Grazing in Relation to Runoff and Erosion on Some Chaparral Watersheds of Central Arizona

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Chaparral lands of central Arizona are important for water production. They are also used as grazing lands for livestock and as habitat for wildlife. An understanding of the relation of grazing to runoff and erosion is thus essential to the development of management systems for sustained high yields. This paper reports the effects of grazing on runoff and erosion as determined on four experimental watersheds called Natural Drainages A, B, C, and D. These watersheds were located on the Sierra Ancha Experimental Forest about 40 miles north of Globe, Arizona.

Previous studies in the Southern Rockies suggest that grazing heavy enough to reduce the perennial grass cover results in decreased infiltration, increased surface flow of water, and additional erosion. For example, on the Rio Grande watershed, destruction of, and change in, plant cover from improper grazing was found to increase flash floods during the summer rainy season, which resulted in destructive erosion and silting of channels, reservoirs, and irrigation works (Cooperrider and Hendricks, 1937). Similar conclusions were reached with regard to improper grazing of watersheds along the Little Colorado River in northeastern Arizona (Thornthwaite et al., 1942).

More recent and detailed studies suggest how grazing of a perennial grass cover influences runoff and erosion. Martin and Rich (1948) worked with lysimeters in the desert grassland type of central Arizona. They found that: (1) winter runoff was independent of amount of perennial grass vegetation; (2) total runoff was unaffected by grazing; but, (3) when grazing reduced the amount of perennial grass, there were marked increases in surface runoff and erosion, and a significant decrease in average areal infiltration capacity. Dortignac and Love (1960), working with an infiltrometer on bunchgrass ranges of Colorado, found that infiltration increased on protected ranges. On bunchgrass ranges of the Front Range of Colorado, Dunford (1954) found that a moderate rate of grazing did not increase erosion substantially in spite of some addition to surface flow.

Arizona Chaparral

Chaparral of Arizona grows between elevations of 4,000 and 5,500 feet and occupies about eight percent of the state (Nichol, 1952). Vegetation consists of a mixture of shrubs and perennial grasses. Complexity varies from dense areas of brush with almost no understory grass to open areas of brush with grass in most intershrub spaces. Important genera of shrubs include: oak *(Quercus)*, manzanita *(Arctostaphylos)*, ceanothus *(Ceanothus)*, sumac *(Rhus)*, mountainmahogany *(Cercocarpus)*, and silktassel *(Garrya)*. Most abundant genera of grasses are: grama *(Bouteloua)*, threeawn *(Aristida)*, bluegrass *(Poa)*, and hilaria *(Hilaria)*.

Few permanent streams originate in the chaparral. Most runoff occurs during the winter months when precipitation is in excess of plant use. Annual runoff varies with precipitation, soil, geology, and amount and kind of vegetation. Most streamflow goes to beneficial use because the lands are close to permanent streams and storage reservoirs. Erosional debris from these lands can be troublesome to irrigation divisions and water impoundments.

Most chaparral lands are grazed by livestock. Some areas are grazed yearlong while others are utilized on a spring-fall-winter basis. Commonly, long-yearlings are marketed in the late spring. When in good condition, chaparral lands have a grazing capacity of five to 15 acres per cow month. Shrubs of the chaparral are particularly nutritious during the spring growth period. Thus, they contribute importantly to animal nutrition when summer-growing perennial grasses are dry, leached, and low in nutrients. Chaparral ranges are especially valuable during drought periods, when growth of perennial grasses is slight.

Mule deer *(Odocoileus hemionus crooki* (Mearns)) is the principal game animal in the chaparral. Peccary *(Peccari tajacu sonoriensis* (Mearns)) and Gambel quail *(Lophortyx gambelii* Gambel) may be found at the lower elevations. Deer abundance varies with composition of the vegetation. When shrub live oak *(Quercus turbinella* Greene) dominates, populations may be as low as five to seven deer per square mile. At higher elevations, where such species as birchleaf mountainmahogany *(Cercocarpus betuloides* Nutt.) and hollyleaf buckthorn *(Rhamnus crocea* Nutt.) are abundant, populations may reach 20 to 30 deer per square mile (Swank, 1958).

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There is some recreational use of chaparral lands during the cool winter and spring months. Use is mostly concentrated in riparian sites where there is shade and water.

Study Area

The Natural Drainage watersheds were located on generally east-facing aspects of gentle topography (slopes of 15 to 25 percent). Elevation ranged from 4,525 to 4,920 feet. On north-facing slopes, chaparral grew in dense stands; on south-facing slopes, the cover was more open, and in some places it gave way to pure grassland (Figure 1).

