (1920: 307), and he recommended rotation of grazing pressure to imitate this natural process (1920: 310). Like Griffiths, Thornber, and Wooton before him, Clements called strenuously for fencing:

> It is immaterial whether control is secured through ownership or leasing, provided it permits fencing. However, leasing has the indirect advantage that it enables the State to exact certain conditions as to utilization (1920: 311).

Although Clements' theory of succession dominated twentieth century range science, as is well known, his practical recommendations did not dominate actual management. There is some evidence that southern Arizona ranchers practiced summer season rest and variable stocking in the 1920s (Sayre 2002), but whether they took their cues from scientists is unknown—I would guess they did not, in view of the fact that continuous yearlong grazing became the norm when ranchers shifted from stocker to cow-calf operations in the 1930s and 1940s. Even among range scientists, Clements' theory did not catch on quickly, if we may judge from the Santa Rita archive. In the minutes of the Forest Service's District 3 Grazing Studies Conference of December 1921, for example, there is no mention of the work of Clements (or Sampson), nor of succession or climax communities. With one exception (Wooton 1916), Clements' influence does not appear in Santa Rita publications until the late 1930s.

Although the number of publications from this period was small, their importance to subsequent research and range administration was great. Griffiths and Clements were pioneers of range science both at the Santa Rita and for the nation. That both of them expressed reservations, tacitly or explicitly, about the central premise of the system of rangeland administration institutionalized over the following decades sheds new light on current debates about range ecology and management in the United States and elsewhere (Illius and O'Connor 1999).

1932 to 1945: Growth and the Shrub Problem

The second period extended from 1932 to the end of World War II, which imposed severe budget restrictions and brought publications nearly to zero by 1945. With a newly enlarged staff, the Southwestern Forest and Range Experiment Station supported more focused studies of particular forage species such as tanglehead, black grama, blue grama, and vine mesquite, as well as of noxious or invasive plants, particularly burroweed. Numerous studies sought more accurate and efficient methods of measuring vegetation and utilization—an outgrowth of the Forest Service's need to define and enforce carrying capacities. These new methods were both scientifically rigorous and practical for agencies, but they did not really address the question of static versus dynamic carry capacities on Southwestern rangelands. Revegetation remained a major focus, but with more attention on underlying ecological factors such as litter cover and soil moisture. Research on wildlife expanded as well to include kangaroo and pack rats, wood rats, quail, jackrabbits, and rattlesnakes. Finally, there was a more specialized attention to practical management issues as viewed from the perspective of private ranchers. Matt Culley (1937) produced a detailed study of the economics of one of the Santa Rita's cooperating ranches, and he and Kenneth Parker placed numerous articles in livestock journals on range and management issues such as poisonous plants, drought, and proper stocking.

Perhaps the most important study performed during this period, historically speaking, was one that was not published. "Occurrence of Shrubs on Range Areas in Southeastern Arizona" (Upson and others 1937) was a cooperative survey conducted in 1936 and 1937 by the Southwestern Forest and Range Experiment Station, the Arizona Agricultural Experiment Station, the Agricultural Adjustment Administration, and the Bureau of Agricultural Economics. It involved vegetation measurements at 450 sites coupled with ocular surveys of nearly 12 million acres, resulting in maps of the dominant vegetation covering all of southeastern Arizona (figs. 3 and 4). Nearly a third of the area was dominated by grasses, and another quarter by creosote; cactus and burroweed dominated just over 9 percent each, and mesquite dominated another 7 percent; wolfberry, saltbush, and snakeweed dominated the remaining 10 percent. The mesquite, snakeweed, and burroweed areas were singled out as having expanded in recent memory, usually at the expense of grasses, and therefore as having the greatest potential for restoration. Up to this point, burroweed had received far more attention from Santa Rita researchers than the other two species, but the survey found mesquite to be the most widespread of the three,

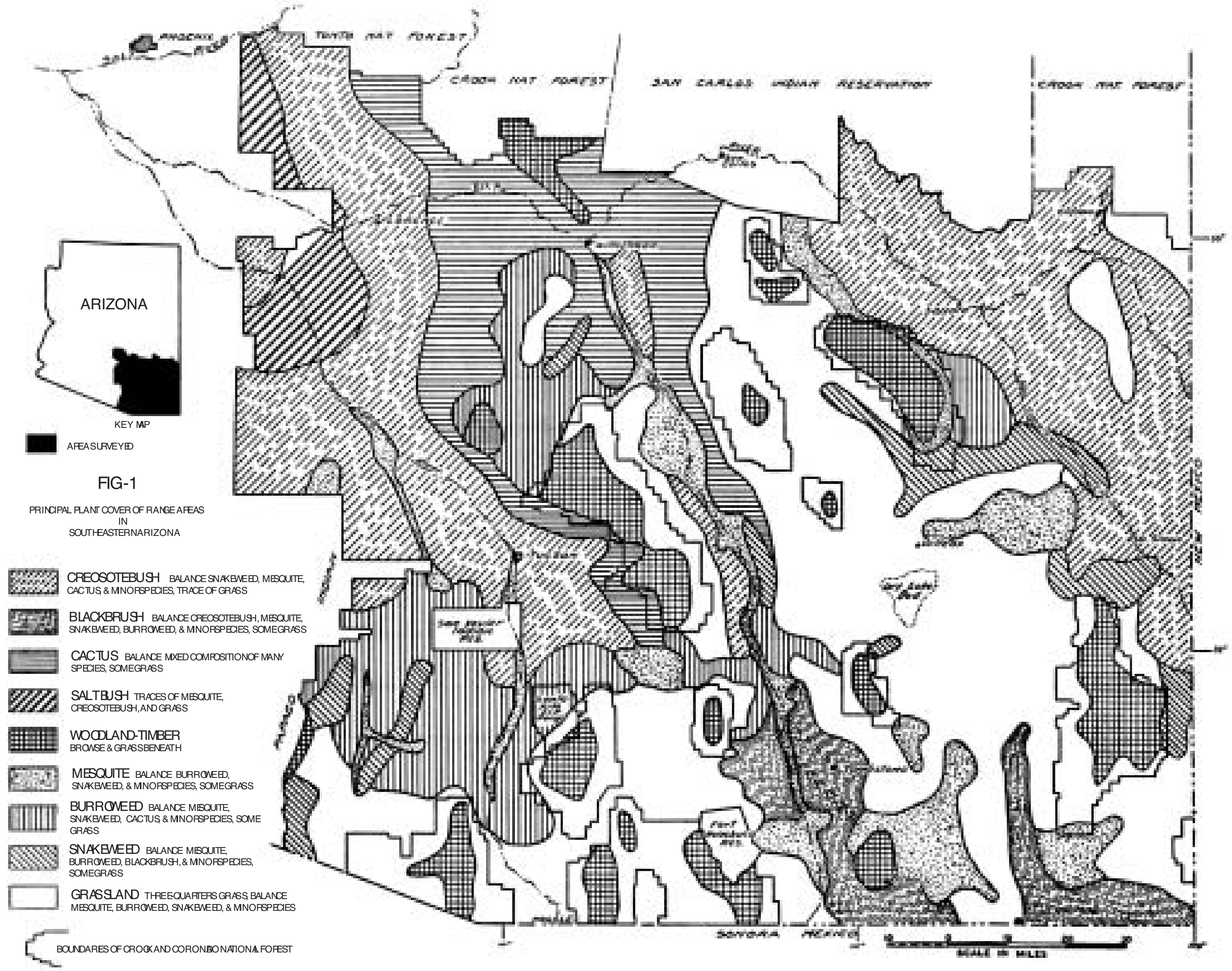

Figure 3—Map of "principal plant cover of range areas in southeastern Arizona," 1936 to 1937. The report containing this map drew attention to shrub encroachment in areas formerly dominated by grasslands, and helped shift attention from burroweed to mesquite (Upson and others 1937).

