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• Relation of Soils, Rainfall and
• Grazing Management to Vegetation
— — Western Edwards Plateau of Texas

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TEXAS AGRICULTURAL EXPERIMENT STATION

R. D. LEWIS, DIRECTOR, COLLEGE STATION, TEXAS

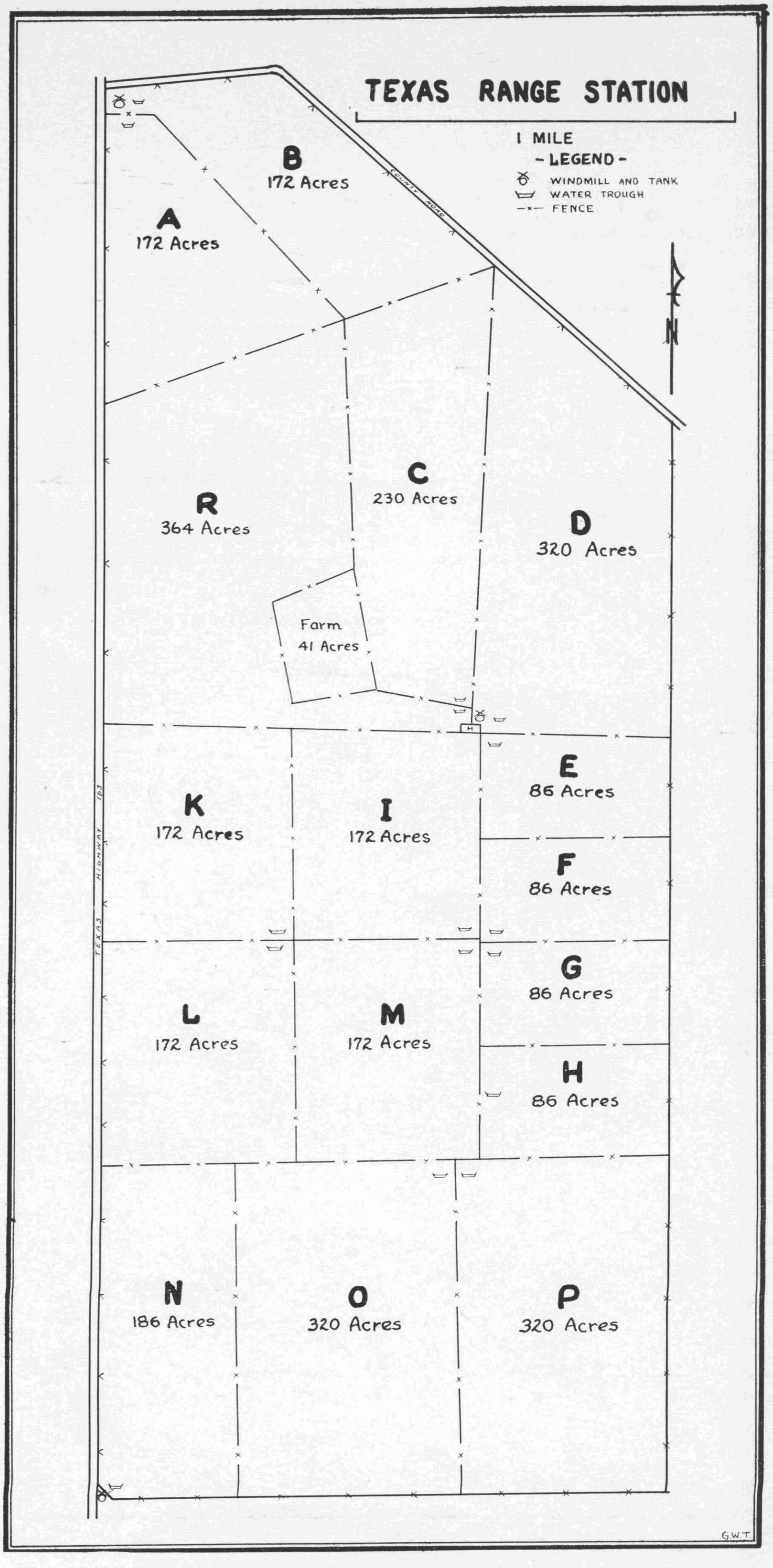

Figure 1. Map of the Texas Range Station showing pasture boundaries, acreages and livestock water facilities.