These watersheds consisted of four drainages designated as: Watershed A, 13.4 acres; B, 19.5 acres; C, 12.1 acres; D, 9.1 acres. Lengths of watersheds varied from 1,300 to 1,650 feet; widths ranged from 300 to 500 feet.

Soils

Soils of these watersheds were derived from two rock types. On upper portions of the watersheds, soils originated from diabase rock; those on lower parts from quartzite. Diabase soil covered 42 percent of watershed A, 54 percent of watershed B, 44 percent of watershed C, and 28 percent of watershed D.

Diabase soils were deeper and sandier than quartzite soils, and seemed better adapted to shrub growth; quartzite soils appeared to favor the growth of grasses.

Vegetation

In 1951, shrubs, the dominant vegetation (Table 1), comprised from 47.1 to 60.5 percent of the total cover. The most abundant was shrub live oak (25.4 to 38.8 percent). Other species of some importance included buckbrush (*Ceanothus greggii* A. Gray), Wright silktassel (*Garrya wrightii* Torr.), and hollyleaf buckthorn. Half-shrubs, second in abundance, made up 11.9 to 24.0 percent of the total cover. Wright eriogonum (*Eriogonum wrightii* Torr.) was the most abundant (4.6 to 15.2 percent). Other species of some importance included rough menodora (*Menodora scabra* A. Gray), toadflax penstemon (*Penstemon linarioides* A. Gray), and false-tarragon (*Artemisia dracunculoides* Pursh).

Perennial grasses occupied from 9.1 to 18.5 percent of the ground cover. Side-oats grama (*Bouteloua curtipendula* (Michx.) Torr.) was the most abundant; hairy grama (*B. hirsuta* Lag.) and three-awns were conspicuous.

Cacti, mainly pricklypear (*Opuntia* spp.), and shrubby monocots, conspicuously sacahuista (*Nolina microcarpa* S. Wats.), (7.2 to 13.6 percent) and forbs (2.0 to 4.9 percent) made up the remainder of the flora. Important genera of forbs were penstemon, spurge (*Euphorbia* spp.), and bahia (*Bahia* spp.).

Methods

The study was designed to test the effect of grazing intensity upon vegetation, runoff, and erosion on a watershed basis.

Grazing Treatments

Watersheds A and D were grazed with cattle and horses. Grazing began on watershed D in June 1939, and on watershed A in June 1942; control watersheds B and C were ungrazed.

Because the watersheds were

Table 1. Important plant species on Natural Drainage watersheds, 1951.

	Composition of vegetation			
	A	B	C	D
	(Percent)			
Perennial grasses:				
Side-oats grama	5.7	6.9	9.7	10.8
Hairy grama	0.9	0.7	1.4	2.1
Three-awn	0.9	1.5	1.9	2.0
Others	1.6	4.6	3.9	3.6
Sub-Total	9.1	13.7	16.9	18.5
Cacti:				
Sacahuista	7.8	2.6	6.3	3.9
Pricklypear	4.4	1.3	0.9	2.4
Others	1.4	1.6	1.8	0.9
Sub-Total	13.6	5.5	9.0	7.2
Forbs:				
Spurge	0.9	0.2	0.1	0.1
Bahia	0.9	0.2	0.1	0.7
Penstemon	0.2	0.6	0.9	0.1
Others	2.9	2.6	0.9	2.3
Sub-Total	4.9	3.6	2.0	3.2
Half-shrubs:				
Wright eriogonum	4.6	4.8	6.9	15.2
Rough menodora	0.4	2.9	4.4	2.6
Toadflax penstemon	2.1	4.2	0.9	1.7
False-tarragon	2.2	2.0	2.2	2.0
Others	2.6	7.4	4.1	2.5
Sub-Total	11.9	21.3	18.5	24.0
Shrubs:				
Shrub live oak	34.2	38.8	25.4	26.3
Buckbrush	6.7	8.6	8.7	2.4
Hollyleaf buckthorn	2.0	2.5	0.3	5.4
Wright silktassel	2.0	2.4	5.6	0.0
Others	15.6	3.6	13.6	13.0
Sub-Total	60.5	55.9	53.6	47.1
TOTAL:	100.0	100.0	100.0	100.0