present on more than 9 million acres—three-quarters of the region. Understanding, explaining and remedying this shift would be the dominant research priority of Santa Rita range scientists for decades to come.

As mentioned above, Griffiths had noted the spread of mesquite nearly 30 years earlier and had attributed it primarily to fire suppression, not grazing. Curiously, "Occurrence of Shrubs" did not discuss fire at all, aside from a brief mention under "Artificial Means of Control" of burroweed (p. 26). The report's explanation of shrub expansion was that grazing—and only grazing—had shifted the competitive balance between grasses and shrubs, and that heavily grazed areas around water sources had provided sites for establishment and subsequent spread of shrubs into the surrounding range (p. 12–15). This argument was framed, moreover, in explicitly Clementsian terms: grasslands "represent, of course, the climax type" for the region, and evidence of former grass dominance in areas of shrubs was taken to indicate that such areas "may also be considered, ecologically, a climax grassland type" (p. 12). The authors argued that reducing or eliminating grazing would retard or prevent shrub encroachment, although they also acknowledged documented cases where this had not worked, suggesting the possibility that "there are other factors than grazing which favor the spread of shrubs" (p. 24).

Researchers initiated studies of mesquite immediately following completion of the report, but they did not focus on adjusting stocking rates. Instead, techniques of killing the trees outright were tested (Parker 1943). In 1940, a study was launched in which mesquite and/or burroweed were killed on 1-acre plots; it was followed in 1945 by another, which used prisoner-of-war labor to thin mesquite to various densities on 2-acre plots. Also in 1940, the Carnegie Institution ceased its support of the Desert Lab and turned its facilities on Tumamoc Hill over to the Forest Service. The SWFRES had its headquarters there until 1953, when

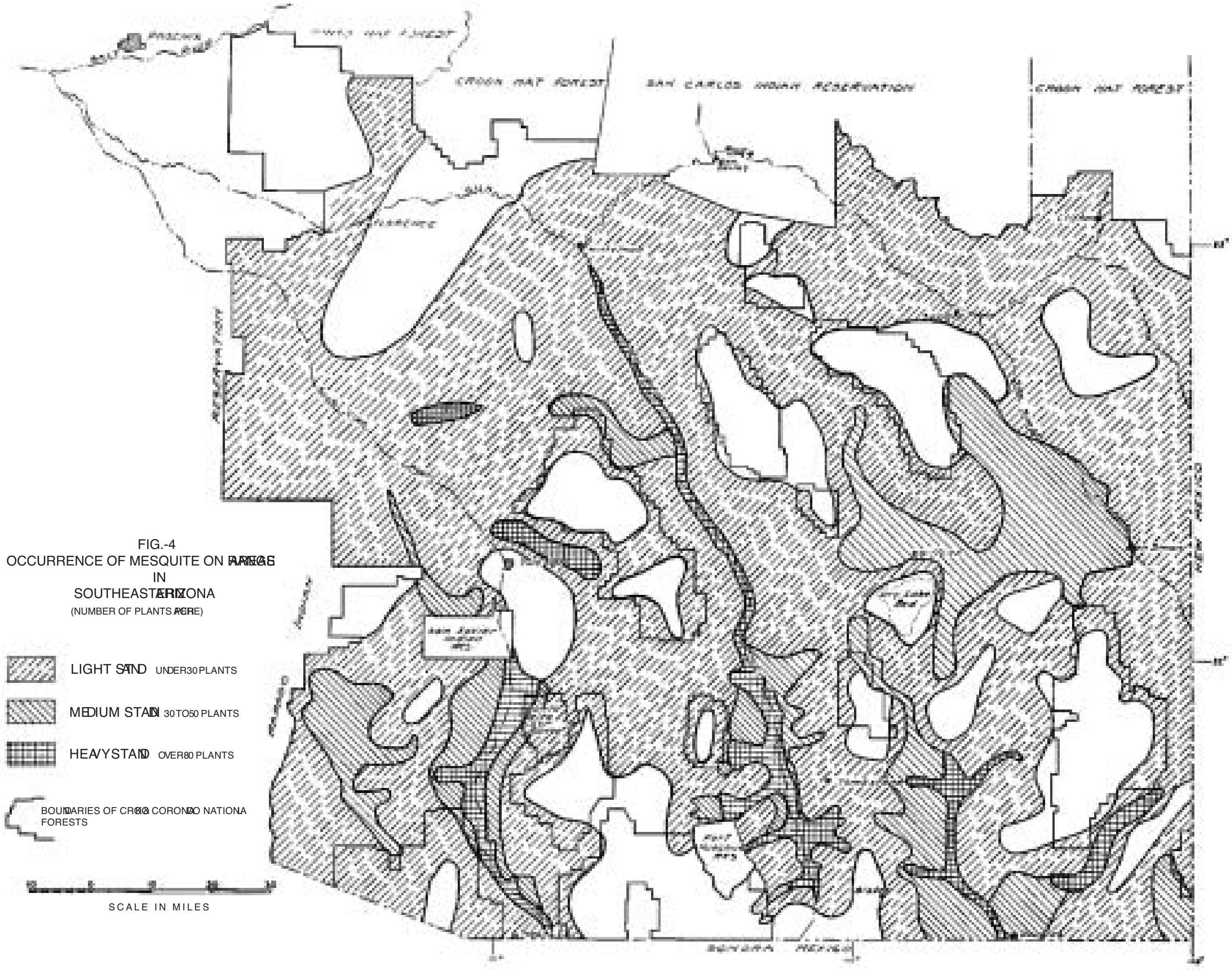

Figure 4—Map of "occurrence of mesquite on range areas in southeastern Arizona," 1936 to 1937. The ubiquity of mesquite, present on roughly 75 percent of the region, led to intense research efforts on the Santa Rita for four decades, and especially from 1946 to 1966. At the time this map was made, however, mesquites exceeded 30 plants per acre on only 15 percent of the region; heavy stands (>80 plants per acre) were confined almost entirely to major drainages (Upson and others 1937).

it was merged into the Rocky Mountain Forest and Range Experiment Station (RMFRES), headquartered in Fort Collins, CO.