DIGEST

Experiments were conducted from 1938-53 at the Texas Range Station near Barnhart to study the effects of climate, soils and grazing on the vegetation. This station comprises approximately 3,160 acres of land, is owned by the University of Texas and is operated by the Texas Agricultural Experiment Station.

The 16 pastures on the station have been subjected to different rates of stocking with various combinations of sheep and cattle since grazing experiments were started in 1938.

Vegetation on the experimental pastures is fairly representative of that supported by several million acres of rangeland on the Edwards Plateau of Texas. The most important forage species are tobosa, buffalo and curly mesquitegrass. Associated with these grasses, but in smaller amounts are three-awn grasses, side-oats grama, vine mesquite and many others. The poisonous bitterweed and annual broomweed are the most abundant weeds. Dominant woody species are mesquite, pricklypear and cholla.

The nature of the soil has had a pronounced effect on the kind and amount of vegetation on the area. The soil also has influenced the response of the vegetation to grazing and rainfall.

A cover of tobosagrass is superior, from the standpoint of soil and water conservation, to a cover of buffalo or curly mesquite, or to bare ground, which is subject to annual weed growth during periods of favorable rainfall. Tobosagrass favors more rapid rates of water intake into the soil, more stable soil aggregation and a more favorable soil temperature for plant growth.

A close relationship was found between available forage and annual rainfall for the period 1938-53. However, fluctuations in the amount of forage usually lag from 1 to 3 years behind the fluctuations in annual rainfall. On areas heavily grazed by livestock, the vegetation does not respond immediately to wet or dry years. Certain changes in floristic composition are caused by the rainfall pattern and should be recognized and separated from changes due to grazing.

The extreme drouth prevailing since the fall of 1950 has caused serious reductions in ground cover and forage production. Death losses have been extremely high in curly mesquitegrass and almost as great in buffalo and purple three-awn. Tobosa was the most drouth resistant of the grasses in the area.

Studies of the response of the vegetation to grazing management show the following:

(1) Sideoats grama, vine mesquite and cane bluestem are the best indicators of past stocking rate in the area. These grasses are more abundant on the lightly stocked pastures and seldom are found on overgrazed areas.

(2) Tobosagrass has been affected very little by the grazing practices for the 16-year period. It decreased slightly on the ridgetop soils but increased on other soils in pastures grazed with sheep. Cattle utilized tobosa more uniformly than sheep, but sheep caused damage to this grass by "spot grazing." Livestock utilization of tobosa noticeably increased by mowing to remove the old growth.

(3) Buffalograss, although more palatable than curly mesquite, was more resistant to heavy grazing. Both of these turf grasses produced less forage than tobosagrass during years of low rainfall.

(4) Three-awn grasses were the most reliable indicators of the class of livestock grazed on the pastures. The three-awns increased under heavy sheep grazing and decreased under cattle grazing. Annual weeds, particularly annual broomweed, were less abundant on the sheep pastures than on the cattle pastures.

(5) Pricklypear increased under heavy yearlong and seasonal grazing. This cactus also increased in the exclosures during the drouth. Mesquite tree populations were more closely related to the type of soil than to the grazing practices used since 1938.

CONTENTS

Relation of Soils, Rainfall and Grazing Management to Vegetation, Western Edwards Plateau of Texas

GERALD W. THOMAS and VERNON A. YOUNG*

SINCE THE BEGINNING OF RANCHING in North America, men have recognized that the kind and amount of vegetation the ranch supports determines to a large degree the success of the enterprise. This vegetation, in turn, is influenced by the various environmental conditions under which it grows. Factors such as climate and soils have pronounced effect on the vegetation. Grazing intensities and kind of livestock also are very important but too often they are overlooked or not understood.