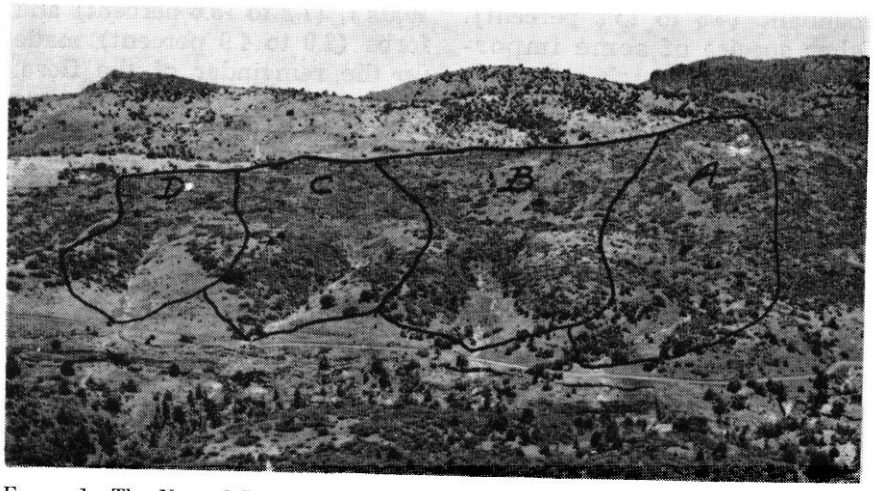

FIGURE 1. The Natural Drainage experimental watersheds. From 1942 to 1952, watershed A was utilized by cattle and horses during spring and fall to 80 percent of perennial grasses; watersheds B and C have been ungrazed since 1935; from 1939 to 1952, watershed D was utilized during spring and fall to 40 percent of perennial grasses.

small, grazing was limited to relatively short periods during fall and spring. Summer-growing perennials were grazed in the fall at cessation of growth; spring grazing was largely on winter annuals. Until 1945, animals were permitted to move into the watersheds from adjacent ranges. Thereafter, animals were confined to the watersheds during the grazing period.

During the fall, watershed D was grazed until 40 percent of the perennial grasses were removed. On watershed A, perennial grasses were utilized to 80 percent. Utilization was judged according to the grazed plant method (Roach, 1950). On watershed D, stocking averaged 4.3 acres per animal month, with a variation from 2.5 to 7.5 acres. On watershed A, stocking averaged 4.9 acres per animal month.

Measurements

Herbaceous vegetation was measured on metersquare quadrats between 1935 and 1952. Quadrats were located on both quartzite and diabase soils. No quadrats were placed in areas of dense chaparral that were little used by livestock. Six quadrats were located in each watershed; they were charted in 1935, 1936, 1940-41, 1942, and 1952 by the method of Hill (1920).

Streamflow was measured by 90° V-notch weirs that were tied into impervious quartzite bedrock underlying all four watersheds. The watersheds were believed to be watertight and to measure total flow. Runoff, as here used, refers to *all* overland and subsurface flow (Wisler and Brater, 1959).

Sediment was measured in the weir basins at the gaging stations by volume-weight relations. Basins were cleaned and sediment measured twice each year.

Precipitation and Runoff

Precipitation

From 1938 to 1952, annual precipitation averaged 20.7 inches. About 65 percent fell from October through May, and 35 percent from June through September. Annual amounts varied widely (Figure 2).

Winter precipitation varied from 242 percent of average in 1940-41 to 66 percent of average in 1947-48. Summer precipitation during 1946 was 200 percent of average, but only 48 percent in 1948.

Runoff

Streamflow averaged one inch on watershed B and 1.9 inches on watershed C from 1934 to 1952. From 12 to 18 percent of this flow resulted from summer storms; the remainder was contributed by winter storms. During this same period, winter precipitation averaged 13.5 inches, and summer precipitation 7.2 inches. On the average, from 4.7

