BOTANIC AND HYDROLOGIC CHANGES ON RANGELANDS OF THE RIO PUERCO BASIN, NEW MEXICO

U.S. GEOLOGICAL SURVEY

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By Farrel A. Branson and Anne Janicki

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METRIC CONVERSION FACTORS

For the convenience of readers who may want to use the International System of Units (SI), the data may be converted using the following factors:

Multiply inch-pound units	*By*	*To obtain SI units*
acre	0.4047	hectare
acre-foot (acre-ft)	1,233	cubic meter
foot (ft)	0.3048	meter
inch (in.)	25.40	millimeter
	0.39	centimeter
mile (mi)	1.6093	kilometer
pound (lb)	0.4536	kilogram
pound per acre (lb/acre)	0.4425	kilogram per hectare
pound per cubic foot (lb/ft^3)	1.602	kilogram per cubic meter
square mile (mi^2)	2.590	square kilometer

To convert degrees Fahrenheit (°F) to degrees Celsius (°C), use the following formula: $°C = (°F-32) \times 5/9$.

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ABSTRACT

A 380-percent increase in vegetation cover occurred in the Cornfield Wash watershed, in the Rio Puerco basin, New Mexico, from 1958 to 1979. Apparent causes for the increased vegetation were increased precipitation and decreased grazing intensities after the initial vegetation sampling. Although precipitation increased, both runoff and suspended-sediment loads from the Rio Puerco basin decreased after 1958. Vegetation improvement is considered a cause for these hydrologic changes.

INTRODUCTION

The Rio Puerco basin, containing the Cornfield Wash study area, provides a typical example of extreme range deterioration (Widdison, 1959), resulting in spectacular valley trenching (Bryan, 1928) and excessive sediment yields (Dortignac, 1956). Although this report is concerned primarily with vegetation changes, the factors affecting erosion and transport of sediment include vegetation, climate, soil character, and topography. According to Antevs (1952), "Arroyo-cutting takes place because the plant and soil mantle is poor or destroyed and permits the water of violent showers to run off too fast and form torrents in trails, ruts, ditches, and stream beds." Increased vegetation cover serves to intercept precipitation, decrease raindrop splash erosion, increase infiltration, bind the soil, and increase surface roughness, thereby slowing runoff and decreasing its erosive capacity (Costa and Baker, 1980).

Cyclical erosion has occurred throughout time in the southwestern United States. Erosion prior to extensive use of the area for grazing of cattle and sheep is considered to have been caused by extreme droughts; arroyo-cutting since 1875 is attributed to overgrazing and cyclic fluctuations in climate (Antevs, 1952; Bryan, 1928). However, "In the last two decades, controlled grazing and a shift to cooler climates seem to have reversed the gullying trend" (Costa and Baker, 1980).

Trenching of the valley floor of the Rio Puerco basin began between 1885 and 1890 (Bryan, 1928); by the late 1920's, it had proceeded upstream more than 110 mi. Trenching occurred to a depth of 50 ft, and channel width enlarged from 75 ft to 790 ft in several places between 1881 and 1939 (Widdison, 1959). Overgrazing within the basin caused decreased forage and increased surface runoff and erosion (Widdison, 1959). Trenching of the Rio Puerco destroyed diversion dams that formerly provided water for irrigation.

These changes resulted in abandonment of several ranches and six small towns that were largely dependent on irrigation (Widdison, 1959). This report will document vegetation changes in a subbasin of the Rio Puerco and in the Rio Puerco basin from 1958 to 1979 and evaluate the cause and effect of such changes.

Description of the Study Area

Cornfield Wash is a tributary of the Rio Puerco by way of Arroyo Torreon and Arroyo Chico (fig. 1). The Cornfield Wash watershed is located about 55 mi northwest of Albuquerque and about 15 mi southwest of Cuba. Average altitude is about 6,500 ft above sea level. Average annual precipitation for the area is about 10 in. The peak rainfall month is August, and about one-half of the annual precipitation falls during July, August, September, and October. At Cuba (slightly higher at an altitude of 6,900 ft), the maximum recorded temperature is 102°F, and the minimum recorded temperature is -40°F. The range of mean maximum summer temperatures (May through September) is 70°F to 85°F. Prominent vegetation types in the watershed are desert grassland, big sagebrush, and pinyon-juniper woodland.

Altitudinal extremes in the Rio Puerco basin are 4,725 ft to 11,301 ft; precipitation ranges from 8 in. to 30 in. Vegetation types in the Rio Puerco basin are saltbush-greasewood, desert grassland, big sagebrush, pinyon-juniper woodland, ponderosa pine, and spruce-fir forest (Dortignac, 1956).

Methods for Determining Botanic Changes

Two exclosures, each about 150 ft on each side, were constructed in Cornfield Wash during 1957. These exclosures were in two different adjacent pastures, separated by a boundary fence between two grazing allotments (fig. 2). A five-strand, barbed-wire fence surrounded each exclosure. At the time of construction, one of the allotments was grazed by sheep and the other by cattle. The area that had uncontrolled grazing by sheep during 1958 became a fenced pasture during 1964, and all gates were padlocked when that area was visited during 1979. In recent years, the allotment formerly grazed by sheep was used by cattle.

Two 100-ft transects were established inside, and two 100-ft transects were placed outside and adjacent to each of the two exclosures. A frame containing 10 pins spaced at 2-in. intervals was placed parallel to a tape to give 600-point readings along each of the 8 transects. Steel fenceposts driven one-half way into the ground were used to "permanently" mark the ends of transects. In an attempt to make measurements of grazed (outside exclosures) and ungrazed (inside exclosures) vegetation comparable, the basal point-quadrant method (Levy and Madden, 1933) was used. Aerial cover changes greatly within seasons on both grazed and nongrazed areas, but measurements of basal-vegetation cover generally are comparable, because basal cover remains relatively constant within seasons. Basal-cover data represent contacts by