1946 to 1965: Age of Mesquite

The pace of research rebounded quickly with the end of the war, and the focus turned decisively to mesquite. The overall goal was the same as in Griffiths' day: restoration of perennial forage grasses. But now shrubs, rather than just bare ground, stood in the way. The postwar period was a prosperous one for both ranchers and agencies, and practices previously deemed uneconomical might now pencil out. Beginning in the late 1940s, the Hope-Flannagan Research and Marketing Act made funds available for research on noxious range plants.

In 1948, with cooperative agreements up for renewal on both the Santa Rita and the Jornada Experimental Range, Kenneth Parker composed "An analysis of range problems in the Southwest," another internal document. He cited the 1937 shrub survey in support of the claim that "mesquite constitutes a problem on some 8 million acres" in southern Arizona (p. 57)—this appears to have been an exaggeration, as the survey had found medium and high densities of mesquite on less than 2 million acres (fig. 4). Parker rejected the earlier study's Clementsian expectation that reduced grazing would reverse the trend toward shrub domination, however. Meter-square quadrats going back to 1916 indicated no consistent relation of vegetation with either climate or grazing pressure (p. 73); herbage productivity had declined substantially, even with steadily reduced stocking rates (p. 77–79). Parker concluded that "no degree of moderation in grazing use will eliminate these low value plants. The meaning, in unmistakable terms, is that if we are to continue grazing use by domestic livestock some positive, drastic treatment which will eliminate these plants will be necessary to achieve conservation of the grazing resource" (p. 71). Because shrub encroachment also threatened watershed function and, therefore, agricultural and municipal water supplies, Parker argued that "[t]he future welfare of the Southwest is dependent on how well and in what manner the range resource is used" (p. 7). During the severe drought of the early 1950s, a sense of emergency pervaded the ranching industry, and the "war on mesquite" played well in local newspapers (Sayre 2002).

In all but 3 years from 1947 through 1965, no less than one-third and often as many as two-thirds of Santa Rita publications focused on velvet mesquite (49 out of 109 papers altogether). Studies ranged from basic questions of life history and reproduction, to demographic analyses, to effects on soils and competition. Herbicidal approaches to mesquite control using diesel oil or chemicals were increasingly prevalent in the publications of this period. As in Griffiths' day, efforts were launched to find (or create by hybridization) a perennial grass capable of establishment on degraded semiarid rangelands, and this time several were found among South African lovegrasses, although the full implications of this success would not be evident until the late 1960s. Work on small mammals also continued, and whereas many earlier rodent studies had emphasized negative impacts on grasses, now some researchers focused on rodents' role in helping to propagate shrubs. Other wildlife research in this period included studies of javelina, cactus wren, Gambel quail, and deer.

This body of research has been of major and lasting significance to scientific understanding of semiarid grass-shrub rangelands, even though it fell short of its own goals for practical management. From a theoretical perspective, the decisive turn was from the Clementsianism of the 1937 shrub report to Parker's observation in 1948 that reducing or eliminating grazing would not by itself cause a reassertion of grasses. This opened up research questions that extended well beyond issues of livestock production, laying the foundation for subsequent investigations into water cycling and erosion, the spatial and temporal distribution of moisture and nutrients as it affects plant growth and competition (fig. 5), and the role of small mammals and invertebrates in semiarid ecosystem processes. These issues would emerge to dominate Santa Rita research in the following period. At the time, however, the concerns of range managers still focused primarily on producing livestock, and from this perspective the research fell somewhat short. The methods developed for controlling mesquite were effective only if the larger economics of ranching were very favorable—cheap diesel and high prices for calves—and only on fairly short time scales of 10 to 20 years, as mesquite steadily reclaimed treated lands. Although vast acreages would be cleared over the 30 years from 1950 to 1980, the goal of restoring native perennial grass domination once again proved elusive.

Today, we think we know the reason for this shortcoming: the near-total absence of fire from Southwestern semi-desert grasslands. Fire was likewise missing from most Santa Rita research and publications of the period. In his 1948 internal analysis, Parker alluded to Griffiths' comments on fire suppression, but he did not elaborate on them or recommend research on the subject. Similarly, "The Santa Rita Experimental Range" booklet of 1952 (USDA 1952) devoted one-sixth of its text and numerous photos to noxious plant control, without a single mention of fire. Somewhat of a maverick, Robert Humphrey—who had originally hired on with the Desert Lab—published numerous papers making the case that fire suppression was the fundamental cause of woody plant encroachment, and that restoring fire could economically control the problem. But his argument was based more in natural history than in experimentation, and the idea did not go far, producing only two Masters theses, one technical bulletin, and two peer-reviewed publications other than Humphrey's own articles during this period. Ranchers, agencies, and the general public were all accustomed to vigorous fire suppression, and the real-world risks were obviously high. Moreover, in Parker and Martin's (1952: 14) words, "[t]he effect of fire or lack of

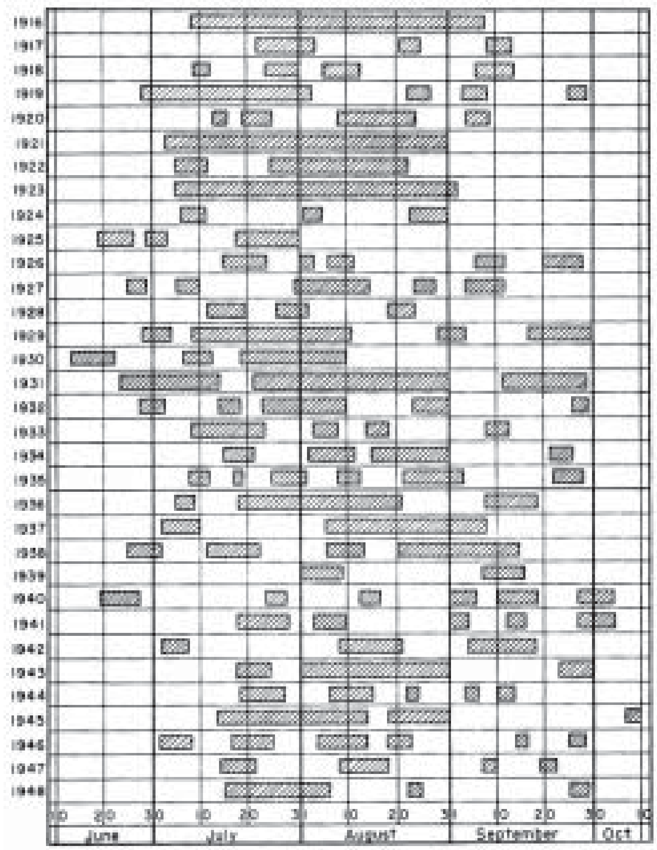

Figure 5—The temporal distribution of effective rainfall, 1916 to 1948. Shaded areas on the graph represent periods when rain fell on successive days or were preceded or followed by storms of 0.4 inch or greater during the summer growing season. The graph reflects growing understanding of the ecology of major forage plants on the Santa Rita, which were predominantly C_4-pathway perennial grasses limited by the distribution of moisture in space and time, rather than by gross annual or seasonal rainfall (USDA 1952).

fire on the occurrence of mesquite stands is a moot question." Whether from grazing, drought, shrub encroachment, or a combination of the three, much of the region's rangelands simply didn't have enough herbaceous fuels to carry a fire. Lehmann lovegrass had the potential to change this, however, and Humphrey stood alone on this subject, too, calling attention to the possible downsides of *Eragrostis lehmanniana* a decade before anyone else (Humphrey 1959).