Grazing experiments were initiated on the Texas Range Station in 1938 to supply information on the influence of soils, rainfall and grazing on a vegetation type common to a large area of West Texas. Results obtained will be of value to ranchmen in this area and in other regions where tobosa, buffalo or curly mesquitegrass are important forage plants.

EXPERIMENTAL AREA

Location

The Texas Range Station is located in Crockett county, between Ozona and Barnhart. It comprises approximately 3,160 acres of land owned by the University of Texas. The area has been managed for experimental purposes since 1938 by the Texas Agricultural Experiment Station under a cooperative agreement with the University of Texas.

The station lies on a broad drainage divide of the Edwards Plateau at an elevation of 2,700 feet between the headwater streams of the Concho River on the north and the Devil's River on the south. The relief of the land is rather smooth with occasional shallow depressions and dry lakebeds. A few areas have gentle to moderate slopes.

Figure 1 shows the pasture boundaries, acreages and livestock water facilities on the Texas Range Station.

Climate

The average annual precipitation, at the station headquarters for the past 16 years was 16.68 inches, Figure 2. This amount is probably too low for a longtime average because of the influence of the recent extended drouth. Rainfall records from other weather stations in the region indicate that the range station is near the 20-inch rainfall belt. Most of the precipitation occurs as rainfall. Figure 2 shows the distribution of this rainfall by years. There is considerable variability among years, and 9 out of the 16 have had less than average rainfall.

Average monthly rainfall also is shown in Figure 2. May has the highest average, 2.18 inches and February the lowest, 0.57 inches.

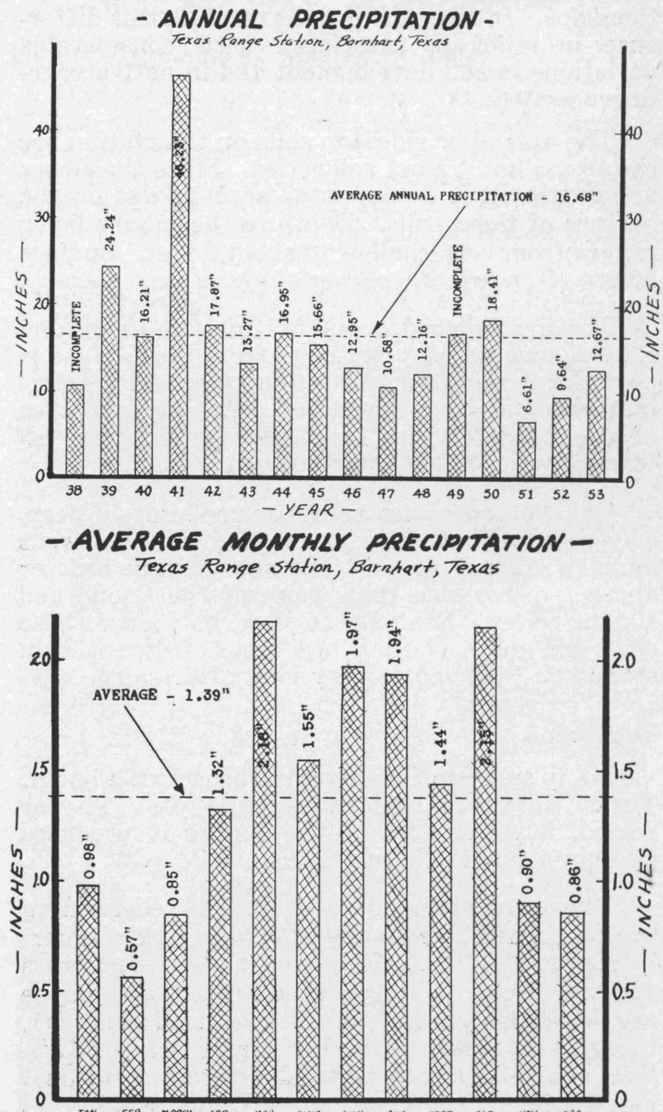

Figure 2. Annual precipitation and average monthly precipitation for the Texas Range Station from 1938 through 1953.