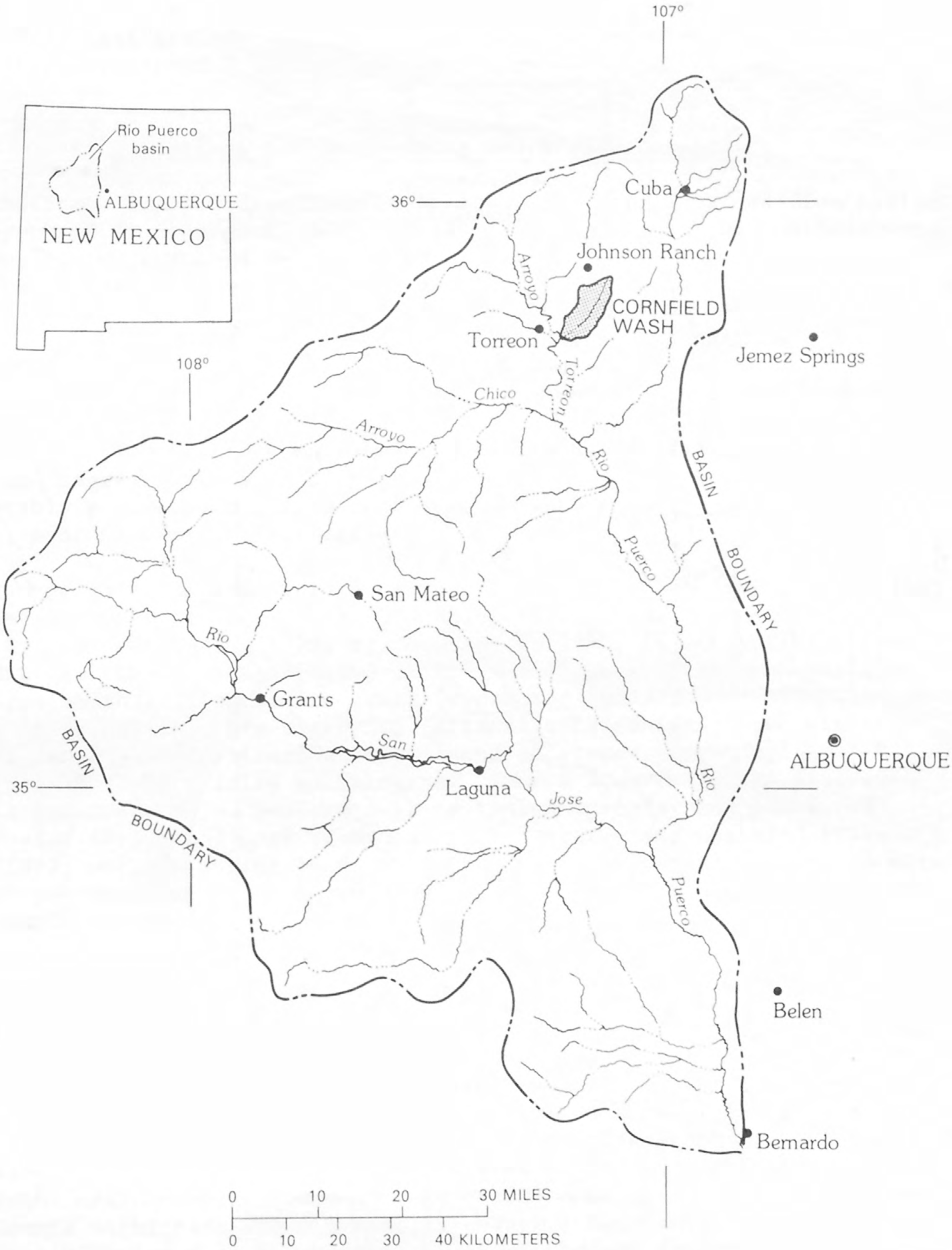

Figure 1.--Location of Cornfield Wash within the Rio Puerco basin.

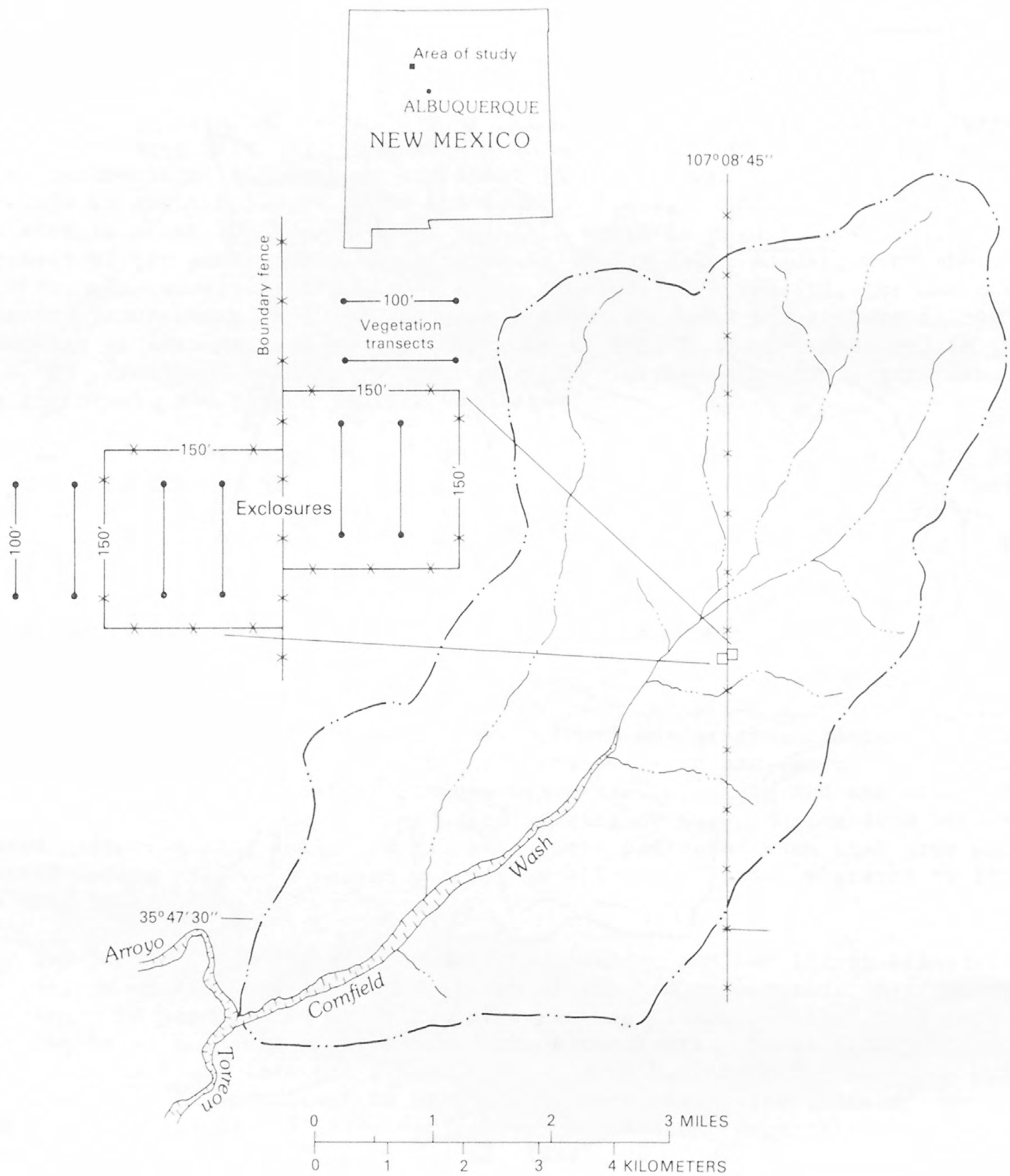

Figure 2.--Locations of exclosures within Cornfield Wash and diagram of vegetation transect locations within and outside exclosures.

pin projections on crowns of bunchgrasses and bases of stems of rhizomatous-grass species, forbs, and shrubs. All vegetation transects were photographed in 1958 and 1979. Sampling procedures followed notes made on records written during 1958, that stated, "When there was doubt about when a contact was made, a contact was recorded."

Methods for Determining Hydrologic Changes

Runoff and suspended-sediment discharge data were obtained from publications by the U.S. Geological Survey (1949-79). For hydrologic methods used, these publications should be consulted.

BOTANIC CHANGES AND FACTORS AFFECTING THE CHANGES

When measured in 1958, one year after exclosure construction, there appeared to be large differences in vegetation cover on grazed and ungrazed plots (fig. 3). However, when remeasured in 1979, the difference between grazed and ungrazed plots remained similar, but differences between years were considerably greater indicating that some causative factor, in addition to grazing, must have been important.

Changes in kinds and amounts of vegetation are shown in table 1. The increase in number of species (representing an increase in vegetation diversity) present during 1979, as compared to 1958, is noteworthy. Some of the additional species on ungrazed plots in 1979 were: western wheatgrass (*Agropyron smithii*), Indian ricegrass (*Oryzopsis hymenoides*), alkali sacaton (*Sporobolus airoides*), big sagebrush (*Artemisia tridentata*), and winterfat (*Eurotia lanata*). Additional species found on grazed plots during 1979, and not during 1958, were false buffalograss (*Munroa squarrosa*) and stickseed (*Lappula heterosperma*). Squirreltail (*Sitanion hystrix*) and snakeweed (*Gutierrezia sarothrae*) were recorded on both grazed and ungrazed transects during 1979, but not during 1958. Total contacts on grasses increased more than 400 percent during the 22-year interval; total contacts on live cover (for example, grasses, forbs, and shrubs) increased 380 percent.

A most noticeable change, both in transect data and photographic evidence, was the decrease of the Russian thistle (*Salsola kali*) from the dominant species on most plots during 1958, to minor importance or absence during 1979. Only in the pasture formerly grazed by sheep (outside the exclosure) did Russian thistle show a slight increase. Perennial species, especially grasses, increased on all plots, almost to replace annuals (figs. 4 and 5). Greater abundance of Russian thistle in the 1958 photograph (fig. 5) gives the impression of less bare soil, than is evident in the 1979 photograph, although basal-point measurements showed a large decrease in bare soil; aerial-cover measurements might have shown a smaller change. Russianthistle seed is disseminated during fall and winter, as plants become detached from the soil and are moved by wind, a process that leaves soil unprotected from raindrop-splash action and the erosive effects of water movement over the soil surface. No Russian thistle is visible in the 1979 photograph. The change from tap-rooted Russian thistle to fibrous-rooted perennial grasses undoubtedly resulted in decreased erosion potential.