The attention placed on chemical and mechanical mesquite control cast a long shadow, obscuring less exciting topics such as grazing management. Recommended practices were not much changed from earlier periods: stock conservatively, distribute grazing pressure evenly, defer or minimize grazing pressure during the summer growing season (USDA 1952). Echoing Clements, the 1952 Santa Rita booklet documented the wide variability of rainfall and forage production, and it cautioned "that the practice of building up numbers in the occasional good years removes the only chance that the range might have to improve" following drought (USDA 1952: 14). But it sought, nevertheless, to establish atemporal guidelines for stocking rates and utilization (fig. 6).

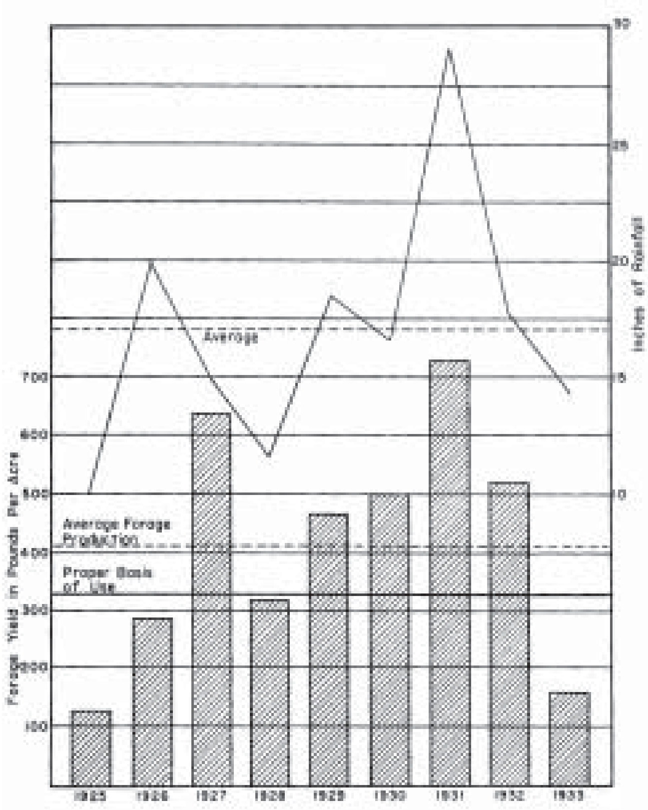

Figure 6—Graph of forage yield and rainfall on an annual basis, 1925 to 1933. Dashed horizontal lines indicate average rainfall (top) and average forage production (bottom); the solid horizontal line signifies the—"proper basis of use," defined as roughly 20 percent below average forage production. Intended to prevent overgrazing during recurrent dry years, this guideline nevertheless perpetuated the conception of carrying capacity as a static attribute of Southwestern rangelands (USDA 1952).

Meanwhile, postwar prosperity allowed greater capitalization of many ranch operations, and mesquite control was only one of a long list of investments ranchers were making: in improved breeding, more fencing and water development, and new technologies for handling cattle (for example, holding corrals, squeeze chutes, calf tables, pickup trucks, and trailers). The "old ways of doing things on the range… were romantic, and led to a simpler and more friendly way of life," according to the booklet. "However, they cannot compete with the modern way of doing business," which involved replacing labor costs with fixed costs (USDA 1952: 9). By this time, cow-calf operations were the norm, and the booklet recommended dividing one's herd into groups of 50 to 100 animals, each group with its own fenced pasture, to allow closer supervision and control of breeding. This amounted to continuous yearlong grazing, which became the norm in the region during this period.

1966 to 1988: Ecology and the Santa Rita Grazing System

Research on mesquite continued through the 1970s, but its dominance waned. The period 1966 to 1988 was the most prolific in the Santa Rita's history, and the proportion of publications devoted to mesquite declined to only 10 percent of the total, compared to 45 percent in the previous period. A wide array of new research foci emerged, reflecting new interests and methods both in range science and in ecology more generally. In the late 1960s, animal scientists used fistulated steers to study cattle diets, nutrition, and weight gain, and the idea of frequent, automated weighing of livestock was pursued. In the early 1970s, the International Biological Program's Desert Biome project produced a small mountain of research on soil nutrient flows, soil moisture, termites, and ants. Other research also looked below the surface of the ground to examine root systems of grasses in grazed and protected sites, competition among plants for soil moisture, variations in soil temperature, factors affecting runoff and infiltration, fungi, and the penetration and breakdown of various chemicals, especially insecticides. Wildlife research picked up considerably in the late 1970s, comprising more than a third (22 of 63) of all publications from 1976 to 1981. Different research activities fed off one another, symbiotically or parasitically depending on your perspective: mesquite removal for range restoration experiments raised the question of wildlife habitat effects; the discovery that termites consume large quantities of biomass provoked attempts to control them, just as had happened in earlier decades with rabbits and rodents.

The problem of mesquite had not gone away. Rather, confidence and funding had dissipated relative to other interests. Herbicidal methods had largely failed, and from the oil crisis of the early 1970s on, the cost of mechanical treatment could not be justified given stagnant real returns to livestock and the likelihood that retreatment would be necessary down the road. Where large-scale mesquite clearing continued, it was underwritten by real estate appreciation and other nonranching investments, and it was motivated at least partially by tax policies that incentivized losses (Sayre 2002). Meanwhile, opposition to mesquite control, especially using chemicals, emerged among nonranchers as part of the larger social concern for the environment.

The turn to a broader ecological orientation was reflected in range science research by Clark Martin's work on grazing systems. Building on earlier Santa Rita findings about the timing of forage growth, Martin had initiated studies of various grazing/rest schedules on small plots beginning in 1957, and in the early 1970s he concluded that spring-summer rest 2 years out of 3 produced significant improvement in perennial grasses compared to continuous yearlong grazing (Martin 1973). He anticipated that these improvements would be concentrated in areas of poor range condition (Martin 1978), a prediction later confirmed in a 10-year study (Martin and Severson 1988). Perhaps the most intriguing discovery of Martin's research, and of related work by Dwight Cable (1971, 1975), was that grazing and drought had interactive, lagged effects extending over 24 to 36 months: significant improvement resulted from 2 successive years of good summer rains, and grazing could retard recovery during the first postdrought summer. These findings echoed the views of Griffiths, Clements, and the 1952 Santa Rita booklet, supporting them with hard data.