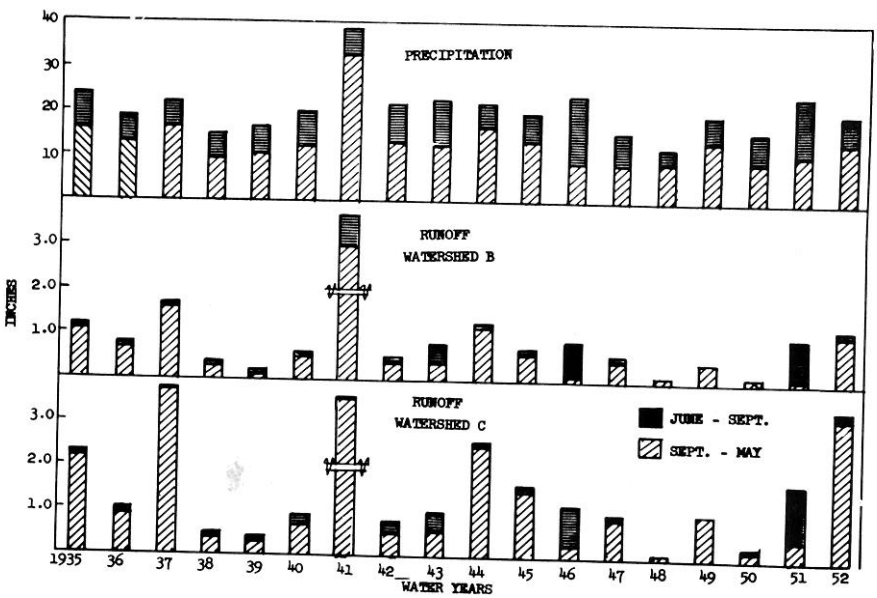

FIGURE 2. Annual and seasonal precipitation compared with water yields from 1935 to 1952 for ungrazed watersheds B and C of the Natural Drainage experimental watersheds.

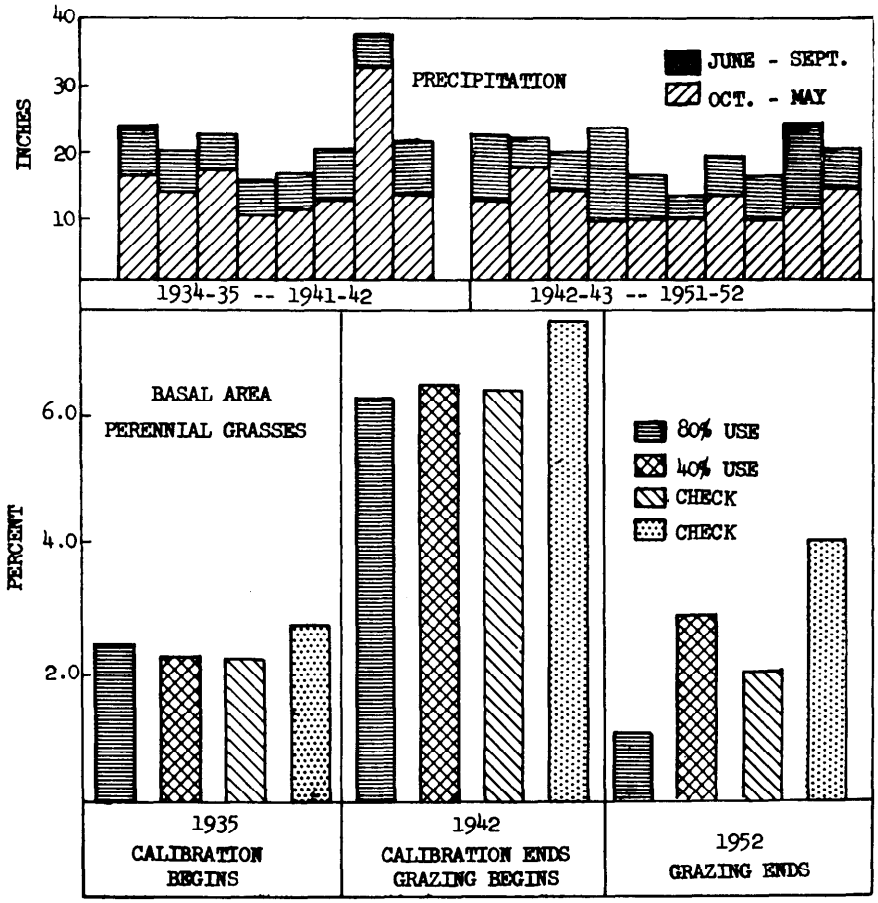

FIGURE 3. Basal area of perennial grasses on quadrats located on each of Natural Drainage experimental watersheds at beginning and end of calibration and grazing.

to 9.4 percent of the annual precipitation appeared as streamflow.

Seasonal streamflow varied greatly but tended to reflect differences in precipitation (Figure 2). For example, on watershed C, winter streamflow in 1940-41 was 11.2 inches from 32.6 inches of precipitation; in 1947-48, runoff during the winter was 0.1 inch from 8.9 inches of precipitation. On the same watershed, summer streamflow and precipitation in 1950-51 averaged 1.2 and 12.8 inches, respectively, whereas in 1947-48 summer streamflow was only 0.01 inch from 3.5 inches of precipitation.