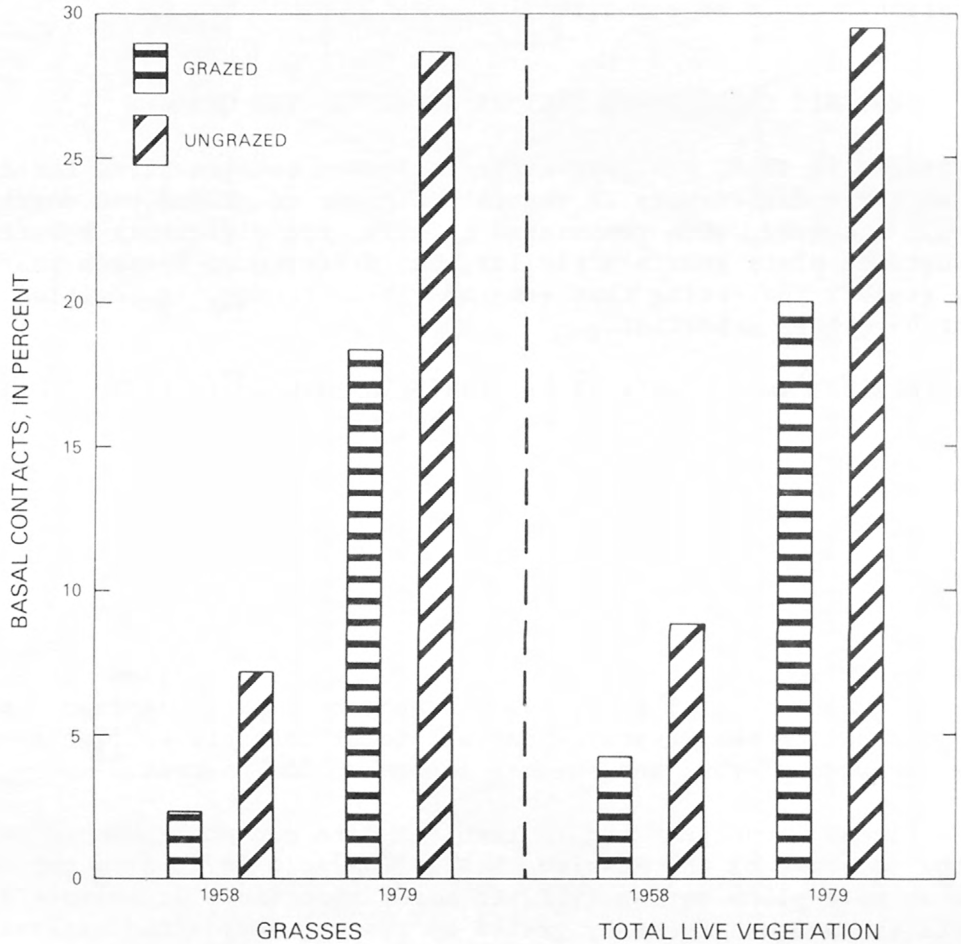

Figure 3.--Grasses and total live vegetation measured on grazed and ungrazed plots, 1958 and 1979.

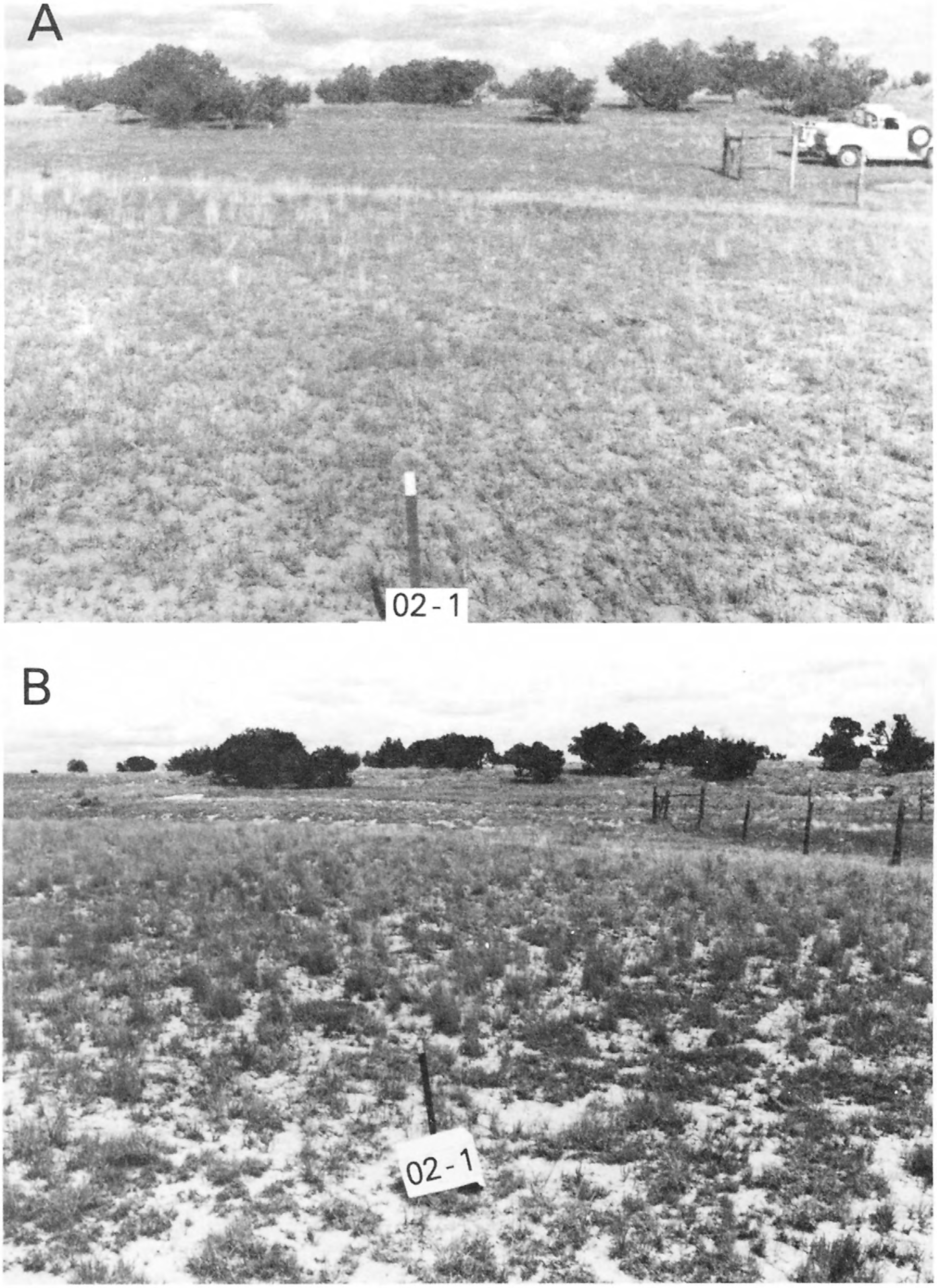

Figure 4.--Outside exclosure (A) during 1958, plant cover consisted mostly of Russion thistle with scattered galleta and blue grama. When measured during 1979 (B), Russian thistle had been replaced almost entirely by perennial grasses.