Rest-rotation grazing was not new, of course. It had antecedents in the work of Clements, among others, and the idea of deferring grazing until late in or after the growing season had been promoted in the 1910s by Jardine and Hurtt (1917) and Sampson (1914). What was new, it appears, was a commitment within the Forest Service to encourage the implementation of rotational systems on allotments throughout the Southwest. Hormay and Talbot (1961) had revived and systematized rest-rotation in the early 1960s, pointing out that under yearlong systems selective grazing would disproportionately impact palatable species, even at conservative stocking rates. Only periodic rest could prevent this, and fairly heavy grazing could be beneficial if it reduced selectivity. Hormay and Talbot even claimed that "grazing is eliminated as an environmental factor under rest-rotation grazing" (p. 40). Whether true or not, their claim completed a paradoxical evolution in range science. The discipline had long embraced Clements' theory of succession while neglecting his practical management ideas. Now it embraced one of his management ideas (without crediting him), and used it to renounce one of the central tenets associated with his theory: the primacy of grazing in determining vegetation. Cable's (1975) research indirectly supported this view by documenting the overriding importance of summer rainfall.

1988 to Present: Land Swap and Reorientation

Medina's bibliography extends only to 1988, and without knowing his methods and criteria I am reluctant to attempt to update it. The date would be an arbitrary endpoint for historical analysis, except that it was also a pivotal year in the administration and ownership of the Santa Rita Experimental Range. Funding for Santa Rita range science research had been stagnant or declining since 1975, when the Tucson-based Southwestern Station of the Rocky Mountain Forest and Range Experiment Station had been merged into the Experiment Station at Tempe. Relative to the Southwest's booming urban and suburban economic sectors, livestock grazing had begun to appear less significant, and by the late 1980s the Santa Rita was in danger of becoming an expensive anachronism. That the title to the range still resided in the Interior Department—a fact that many people had overlooked, it seems—now became significant. It meant that the Rocky Mountain Station, and the USDA as a whole, could simply walk away from the range in response to shifting priorities and limited budgetary resources. This would leave it in the hands of the BLM, inheritor of all undisposed General Land Office holdings. But the BLM did not have resources or reason to manage an experimental range either.

Resolution came rather hastily and from an unexpected direction (Sayre 2002). Some 50 miles southwest of the range, in the Altar Valley, another branch of the Interior Department faced a difficulty. The Fish and Wildlife Service (FWS) had purchased the Buenos Aires Ranch in 1985, mainly for the purpose of restoring the endangered masked bobwhite quail. The ranch included leasehold to nearly 90,000 acres of State Trust lands, intermixed with 21,000 acres of deeded land. The FWS had removed all livestock from the new Buenos Aires National Wildlife Refuge, and it had no intention of grazing there. This meant, by policy, that the State Land Department had to reclassify the leases as commercial and charge the FWS commercial rates: 10 percent of fair market value of the land, or more than half a million dollars a year. Several small land exchanges were formulated, which would have enabled the refuge to consolidate its ownership of the prime masked bobwhite habitat. But the vast majority of the Buenos Aires lease lands would have remained subject to reclassification, or to reassignment to livestock operators.

Following a change in the governor's office in 1987, the Land Department began to press its case and the Buenos Aires lease fees started to increase, forcing regional FWS officials to scramble to cover the payments. Early in 1988, Regional Director Michael Spear and Arizona BLM Director Dean Bibles came up with a solution, which passed into law with the Idaho-Arizona Conservation Act that November. Nearly two and a half years later, in April 1991, the transaction was executed: The Interior Department got the Buenos Aires lease lands, and the State Land Department took possession of the Santa Rita. Under a special designation passed by the Arizona legislature, the experimental range was rededicated to research and education. It was also assigned as its beneficiary the University of Arizona, which administers the range and collects lease payments directly from cooperating graziers. In this way, the Santa Rita conforms to the constitutional mandate of the State Trust to generate revenue for beneficiaries, but it is outside of the ordinary policies and procedures of the Land Department. The designation remains in place indefinitely, until and unless superseded by legislative action (Mitch McClaran, personal communication).

Under its new ownership, the Santa Rita has continued to host research projects and to work with its cooperating grazing lessees. The larger social, economic, political, and scientific context has shifted dramatically since 1903, however, and the orientation of research on the experimental range is changing to reflect new interests, opportunities, and constraints. Issues of forage and livestock production are receding relative to those of climate change, ecological restoration, watersheds and wildlife. I will return to this reorientation in a moment, after considering the second question with which I began.

Effects on the Range

What difference did Santa Rita research make on Southwestern rangelands? The question is surprisingly difficult to answer.

Many innovations developed or recommended by Santa Rita researchers have been widely adopted: the installation of water sources every 2 to 3 miles across the range and the careful placement of mineral supplements to distribute grazing pressure evenly; the use of improved breeds and livestock handling techniques; various methods of brush control and revegetation with grasses; the construction of interior fences to control both breeding and grazing; rigorous culling of underperforming animals; and myriad variations on rotational grazing. Exactly where and when these practices have been implemented, however, and to what effect on range conditions, are difficult to determine. Grazing impacts have probably been made more homogeneous and less severe over the landscape, with differential effects depending on the scale and organism of concern. Lehmann lovegrass is established in most of the areas suited to it; whether it is choking out native grasses or otherwise causing harm is still a matter of debate, but it has unquestionably succeeded in reducing erosion compared to former conditions of shrub dominance. Many ranchers now understand the historical role of fire in these landscapes, and some are working diligently to restore it; how widely this will succeed, it is too early to tell.

One core message—avoid overgrazing—has been a constant of Santa Rita management recommendations, along with the goal of restoring perennial, warm-season grasses. Beginning early in the twentieth century, these came together in policies focused on proper stocking of National Forest allotments; later, a similar approach was applied to BLM and State lands. Clearly, proper stocking was, and remains, central to good range management. But what did it mean in practice, and what role did research play in actual stocking decisions?

It is generally known that forage production and stocking rates, as well as carrying capacity figures, have declined significantly in the past 125 years. The stocking rates recommended by Clark Martin in 1975, for example, ranged from less than 4 to 18 to 25 AU per section, depending on condition and elevation (Martin 1975: 10); these are all lower than the rates recommended by Griffiths in 1910 and Wooton in 1916, and less than half of actual rates described by Potter for the area pre-1891. Actual stocking of the Altar Valley before 1920 was three to fives times greater than at present (Sayre 2000). As with the West as a whole, assessments of regional range conditions have been sporadic and hampered by inconsistent or disputed methodologies (National Research Council 1994).