*Respectively, assistant professor and head, Department of Range and Forestry.

Summer temperatures at the range station are high, with maximums of 100 to 110° F. The nights usually are cool. Frequent southerly winds occur throughout the day and often continue into the night. In general, the winters are mild with occasional periods of below-freezing weather which may last for several days. The mean annual temperature is about 65° F.

Soils

Soils of the Texas Range Station are typical of the western part of the Edwards Plateau. These soils are clay types or phases of clay types, moderately deep, and underlain with limestone or caliche. A survey made in 1938 by Carter, Templin and Mowery showed that there are five soil series on the station: Ozona, Valera, Tobosa, Irion and Randall. Although the general surface appearance of these soils is similar, there are differences in surface relief and moisture relationships. In a region of light rainfall, this difference in relief is associated with considerable variations in soil development and in native vegetative growth.

The upland or ridgetop soils on the station are the Ozona and Valera soil series. Since the slopes are gentle, little or no water accumulates on the surface of these soils. Depth to the caliche layer ranges from very shallow to about 2 feet. Surface layers often are gravelly or stony.

The dry lakebed areas fall into the Irion and Randall soil series. Drainage from these areas is poor, occurring mainly through holes and crevices in the underlying limestone. The deeper lakes of the Randall series may contain water for extended periods following heavy rains.

The Tobosa series comprise moderately deep, clayey soils that occur between the high swells and the lakebed areas. The subsoils are heavier and less permeable than those of the Ozona and Valera series. Drainage is slow, but, since these soils are above the lakebed areas, water seldom stands on the surface very long after rains.

Vegetation

Many species of plants have been found on the Texas Range Station during the past 16-year period, but the bulk of the forage is produced by only a few of these species.

The most abundant grasses are sod-forming species: buffalograss (*Buchloe dactyloides*), curly mequite (*Hilaria belangeri*) and tobosagrass (*Hilaria mutica*). Species of lesser abundance are sideoats grama (*Bouteloua curtipendula*), three-awn grasses of the Purpureae group (*Aristida spp.*), vine mesquite (*Panicum obtusum*), hairy tridens (*Tridens pilosus*), fall witchgrass (*Leptoloma cognatum*), muhly (*Muhlenbergia arenacea*), tumblegrass (*Schedonnardus paniculatus*) and hairy grama (*Bouteloua hirsuta*). A few scattered plants of cane bluestem (*Andropogon barbinodis*) and green spangletop (*Leptochloa dubia*) grown in pastures C and N which have been lightly stocked.

Several annual grasses were noted following periods of high rainfall. The most important of these were little barley (*Hordeum pusillim*), 6-weeks fescue (*Festuca octoflora*) and annual panic (*Panicum fasciculatum*).

Approximately one-fourth to one-half of the ground area on the station is bare. These bare areas between the bunches of perennial grass are subject to invasion by many species of weeds during periods of favorable rainfall. The most important species are bitterweed (*Actinea odorata*) and annual broomweed (*Gutierrezia texana*).

Forbs of lesser importance are croton or goatweed (*Croton neomexicanus*), buffalo-bur (*Solanum rostratum*), caltrop (*Kallstroemia brachystylis*), snow-on-the-mountain (*Euphorbia marginata*), perennial broomweed (*Gutierrezia microcephala*), buckhorn plantain (*Plantago lanceolata*), hoarhound (*Marrubium vulgare*), American carrot (*Daucus pusillus*), rose verbena (*Verbena canadensis*), prairie thistle (*Erynigium leavenworthii*), Engelmann's daisy (*Engelmannia pinnatifida*), Drummond phlox (*Phlox drummondii*) and many others.

The dominant species of brush are mesquite (*Prosopis glandulosa*) and pricklypear (*Opuntia spp.*). Other species of cacti include cholla (*Opuntia imbricata*) and species of *Echinocactus* and *Mammillaria*. Several other brush species of minor importance also are present.