Table 1.--*Basal contacts, in percent, of vegetation, mulch, rock, and bare*

[Measurements were made inside (ungrazed and outside

Grazing status	Transect number	Year	Grasses									
			Agropyron smithii	*Aristida arizonica*	*Bouteloua gracilis*	*Hilaria jamesii*	*Muhlenbergia torreyi*	*Munroa squarrosa*	*Oryzopsis hymenoides*	*Sitanion hystrix*	*Sporobolus airoides*	*Sporobolus cryptandrus*
Un-grazed	1-1	1958	--	--	5.8	2.0	0.3	--	--	--	--	--
	1-1	1979	--	--	22.7	1.5	2.8	--	--	0.8	--	0.2
	1-2	1958	--	--	1.3	.7	--	--	--	--	--	.5
	1-2	1979	0.2	--	16.0	2.2	--	--	--	--	--	--
Grazed	01-1	1958	--	--	.3	.5	.2	--	--	--	--	--
	01-1	1979	--	--	2.8	6.5	3.3	.2	--	.3	--	.8
	01-2	1958	--	--	1.5	.7	--	--	--	--	--	--
	01-2	1979	--	--	8.2	4.0	2.5	--	--	--	--	1.2
Un-grazed	2-1	1958	--	0.3	3.3	2.8	--	--	--	--	--	1.2
	2-1	1979	.8	1.7	11.3	10.0	3.2	--	--	--	1.8	2.2
	2-2	1958	--	--	9.5	.8	--	--	--	--	--	.3
	2-2	1979	.5	--	34.0	1.8	--	--	0.3	--	.8	--
Grazed	02-1	1958	--	.5	1.2	1.3	.2	--	--	--	--	.2
	02-1	1979	--	6.2	9.2	7.0	1.2	--	--	--	--	--
	02-2	1958	--	--	.2	2.0	--	--	--	--	--	.3
	02-2	1979	--	7.5	1.0	12.5	.5	--	--	--	--	.3

soil as measured by the basal-contact point-quadrant method

of two exclosures during 1958 and 1970]

Forbes			Shrubs						
Salsola kali	*Lappula heterosperma*	Unidentified forb	*Artemisia tridentata*	*Eurotia lanata*	*Gutierrezia sarothrae*	Mulch	Bare soil	Rock	Total live cover
1.7	--	--	--	--	--	11.0	79.2	--	9.8
.8	--	--	--	--	0.2	19.5	51.2	--	29.0
3.0	--	--	--	--	--	19.8	74.7	--	5.5
--	--	--	1.0	0.5	--	34.8	45.3	--	19.9
2.0	--	--	--	--	--	22.8	73.9	0.3	3.0
2.7	--	--	--	--	1.2	16.5	63.3	2.3	15.8
1.3	--	0.2	--	--	--	17.0	79.1	.2	3.7
2.0	0.3	--	--	--	.2	20.0	.2	.3	18.4
1.2	--	--	--	--	--	19.7	71.5	--	8.8
.2	--	--	--	--	.3	18.2	48.0	2.2	31.5
.7	--	--	--	--	--	22.8	65.2	.7	11.3
--	--	--	--	--	--	18.5	43.3	.8	37.4
2.0	--	--	--	--	--	16.7	75.7	2.2	5.4
--	--	--	--	--	.2	10.8	63.0	7.5	23.8
2.2	--	--	--	--	--	17.8	75.8	1.7	4.7
--	--	--	--	--	--	9.5	66.0	2.7	21.8

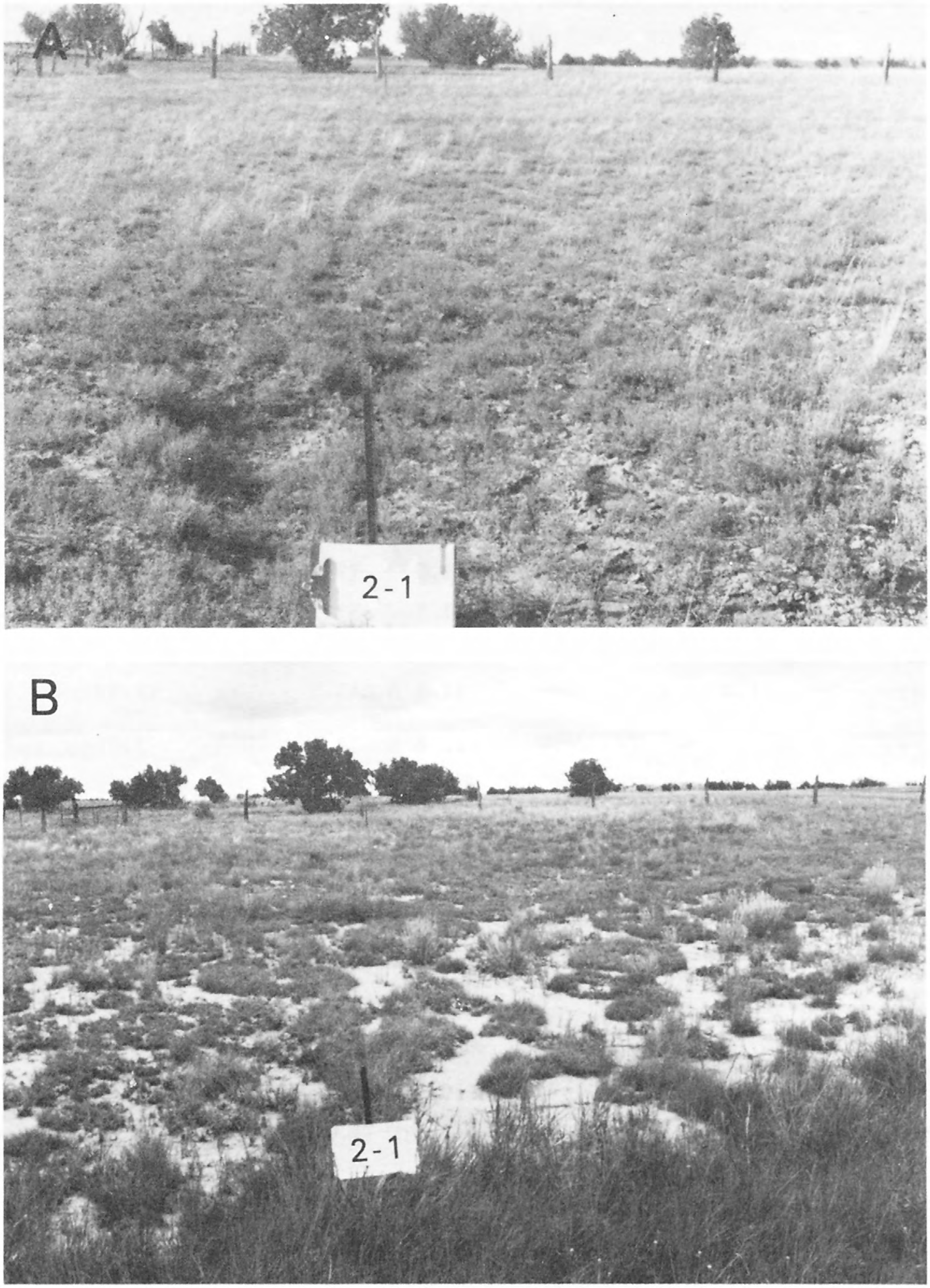

Figure 5.--Cover inside exclosure (A) during 1958 was similar to cover outside, consisting of Russian thistle with scattered plants of galleta and blue grama. Prominent species not present during 1958, but abundant during 1979 (B), were winterfat in the midground and a colony of western wheatgrass in the foreground.

Vegetation changes similar to those documented for the Rio Puerco basin occurred elsewhere in the Southwest. For example, on the Navajo Indian Reservation in northeastern Arizona, Campbell (1970) found, "The Klethla Valley is today dominated by almost pure stands of Russian thistle." Russian thistle did not become abundant in the valley until the 1920's "...at the earliest...," but was widespread during 1937 and "...continues to persist as the dominant..." (Campbell, 1970). As was true in many parts of the Southwest, trenching of channels began on the reservation during the 1880's. Between 1883 and 1937, 25 mi of trenching 50 ft deep occurred on Laguna Creek. Today, most of the gulleys are stabilized even though sheep units, yearlong, increased from 20,506 during 1937 to 35,000 during 1966 (Campbell, 1970). No explanation is offered for this phenomenon, but we suspect that increased precipitation after the drought of the 1930's had caused an increase in forage production that permitted increased animal numbers without further damage to the range resource.