Excessive grazing is usually viewed as the major cause of these declines. The agencies were expected to enforce stocking rates, but on the expansive range compliance had to be largely voluntary, and there is evidence that overstocking was widespread in the past. Using sales data and interviews for 160 ranches that changed ownership from 1957 to 1963, Martin and Jefferies (1966) found that actual stocking of BLM and State Trust allotments was, on average, twice the official rates. Stocking decisions on State lands were largely at ranchers' discretion until the early 1980s, and it seems that every old timer has stories to tell of permittees who chronically overstocked their Federal or State allotments. For obvious reasons, however, more comprehensive data on the extent and severity of overstocking are extremely difficult to find.

Any assertion of causality between overstocking and range depletion must be qualified, however. A recent analysis of regional vegetation change argues that the drought of the 1890s might well have resulted in widespread arroyo formation even if unaccompanied by overgrazing (Turner and others 2003). Likewise, the drought of the 1950s appears to have pushed some Southwestern rangelands—with and without livestock grazing—across thresholds from which a return to climax has not occurred (Herbel and Gibbons 1996). Studies such as these suggest that grazing impacts may have been significant during periods of severe drought and much weaker, or even nil, during wetter periods. When summer rains were good, conditions could improve in the direction of the "climax" of perennial bunchgrass dominance, even under rates of stocking that we now characterize as excessive. This occurred, for example, in the upper end of the Altar Valley in the 1930s (Sayre 2002). Depletion appears to have been concentrated in drought periods, when herbaceous vegetation could decline significantly even without livestock present.

It can plausibly be argued—although not proven—that the changes in vegetation observed during the twentieth century would have occurred *even if actual stocking had adhered to official carrying capacity estimates*. Very likely, those estimates were unnecessarily restrictive during wet years and too permissive during severe droughts. In spite of the great natural variability in forage production, ranchers had obvious economic incentives to maintain their herds, even at the risk of overgrazing. "The general practice of stockmen takes no account of the great variation in yield between the dry and wet phases," complained Clements (1920: 297); this sentiment recurs in reports and bulletins throughout much of the century. Of course, actual stocking was never completely static, and carrying capacity estimates continued to be debated, studied, and revised throughout the century. But the expectation that some correct number of livestock should exist for each allotment, *independent of time*, was a misconception perfectly suited to strain relations between agencies and lessees. How could the agencies ever demand reductions below official capacities, even in severe drought, if the figures were supposed to account for poor years? Conversely, how could lessees take official capacities seriously in wet periods, when forage was many times greater than permitted numbers of animals could consume? Range scientists generated carrying capacity estimates that aspired to be independent of fluctuating rainfall, and economic and political constraints compelled ranchers and agencies to interpret proper stocking in terms of static carrying capacities—Griffiths' muted doubts and Clements' explicit admonitions notwithstanding.

In summary, the effects of Santa Rita research on regional rangelands are uncertain. Many management practices have been adopted, although we do not know how directly to attribute adoption to research findings. In some cases, such as the shift from stocker to cow-calf operations, the science may have reflected, rather than prompted, the actions of producers responding to market incentives. Santa Rita research did provide a relatively independent and objective point of reference for agencies and ranchers as they endeavored to control the number of livestock grazing on the region's Federal and State lands. This appears to have worked reasonably well provided that moisture was close to normal—although the norm may itself have been little more than a statistical artifact. Wet periods probably undermined ranchers' respect for agency guidelines (and perhaps the science behind them as well); dry periods probably undermined agencies' confidence in ranchers' judgment and intentions.

Whether observed changes in vegetation are reversible depends on whether twentieth century erosion has permanently altered the capacity of a given site to support the earlier vegetation (Turner and others 2003: 261). Where the answer is yes, overgrazing may have been responsible, and the threshold was probably crossed during a major drought. The static conception of carrying capacity—which Southwestern range scientists did not expressly denounce until the 1960s (Paulsen and Ares 1961), and which in practice remains pervasive to this day—may in turn be viewed as a contributing factor. In view of the writings of Griffiths and Clements, however, blame should fall not so much on the science produced from the Santa Rita and other experimental ranges as on the translation of research findings into policy and administration. Had Clements' dynamic notion of carrying capacity been more widely embraced, it is possible that the shortcomings of his theory would not be so obvious today: Agencies and ranchers might have adjusted stocking rates more aggressively, and the lasting damage of heavy grazing during drought might have been avoided. Then again, highly variable carrying capacities might have made Clements' theory economically and administratively impractical and precluded its adoption in the first place. Ironically, Clements himself feared that his theory might serve as "an excuse for overgrazing" (1920: 310), but whether any ranchers or agency officials rationalized heavy stocking in this way is unknown.

Conclusions

The decision to create the Santa Rita Experimental Range in 1903 rested on at least two interlocking premises. The first was that it was biogeographically representative of a large swath of Southwestern rangelands. Within its boundaries could be found conditions of vegetation, topography, soils, and climate similar to those of some 20 million acres in Arizona, New Mexico, and Texas (USDA 1952; fig. 7). The second was that it was a representative management unit, similar in size to the larger ranches that dominated the region. Both premises reflected the judgment that the highest economic use of Southwestern rangelands was grazing, such that research aimed at the needs of ranchers and range managers could benefit the entire area. A century later this judgment no longer holds, and both premises therefore warrant reconsideration.

The highest uses of rangelands today, economically speaking, are housing development and recreation. Livestock grazing in and of itself is relatively insignificant from this perspective, although in combination with other demands—for open space, wildlife habitat, and watershed function, for example—the overall value of ranching remains high. Without getting into whether social demands on rangelands complement or compete with one another, one can safely say that the "highest and best" use is no longer uniform. Rather, it varies depending on factors such as proximity to urban areas, transportation corridors, or recreational hotspots; the distribution of wildlife species and their habitats; amenity values such as scenery and fine weather; and the threats posed by wildfire, floods, and drought to urban and exurban settlements.

The landscape is further differentiated by the history of management. Under equilibrial assumptions this was a secondary matter because the essential features of the range were fixed by soils and climate and would reassert themselves if given a chance. In theory, once scientists figured out how things worked on the experimental range, their knowledge could be taken and applied elsewhere. Now things don't look so simple, because we understand—at least in theory—that discrete events or combinations of events may have shifted conditions in different ways at different places or times. Some drainages are cut by arroyos, while others are not. In some valleys Lehmann lovegrass was planted on large areas and has spread, while in others it is limited to roadways or absent altogether. Fields cleared for crops in the early 1900s still show the effects, decades after abandonment. In some places landscape-scale fires have happened in living memory, although in most they have not. All these factors are superimposed on the natural variability of rainfall across space and time as well as the complex patterns of slope, aspect, soils, and vegetation.