Grazing Affects Perennial Grasses

In 1935, basal area of perennial grasses was about the same on all watersheds (Figure 3).

Basal area of perennial grasses more than doubled on all watersheds by 1942—the beginning of grazing on watershed A, and three years after initiation of grazing on watershed D. Basal area of perennial grasses on watershed D continued to increase between 1939 and 1942, even though it was grazed.

By 1952, when grazing was terminated, basal area was greatly reduced on watershed A (80 percent utilization) as compared to the check watersheds; watershed D (40 percent utilization), however, had a greater basal area than one of the check watersheds.

Grazing and Runoff

Covariance analysis was used to compare differences in runoff that resulted from grazing. This procedure permitted adjustments for differences in length and number of runoff periods, and adjustment of means to a common base (Snedecor, 1956).

Water yields were grouped for analysis by three-month periods as follows: January-March (winter runoff); April-June (growth of spring vegetation); July-September (growth of summer vegetation); and October-December (soil moisture recharge). Tests for independence of consecutive measurements showed that such grouping was justified (Hafstad, 1940).

Grazing, and accompanying changes in vegetation for these soils, topography, and climatic conditions, were found to have no significant effect upon water yields in the following comparisons: (1) watershed B (check) versus watershed A (80 percent use), (2) watershed C (check) versus watershed D (40 percent use), (3) watershed D (40 percent use) versus watershed A (80 percent use), and (4) watershed B (check) versus watershed C (check).

Adjusted changes in water yields following grazing were small — +0.006 area-inch for watershed A (80 percent use) and −0.016 area-inch for watershed D (40 percent use). During the same period, check watersheds differed by −0.003 area-inch. None of the differences was statistically significant.

Grazing and Erosion

Annual sediment trapped from 1935 to 1952 varied from 0 to 295 tons per square mile. The average for all watersheds for the period was 17 to 132 tons per square mile per year.

Amounts of sediment trapped were so variable from year to year that differences resulting from grazing treatment were not statistically significant. Soil movement to the gaging stations varied with topography of individual watersheds, intensity

and duration of precipitation, and other factors.

Management Implications

These data suggest that chaparral lands of central Arizona, where characterized by an interspersion of shrubs and perennial grass on moderate topography, can be properly grazed without detriment to soil stability or water regime. If no more than 40 percent of perennial grass production is removed at the end of the summer growing season, ground cover does not deteriorate and appears sufficient to maintain a stable soil.

The findings corroborate results on small lysimeters (Martin and Rich, 1948) which indicated that density of summer-growing perennial grasses had little influence on total water yields. Presumably, grazing must be severe enough to reduce abundance of perennial grasses in order to lower infiltration, to change runoff from a subsurface to a surface phenomena with accompanying increased erosion.

Proper grazing and water production appear compatible in a chaparral, shrub-perennial grass interspersion, and justify application of the multiple use principle to such lands. Moreover, destructive use does not produce additional runoff, nor does protection reduce runoff.

Summary

1. Chaparral of central Arizona furnishes water for domestic, industrial, and agricultural use; forage for livestock; and habitat for game, particularly deer.
2. This study of chaparral watersheds was designed to test the effect of grazing with cattle and horses at two different intensities (80 percent and 40 percent use of perennial grasses during a spring-fall grazing season) on basal cover of perennial grasses, runoff, and erosion.
3. Vegetation, water, and sediment were measured on four watersheds between 1935 and 1952. These watersheds, underlain by impervious quartzite, varied in size from 9.1 to 19.5 acres. Two watersheds were grazed while two served as checks.
4. From 1935 to 1952, precipitation averaged 20.7 inches; streamflow on the ungrazed watershed C averaged 1.9 inches, 88 percent of which came from October-May. Sediment losses for all watersheds and all years averaged 17 to 132 tons per square mile per year—a comparatively low rate.
5. Grazing 80 percent of the growth of perennial grasses reduced their basal cover. Grazing 40 percent of perennial grasses did not adversely affect basal cover.
6. Reduction in basal area of perennial grasses by grazing for these soils, topography, and climate conditions had no significant or practical effect on total water yield.
7. Proper grazing of perennial grass-shrub complexes in the chaparral of central Arizona had no measurable effect upon water production or erosion. Such a finding appears to justify application of the multiple use principle in management.

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