For the middle Rio Puerco Valley, Widdison (1959) observed, "The grass cover of many large areas has been ruined by overgrazing and replaced by Russian thistle (*Salsola kali tunuifolia*)." Livestock numbers of the Rio Puerco basin peaked during 1900, then decreased by 60 percent by 1935, largely due to decreased forage production.

In an earlier study (1958-60) of four small subwatersheds (6 to 1,952 acres) in the Cornfield Wash watershed (Burkham, 1966), Russian thistle was a major vegetation component. In these subwatersheds, average annual yields were 267 lb/acre for Russian thistle and 224 lb/acre for all grasses. Additional vegetation accounted for only 15 lb/acre. It is probable that continued intensive grazing by sheep prior to 1958 caused Russian thistle to be the dominant species on these watersheds. The improvement in vegetation by 1979 (table 1) leads one to suspect that similar changes have occurred in the entire Rio Puerco basin, and possibly also in the Navajo Indian Reservation studied by Campbell (1970).

On U.S. Forest Service lands in New Mexico from 1939 to 1964, vegetation improved in both species composition and cover for both grazed and ungrazed areas within most of the six vegetation types studied (Potter and Krenetsky, 1967). Our data agree with Potter and Krenetsky's (1967) findings that, within the vegetation type most similar to that in the Cornfield Wash watershed, desert-grassland forbs (species not reported) decreased, and grass cover increased nearly 300 percent on both grazed and ungrazed plots. Vegetational improvement was reported for other vegetation types (grassland, pinyon-juniper, ponderosa pine, and aspen), that also may have significance for similar vegetation types in the Rio Puerco basin. Climatic effects are not discussed, but dry years during the 1930's may have contributed to sparse plant cover during 1939, whereas, the moist years following 1939 resulted in more vegetation cover during 1964.

Improvement in vegetation from 1958 to 1979 was substantial; the obvious questions are: Why did the change occur? How did the change affect other variables within the basin? Possible causes are discussed in the next section.

Changes in Stocking Rates

Data on livestock-grazing intensities for the Rio Puerco basin are not readily available, if available at all, for the years of interest. However, information for the entire State of New Mexico (fig. 6) and trends in livestock numbers for the State are expected to be similar to those for the Rio Puerco basin.

Prior to 1964, the pasture east of the boundary fence (fig. 2) was licensed by the U.S. Bureau of Land Management for cattle only, at a rate of 4.2 acres per animal-unit month. This stocking rate was decreased to 5.4 acres per animal-unit month for 1964. Results of a range survey by the U.S. Bureau of Land Management during 1975 indicated the proper stocking rate to be 18 acres per animal-unit month; the proposed implementation of this rate was subjected to court action during 1980.

Stocking rates before 1964, in the pasture west of the boundary fence (fig. 2) in the study area, apparently are unknown; however, observations by the senior author during 1958, 1959, and 1960 indicated intensive use by sheep and goats. A probable reason for the heavy use was development of numerous livestock reservoirs during 1950 and virtually uncontrolled grazing. The pasture was fenced during 1964, and a licensed stocking rate of 4.7 acres per animal-unit month was established.

Although grazing intensity decreased during more than 2 decades between vegetation samplings, the fact that vegetation improvement, both inside and outside the livestock exclosures, was about the same, indicates that some factor other than grazing may have caused the positive response of vegetation.

Changes in Climatic Variables

Although climatic fluctuations are difficult to assess in areas where records are short and sporadic, statistical analyses were conducted in an attempt to determine whether a statistically significant increase in precipitation occurred from 1958 to 1979 in both the study area and the Rio Puerco basin as a whole. (All climatic data presented in this report are from records published by the U.S. Weather Bureau of 1949-80.)

Thirty years of mean annual precipitation records at Johnson Ranch (about 1 mi north of Cornfield Wash) were evaluated, using a chi-square test and a t-test. Results did not indicate a statistically significant increase in precipitation after 1957, as compared to precipitation before 1957, at the 0.05 level of significance.

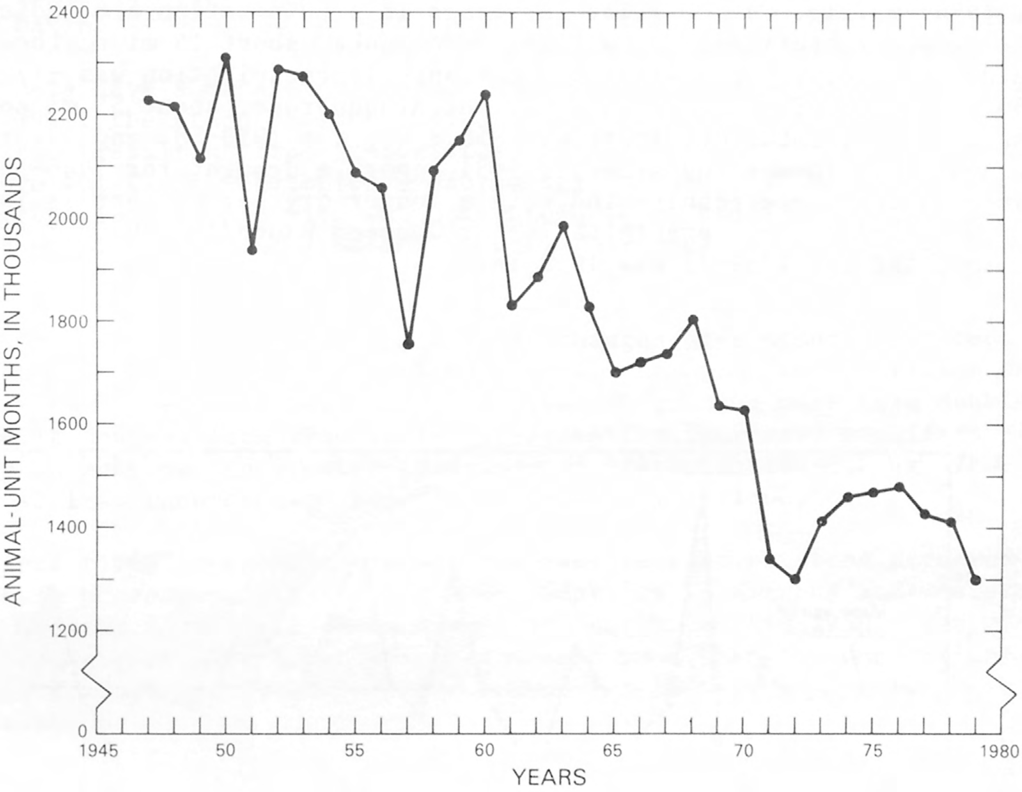

Figure 6.--Use by livestock (in animal-unit months) of Public Domain rangelands in New Mexico for 1947-79. (Data from U.S. Bureau of Land Management, written commun., 1980.)

In evaluating precipitation changes in the Rio Puerco basin, an eight-station average of mean annual precipitation records were evaluated, using the same statistical tests. Once again, results did not indicate an increase in precipitation at the 0.05 level of significance; however, the calculated chi-square value was significant at levels greater than or equal to 0.1. This appears to indicate that statistical significance might be obtained, had the period of record prior to 1957 been longer. In this remote area, records begin around 1949, leaving only 9 years to evaluate conditions prior to 1957.

Although statistical tests do not tend to support climatic fluctuation as a cause for increased vegetation in the study area, comparisons of total departure from the mean and cumulative precipitation through time indicate apparent increases in precipitation after 1957. Total departure from mean annual precipitation at Johnson Ranch was -7.17 in. for 1950-58, and was +6.69 in. for 1959-79 (fig. 7). Similar increases in precipitation are indicated for other weather stations in New Mexico. At Cuba, about 15 mi northeast of Cornfield Wash, total departure from mean annual precipitation was -17.04 in. for 1950-58, and +4.35 in. for 1959-79. At Albuquerque, about 55 mi southeast of Cornfield Wash, total departure was -16.8 in. for 1950-58, and was +10.32 in. for 1959-79. Thomas and others (1963) report a drought for 1946-56 in the Rio Grande basin; these results indicate a longer dry period than is indicated in figure 6. Mean annual precipitation at Johnson Ranch for 1950-58 (fig. 8) was 9.6 in., and for 1959-79 was 10.8 in.