There is still a near consensus that native perennial grasslands are the most desirable state for the region's semiarid rangelands, but the goals of restoration are no longer rooted in livestock production nor measurable in terms of carrying capacity. Consequently, how to achieve restoration, and at what cost, are far from clear. New goals include wildlife conservation, watershed function, open space for recreation or for scenery, and ecological restoration. Most of these generate revenues only indirectly, if at all, and they are often pursued in the absence of long-term, site-specific data. Where were various wildlife species present at what points in the past? How many livestock did each watershed support during the drought of the 1950s? Which arroyos have grown in recent decades, which have aggraded, and what factors are responsible? In summary, a map of the areas to which knowledge from the Santa Rita might be applied today would look quite different from the one shown in figure 7.

The second premise is still true, but less universally so, and its significance is different from before. Fifty-six thousand acres remains a good size for addressing practical management problems on Southwestern ranches and on ranches converted to preserves (if not ranches that have subdivided). The nature of those problems has changed in fundamental ways, however, keyed to both spatial and

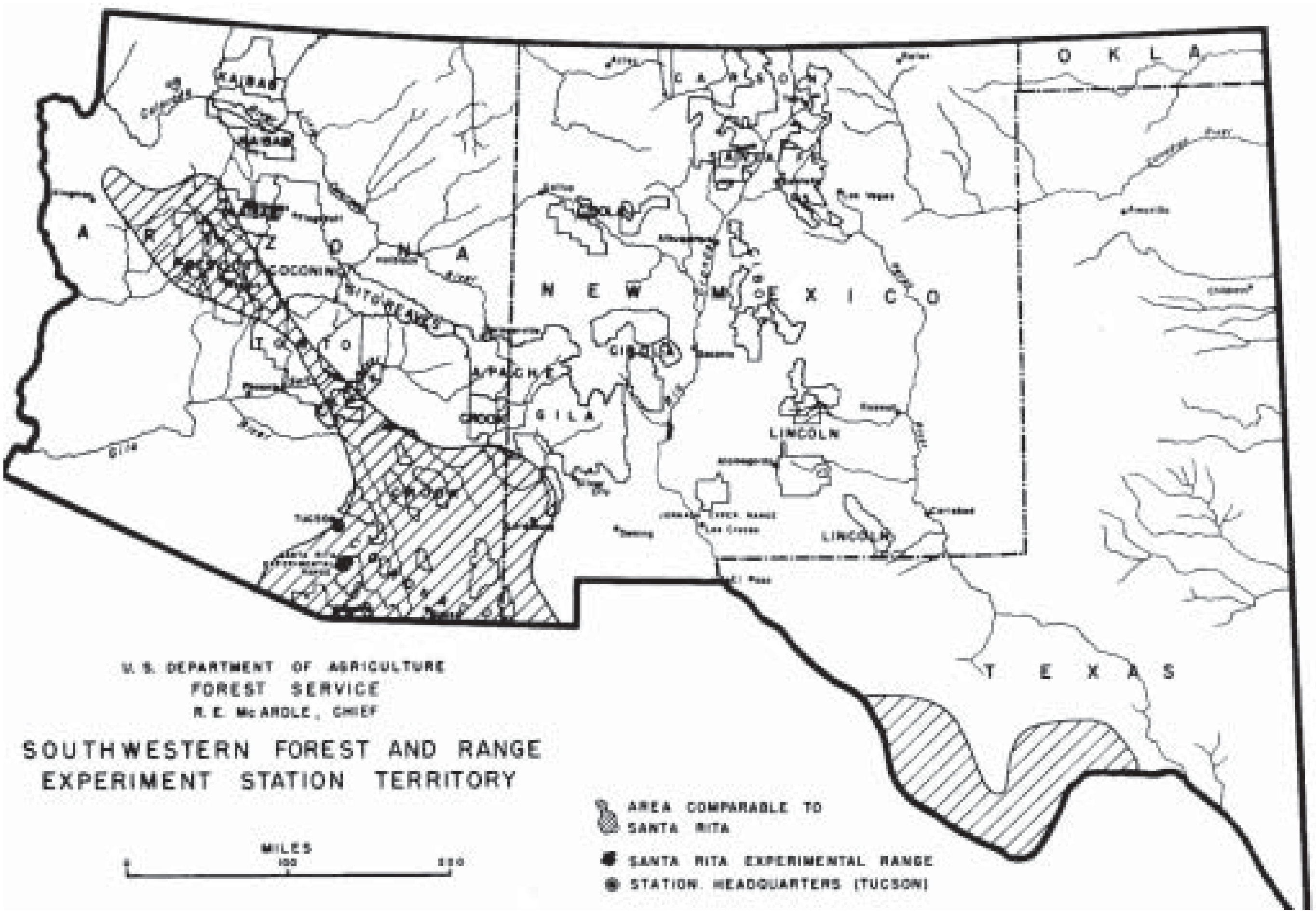

Figure 7—Map depicting the geographical areas deemed comparable to the Santa Rita Experimental Range, 1952. Although based primarily on biogeographical criteria, this judgment of the range of applicability of Santa Rita research also contained social and economic assumptions, many of which must be reconsidered in light of dramatic changes in the region's economy and demography (USDA 1952).

temporal scale. Although the Santa Rita is large, the vast majority of experiments conducted there have been relatively small (<100 acres, certainly); this reflected both practical constraints and the overriding interest in maximizing forage production and optimizing utilization. It was generally assumed that findings would extrapolate to larger areas unproblematically. More recent empirical and theoretical work casts doubt on this assumption, and today scientists aspire to landscape-scale observations and experiments.

A parallel change has occurred along the temporal axis. Most experiments have been less than 5 years in duration, but longer term data sets have had the most enduring value, even when they did not lead to publications. Perhaps the most valuable information derived from the Santa Rita in the past century, given today's needs and concerns, is the long-term series of matched photographs. The power of the photos is greater than just visual—it derives from their ability to capture change on a temporal scale unavailable to the mortal eye and impractical for more sophisticated techniques of data collection. With knowledge and concern about climate change growing, data reaching back a century are increasingly important. That more research has not been conducted over periods of about 50 years is regrettable, but it appears that it took that long for us to recognize the need. Stewarding and sustaining the Santa Rita is essential for the continuation of past research and for crafting further long-term studies designed to answer today's questions.

Finally, it is worth reconsidering the assumption that knowledge about rangelands must originate from experiments performed in places such as the Santa Rita. In 1903, few ranchers had more than 30 years' experience managing their lands, and it made sense to aspire to teach them what could be learned by careful scientific investigation. Today, there is a significant, albeit shrinking, number of ranchers whose families carry 100 or more years' experience in one place. Their history, and their knowledge, ought now be understood as a storehouse of genuine and valuable knowledge for the second century of range science in the Southwest.

References

Bowers, Janice E. 1990. A debt to the future: scientific achievements of the Desert Laboratory, Tumamoc Hill, Tucson, Arizona. Desert Plants. 10(1): 9–47.

Cable, Dwight R. 1971. Growth and development of Arizona cottontop (*Trichachne californica* [Benth] Chase). Botanical Gazette. 132(2): 119–145.