METHODS OF STUDY

Location of Plots for the Study of Vegetation

The original 86 plots for vegetational studies on the Texas Range Station were established in 1938. An additional 210 plots were located later at random on soil types which had not been adequately sampled.

All permanent plots were marked by two steel stakes, spaced approximately 25 feet apart, and set in the ground to a depth of about 2 feet. A metal tag with the pasture identification and plot number was attached to the south stake at each location, Figure 3.

Survey Procedure for the Inclined-point-contact Method

The inclined-point-contact method has been used for measuring relative abundance of vegetation on the Texas Range Station since 1938. The point-contact frame consisted of 10 pins. Each pin was dropped toward the ground, and a hit recorded for each species contacted between the lower crossbar and the ground. For example, if pin number 1 contacted species A more than once, only one hit was recorded. If pin number 1 contacted species A and species B two hits were recorded, one for each species. The point-contact frame was moved 10 times along the line between stakes at each plot location. Readings were made in this manner for 100 pins at each plot.

The Belt-transect Method

During the period 1950-53 belt transects were mapped at each of the permanent plot locations. These belts covered approximately the same area charted by the inclined-point-contact method.

The belt transect used in this study was 1 foot wide and 20 feet long. The zero point on the belt was maintained at the tagged stake. The vegetation within this belt was mapped by means of a standard square-foot quadrat and chain.

From these belt transects, it was possible to study the effect of grazing and drouth on individual plants and to follow trends through the years. Only perennial plants were located on the map of the belt. Annual weeds were counted within sod and bare areas along the belt. Stubble height and foliage-density measurements were indicated for the area of each sod grass mapped. Additional notations were made of other factors considered important, such as amount of erosion.

Brush Survey by the Circular-plot Method

Woody plants were charted on circular plots at each sampling location to supplement the data derived from the belt transects. These plots had a 20-foot radius and were centered on the tagged marker stake of each permanent charting location. The position of the belt transect within the circular plot and the location of all brush species were noted with the proper orientation in relation to true north. Basal diameter, height and canopy coverage were recorded for all tree species.

The positions of pricklypear, cholla and other cacti were mapped within the circular plot. Ant beds, livestock trails and other factors which may have influenced the vegetation also were indicated.

Methods of Measuring Forage Production and Utilization

Temporary exclosures were established during the summer of 1951 in pastures O and P for the measurement of forage production and utilization. Twelve exclosures were placed in each pasture, 10 on Ozona clay soils and 2 in the lakebed areas. Half of the exclosures on Ozona clay were located on tobosa sod and half on mixed buffalo and curly mesquite sod. All of the exclosures in the lakebeds were located on buffalograss sod.

Clippings of forage in the exclosures and in the grazed areas were based on standard 9.6 square-foot plots. Plots of this size allowed for rapid conversion to pounds per acre by multiplying the number of grams per plot by 10. Clippings were weighed in an air-dry condition. Subsamples were ovendried for determinations of moisture content.

Sod areas of buffalo and curly mesquite were clipped to a stubble height of approximately one-half inch for production and utilization measurements. This stubble height was very close to that actually remaining after intense sheep grazing. Tobosagrass was clipped to within 1 inch of the ground.

Exclosures were moved twice each year—in August and December. Actual forage production during each period was determined from the clippings made inside the exclosures. The amount of forage remaining after livestock grazing was found by clipping the forage from plots outside of the exclosure. Forage utilization by livestock was determined by comparisons of clippings from the exclosures with those of the grazed areas.

The amount of utililzation of forage by both sheep and cattle also was obtained by stubble-height measurements of species within the belt transects in each pasture.

SOIL AND PLANT RELATIONSHIPS

Plant Distribution as Related to Soils

Differences in the amount and composition of the vegetation on the Texas Range Station were closely associated with differences in soil characteristics, particularly surface texture, soil depth and the nature of the soil profile. The greatest differences in the vegetation were due

Figure 3. A typical plot location in pasture D. Note the tagged stake in the foreground and the general vegetation condition (summer 1950).