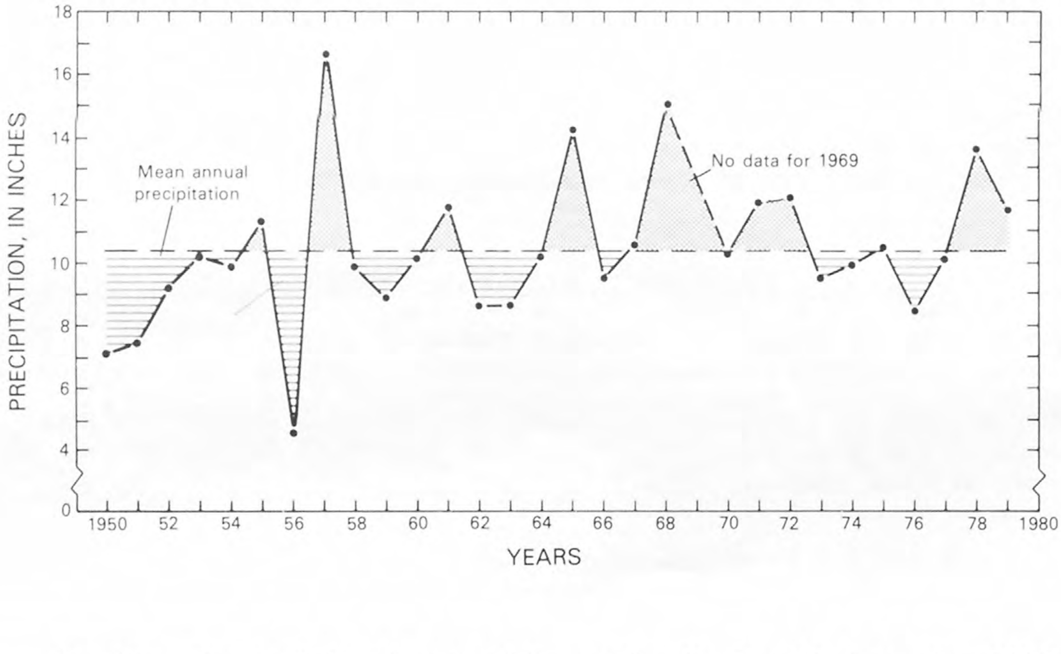

Figure 7.--Annual precipitation at Johnson Ranch, New Mexico, for 1950-79. (The horizontal dashed line is the mean annual precipitation for the period of record.)

Temperature changes in the Río Puerco basin tend to be the inverse of those for precipitation; these temperature differences tend to compound the beneficial and adverse effects of wet and dry periods. At Albuquerque, the accumulated departures (algebraic sum) from the mean were 13.8°F lower for 1959-79 than for 1950-58. At Cuba, the change for the two periods was small--a decrease of 0.7°F for 1959-79. No temperature records are available from the nearby Johnson Ranch. In the relatively warm climate of the study area, lower temperatures would decrease evaporation and result in more water available for vegetation production.

Cumulative mean annual precipitation (single mass curves) for eight stations in and near the Rio Puerco basin (airport at Grants, Belen, Cuba, Jemez Springs, Johnson Ranch, Laguna, San Mateo, and Torreon; see fig. 1) is shown in figure 8. The eight stations are distributed almost uniformly in and near the basin.

The data have a break in slope on the regression line occurring between 1955 and 1957; the steeper slope indicates a more rapid accumulation of precipitation resulting from greater-than-average rainfall after 1957 (the year before the first vegetation measurements in Cornfield Wash). Although this increase in precipitation was not enough to be statistically significant, further analysis indicates a marked change from conditions existing prior to 1957.

In the northern Great Plains, similar changes have occurred--recent increased precipitation and associated vegetation improvement (Branson and Miller, 1981; White and others, 1978). Although grazing more than doubled in a pasture in Montana from 1960 to 1977, vegetation increased significantly, primarily in response to greater-than-average precipitation during 1960-77, compared to less-than-average precipitation during 1951-60.

Sellers (1960) determined that a decrease in precipitation occurred for the 50 years preceding 1959 at 18 weather stations in Arizona and western New Mexico. Sellers (1960) also considered the drought of the 1950's the most severe for the past 350 years, possibly more severe than the one during the 13th century, that is thought to have caused Indian migrations from Mesa Verde, Colorado.

HYDROLOGIC CHANGES RESULTING FROM BOTANIC CHANGES

The Rio Puerco basin is of interest because of its extensive valley trenching and excessive sediment yields in relation to runoff. As mentioned previously, vegetation is a major factor affecting the rate and extent of erosion in a drainage basin. Therefore, the question may be asked: What are the implications of changes in vegetation in the Cornfield Wash watershed for the entire Rio Puerco basin?

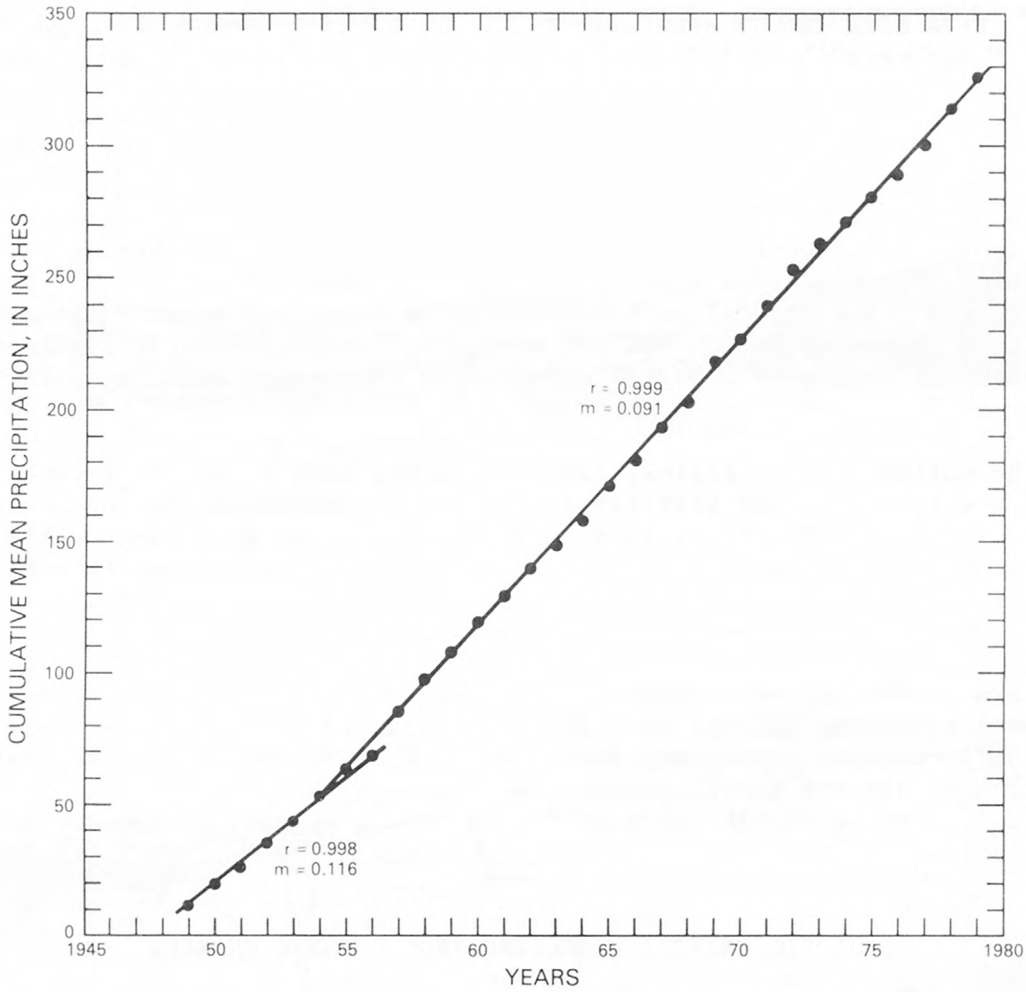

Figure 8.--Cumulative precipitation in the Rio Puerco basin. Each data point is the mean of values obtained from eight National Weather Service stations [airport at Grants, Belen, Cuba, Jemez Springs, Johnson Ranch, Laguna, San Mateo, and Torreon (fig. 1)] in and near the basin; r = correlation coefficient, m = mean or average of values.