Cable, Dwight R. 1975. Influence of precipitation on perennial grass production in the semidesert Southwest. Ecology. 56: 981–986.

Chapline, William R.; Campbell, Robert S.; Price, Raymond; Stewart, George. 1944. The history of Western range research. Agricultural History. 18: 127–143.

Clements, Frederic E. 1916. Plant succession: an analysis of the development of vegetation. Publ. 242. Washington, DC: Carnegie Institution of Washington.

Clements, Frederic E. 1920. Plant indicators: the relation of plant communities to process and practice. Publ. 290. Washington, DC: Carnegie Institution of Washington.

Culley, Matt J. 1937. An economic study of cattle business on a Southwestern semidesert range. Circ. 448. Washington, DC: U.S. Department of Agriculture. 24 p.

Griffiths, David. 1901. Range improvement in Arizona. Bureau of Plant Industry Bull. 4. Washington, DC: U.S. Department of Agriculture. 31 p.

Griffiths, David. 1904. Range investigations in Arizona. Bureau of Plant Industry Bull. 67 (10 plates). Washington, DC: U.S. Department of Agriculture. 62 p.

Griffiths, David. 1907. The reseeding of depleted range and native pastures. Bureau of Plant Industry Bull. 117 (3 plates). Washington, DC: U.S. Department of Agriculture. 22 p.

Griffiths, David. 1910. A protected stock range in Arizona. Bull. 177. Washington, DC: U.S. Department of Agriculture. 28 p.

Herbel, Carlton H.; Gibbons, Robert P. 1996. Post-drought vegetation dynamics on arid rangelands of southern New Mexico. Agricultural Experiment Station Bull. 776. Las Cruces: New Mexico State University, College of Agriculture and Home Economics.

Hormay, A. L.; Talbot, M. W. 1961. Rest-rotation grazing: a new management system for perennial bunchgrass ranges. Production Res. Rep. 51. Washington, DC: U.S. Department of Agriculture, Forest Service. 43 p.

Humphrey, Robert R. 1959. Lehmann's lovegrass, pros and cons. In: Your range—its management. Rep. 2. Tucson: University of Arizona, Agricultural Experiment Station. 28 p.

Illius, A. W.; O'Connor, T. G. 1999. On the relevance of nonequilibrium concepts to arid and semiarid grazing systems. Ecological Applications. 9(3): 798–813.

Jardine, James T.; Hurtt, L. C. 1917. Increased cattle production on Southwestern ranges. Bull. 588. Washington, DC: U.S. Department of Agriculture.

Martin, S. Clark. 1973. A grazing system for semidesert ranges based on responses of grasses to seasonal rest. In: Abstracts of papers: 26th annual meeting, Society for Range Management; 1973 February; Boise, ID. Denver, CO: Society for Range Management: 21.

Martin, S. Clark. 1975. Ecology and management of Southwestern semidesert grass-shrub ranges: the status of our knowledge. Res. Pap. RM-156. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 39 p.

Martin, S. Clark. 1978. The Santa Rita grazing system. In: Hyder, Donald N., ed. Proceedings of the First International Rangeland Congress; 1978 August 14–18; Denver, CO. Denver, CO: Society for Range Management: 573–575.

Martin, S. Clark; Severson, Keith E. 1988. Vegetation response to the Santa Rita grazing system. Journal of Range Management. 41(4): 291–295.

Martin, William E.; Jefferies, Gene L. 1966. Relating ranch prices and grazing permit values to ranch productivity. Journal of Farm Economics. 48: 233–242.

Medina, Alvin L. 1996. The Santa Rita Experimental Range: annotated bibliography (1903–1988). Gen. Tech. Rep. RM-GTR-276. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 67 p.

National Research Council. 1994. Rangeland health: new methods to classify, inventory, and monitor rangelands. Washington, DC: National Academy Press. 180 p.

Parker, Kenneth W. 1943. Control of mesquite on Southwestern ranges. Leaflet 234. Washington, DC: U.S. Department of Agriculture. 8 p.

Parker, Kenneth W. 1948. An analysis of range problems in the Southwest. Unpublished report on file in: Archives of the Santa Rita Experimental Range, University of Arizona, box SRP 60. 130 p.

Parker, Kenneth W.; Martin, S. Clark. 1952. The mesquite problem on southern Arizona ranges. Circ. 908. Washington, DC: U.S. Department of Agriculture. 70 p.

Paulsen, Harold A., Jr.; Ares, Fred N. 1961. Trends in carrying capacity and vegetation on an arid Southwestern range. Journal of Range Management. 14(2): 78–83.

Potter, Alfred F. 1902. Report of the examination of the proposed Santa Rita Forest Reserve. Unpublished report on file in: Archives of the Santa Rita Experimental Range, University of Arizona, box SRP 67. 27 p.

Sampson, Arthur W. 1914. Natural revegetation of range lands based upon growth requirements and life history of the vegetation. Journal of Agricultural Research. 3(2): 93–147.

Sayre, Nathan F. 2000. Land use history of the Altar Valley. Task 3 of the Altar Valley watershed resource assessment. Tucson, AZ: Altar Valley Conservation Alliance.

Sayre, Nathan F. 2002. Ranching, endangered species, and urbanization in the Southwest: species of capital. Tucson: University of Arizona Press.

Smith, Jared G. 1899. Grazing problems in the Southwest and how to meet them. Division of Agrostology Bull. 16. Washington, DC: U.S. Department of Agriculture. 47 p.

Society for Range Management. 1995. New concepts for assessment of rangeland condition. Journal of Range Management. 48(3): 271–282.

Thornber, J. J. 1910. The grazing ranges of Arizona. Bull. 65. Tucson: University of Arizona, Agricultural Experiment Station. 360 p.

Toumey, J. W. 1891. Arizona range grasses in general; overstocking the range. Arizona Agricultural Experiment Station Bull. 2. Tucson: Arizona Agricultural Experiment Station.

Turner, Raymond M.; Webb, Robert H.; Bowers, Janice E.; Hastings, James Rodney. 2003. The changing mile revisited. Tucson: University of Arizona Press.

Upson, Arthur; Cribbs, W. J.; Stanley, E. B. 1937. Occurrence of shrubs on range areas in southeastern Arizona. Unpublished report issued by the Arizona Agricultural Experiment Station. On file in: Archives of the Santa Rita Experimental Range, University of Arizona, box SRP 60. 30 p.

U.S. Department of Agriculture. 1952. The Santa Rita Experimental Range. Booklet (revised). Tucson, AZ: U.S. Department of Agriculture, Forest Service, Southwestern Forest and Range Experiment Station. 17 p.

Webb, George E. 2002. Science in the American Southwest. Tucson: University of Arizona Press.

Wooten, E. O. 1916. Carrying capacity of grazing ranges in southern Arizona. Bull. 367. Washington, DC: U.S. Department of Agriculture. 40 p.