For any given volume of precipitation, changes in the soil and vegetation conditions in a basin will cause variation in the portion of precipitation that does not contribute to direct runoff. The trend of the cumulative ratio of runoff to precipitation (the proportion of precipitation that occurs as runoff) tends to support this statement (fig. 9). Although precipitation increased from 1957 through 1979, runoff as a proportion of precipitation decreased. The larger quantities of precipitation retained on the land would be expected to result in greater amounts of vegetation present in years after 1957, and greater amounts of vegetation would contribute to decreases in both runoff and sediment yields.

For both the Rio Puerco basin and the two subbasins, trends toward decreased runoff as related to precipitation began about 1960. The change in curve slopes occurred during 1957 for the Rio Puerco basin and Arroyo Chico; the trend for Rio Puerco upstream from Arroyo Chico is not definite until 1961. Ratios, such as those plotted in figure 9, usually are more easily understood if converted to percent. Runoff as a percent of precipitation increased with a decrease in size of watershed (Rio Puerco basin = 6,220 mi^2; Arroyo Chico = 1,390 mi^2; and Rio Puerco upstream from Arroyo Chico = 420 mi^2). Precipitation during 1957 was greater than in any other year during 1950-79 and caused greater-than-average runoff from and within the Rio Puerco basin. Two other years, 1969 and 1972, also were characterized by greater-than-average precipitation, but the increased precipitation during these years did not result in noticeable increases in runoff, except for a possible antecedent-moisture effect on 1973 runoff from the Rio Puerco upstream from Arroyo Chico. Curves plotted for cumulative runoff (not shown) for the same time period have shapes very similar to those for precipitation-runoff ratios shown in figure 9; these curves also have similar interpretations.

The additional decrease in the precipitation-runoff ratio after 1967 (as shown in the curve for Arroyo Chico; fig. 9) may have been the result of additional vegetation improvement and associated increase in infiltration. For almost the same years (1960 to 1977), increased precipitation caused significant improvement in vegetation cover and forage production in northeastern Montana (Branson and Miller, 1981). Vegetation cover is related closely to infiltration rates. In the comprehensive study by Rauzi and others (1968), total vegetation cover was more closely related to infiltration rates ($r = 0.586$; significant at $p = <0.01$) than the additional 14 variables studied within 9 range-soil groups located in 6 States. Results for Rio Puerco upstream from the confluence with Arroyo Chico (6 percent of the basin) indicated a similar decrease in the precipitation-runoff ratio during 1967-79.

Cumulative suspended-sediment loads for the Rio Puerco basin also decreased during 1957-79 (fig. 10). Mean sediment load for 1948-57 was 3,293 acre-ft, and for 1958-79 it was 1,919 acre-ft. This decrease also may be a response to improved vegetation within the basin during the moist period of 1957-79. In eight small subwatersheds in the Cornfield Wash watershed, Shown (1971) determined that sediment yields decreased as vegetation plus mulch increased ($r^2 = 0.79$; significant at $p = <0.01$) and runoff increased as bare soil increased (Shown, 1971; Branson and Owen, 1970).

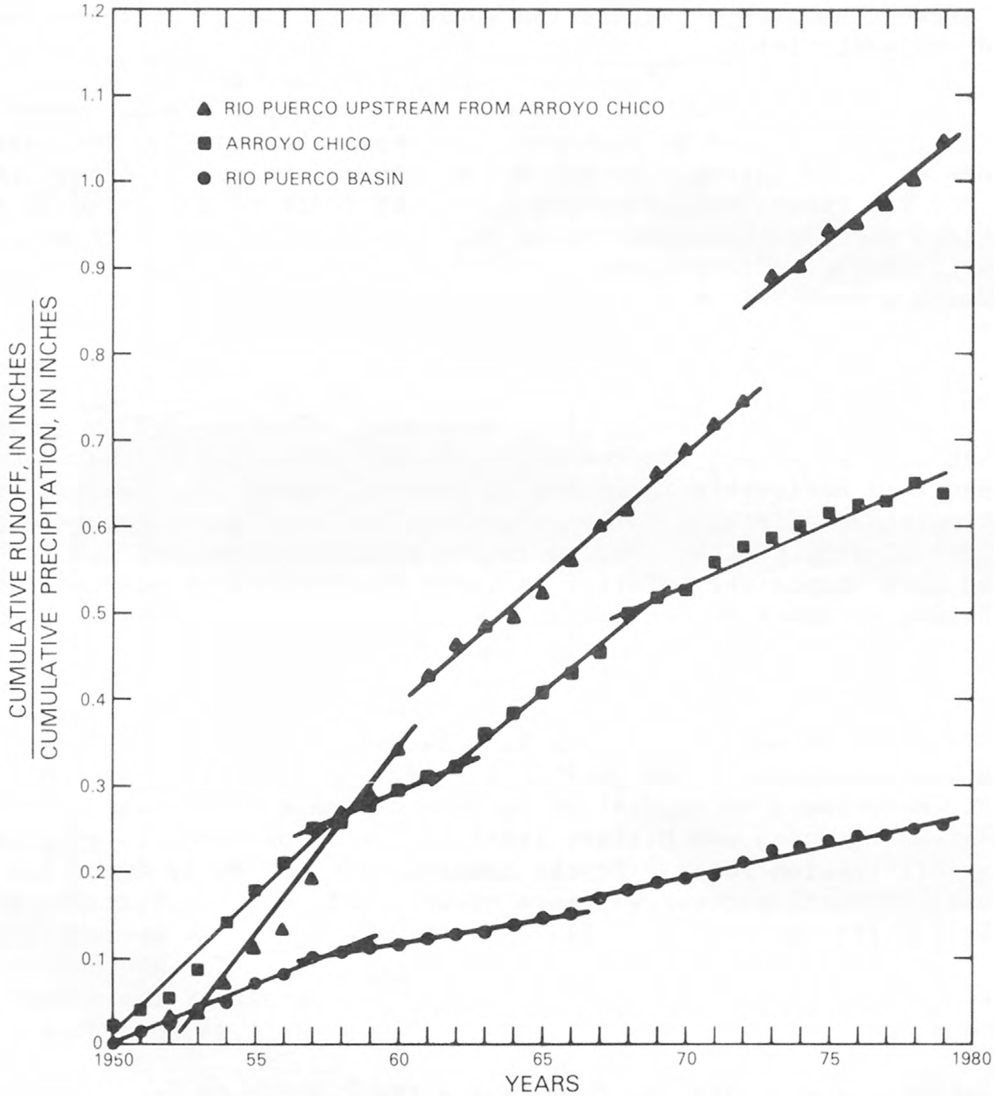

Figure 9.--Cumulative ratios of runoff to precipitation for the Rio Puerco basin and two subbasins within the basin: Arroyo Chico subbasin and Rio Puerco upstream from the confluence with Arroyo Chico.

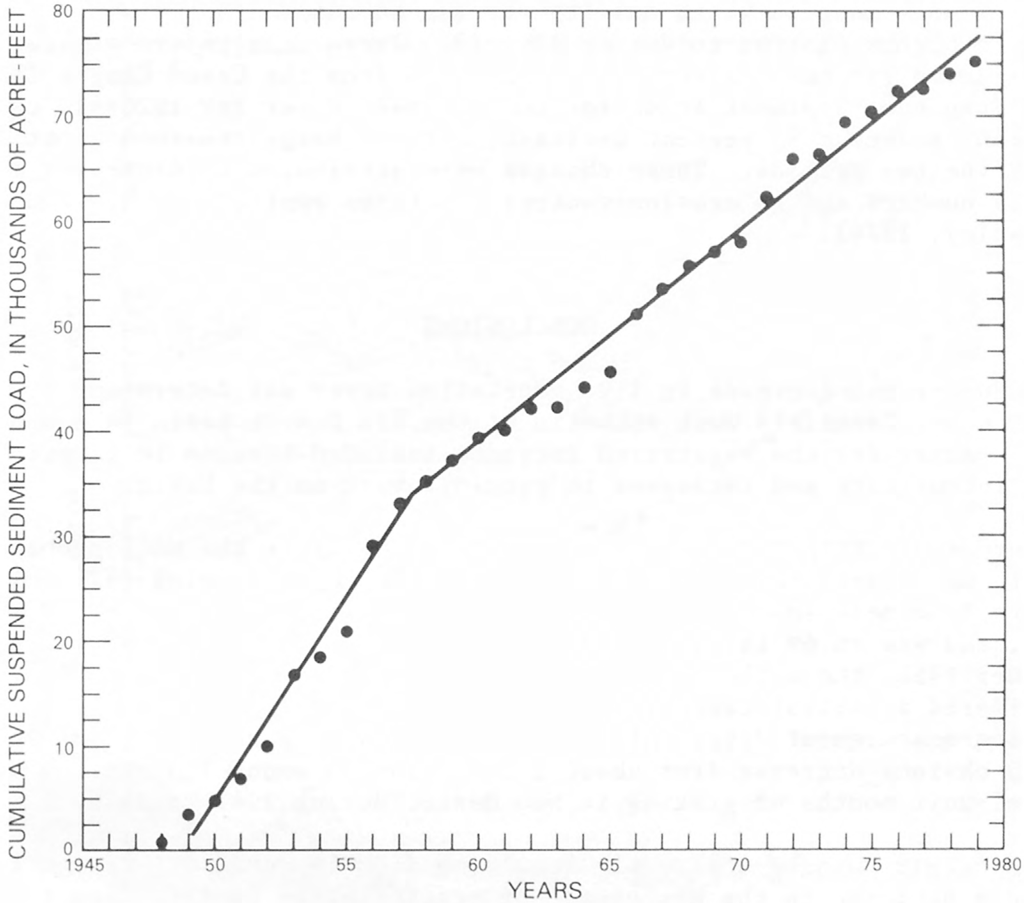

Figure 10.--Cumulative suspended-sediment loads for the Rio Puerco basin, 1948-79.

Ratios of sediment yields to runoff (fig. 11) for the Rio Puerco basin showed changes similar to those for runoff and sediment yields, but the change to smaller ratios, indicating lower sediment yields, occurred about 5 years later (1962, as compared to 1957). Mean sediment ratio for 1949-61 was 0.108, and for 1962-79 it was 0.068. A conversion factor of 100 lb/ft^3 was used in the conversion of suspended-sediment load, in tons, to acre-feet of sediment; thus, computed sediment ratio is volume of discharge to volume of sediment (fig. 11). If vegetation improvement was a cause for these changes, several moist years might be expected to be required for significant vegetation improvement, which would delay the decrease in sediment yields. These data indicate improvement in water quality (decreased suspended sediment) discharged by the Rio Puerco during 1962-79. These results are similar to those reported for the Colorado River upstream from the Grand Canyon (Hadley, 1974). Suspended-sediment loads for the Colorado River for 1926-41, compared to 1942-60, showed a 50-percent decrease, but discharge remained about the same for the two periods. These changes were attributed to decreases in livestock numbers and to erosion-control practices applied to the land after 1941 (Hadley, 1974).

CONCLUSIONS

A 380-percent increase in live vegetation cover was determined from 1958 to 1979 in the Cornfield Wash subbasin of the Rio Puerco basin in New Mexico. Apparent causes for the vegetation increase included changes in livestock-grazing intensities and increases in precipitation on the basin.

Increased precipitation after the 1958 sampling is the most probable cause of improvement in vegetation on all plots sampled during 1979. Total departure from mean annual precipitation for Cornfield Wash was -7.17 in. for 1950-58, and was +6.69 in. for 1959-79. In addition to increased precipitation after 1958, the marked decrease in use by livestock (shown in fig. 5) can be considered a partial cause for improved vegetation indicated by the 1979 vegetation-measurement data. Although erratic values occurred from year to year, an obvious decrease from about 2.2 million to about 1.3 million occurred in animal-unit months of grazing in New Mexico during 1947 to 1979.

Hydrologic changes apparently resulting from improved vegetation cover included a decrease in the percentage of precipitation contributing to direct runoff, a decrease in mean sediment load, and a subsequent decrease in sediment concentration.

The present trend toward improved vegetation and hydrologic conditions in the Rio Puerco drainage and elsewhere in the Western United States is not expected to continue indefinitely. Should a drought of the same or greater magnitude to that of the 1930's occur, the current trend could be reversed and result in decreased vegetation cover, accelerated runoff rates, and the increase in erosion that accompanied such events in the past.

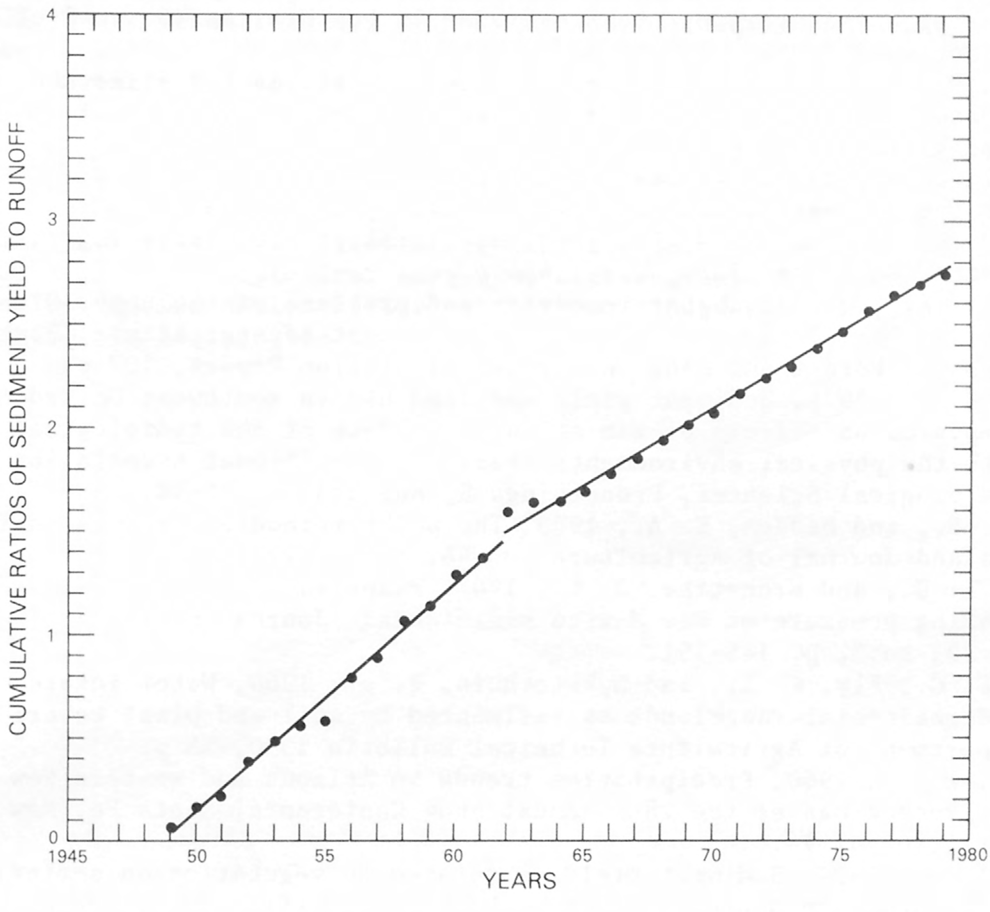

Figure 11.--Cumulative sediment concentrations (ratios of sediment yield to runoff) for the Rio Puerco basin, 1949-79.

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