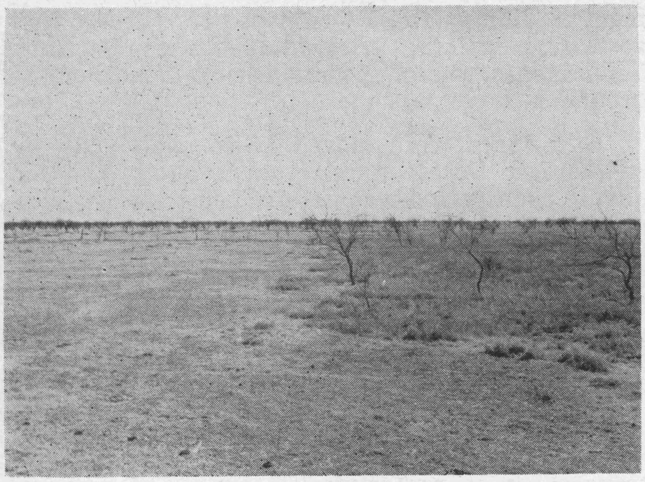

Figure 4. Soil boundary in pasture C between Ozona clay (left) and Tobosa clay (right). Note the abundance of mesquite trees and tobosagrass on the Tobosa clay area.

to differences among the soil series. Soil types and phases within these soil types also affected plant distribution and abundance but not as much as the soil series.

Differences in plant occurrence among soils often were as pronounced as those shown in Figure 4.

The relationships among soil series and the occurrence of the major plant species are shown in Figures 5 and 6. These graphs present summaries of data collected in 1950, 1952 and 1953.

The greatest density of tobosagrass was found on the Tobosa and Valera series. Very little tobosagrass grew in the dry lakebeds of the Randall series. Highly significant differences in the amount of tobosagrass were found between the Tobosa clay and Ozona clay types. Both the shallow phase of Ozona clay and the shallow phase of Irion clay showed small amounts of tobosagrass.

Buffalograss occurred in the largest amounts in the dry lakebed areas of the Randall soil series where it sometimes formed pure stands. The second highest concentration was found on the poorly drained Irion soils. Fairly large stands of this species also were encountered on the ridgetop soils of the Valera series. Highly significant differences in the amount of buffalograss on different soils were noted by Potts (1946) and Thomas (1951).

Curly mesquitegrass grew in close association with buffalograss on all soils except those of the Randall series. Curly mesquite seldom occurred in the large lakebeds or on the Irion soils.

Sideoats grama occurred in small amounts on all soils except the depressional areas of the Irion and Randall series. This species was most abundant on Ozona clay.

All soil types on the range station were found to support three-awn grasses. The dry lakebeds showed the highest densities of purple three-awn and the uplands supported more Wright's three-awn.

The relationships between soil series and the amount and kind of brush species are shown in Figure 6. The highest concentration of brush was recorded on the Randall and Tobosa soils. Mesquite trees were more abundant on Tobosa clay than on the other soils. Pricklypear plants were most common in the lakebed areas. The upland areas of the Ozona and Valera series were not as heavily populated with brush species as the other soil series.

The lakebed areas of the Randall and Irion soil series had the lowest total densities of vegetation of all soil series represented. The large amount of bare ground on these soils was subject to invasion by bitterweed and other annual weeds during years of favorable rainfall. Ozona clay had the smallest amount of bare ground before the drouth but Tobosa clay had the least bare ground in 1953. Extensive areas of bare ground also were noted on the shallow phases of Ozona clay and Irion clay. These areas have been classified as "hazard areas" during the bitterweed season.

Effects of Vegetation and Soils on Water Infiltration

Infiltration tests were made during the summers of 1950, 1951 and 1952 to determine the relative effects of the major grass species on rate of water intake into the soil. Infiltration was measured by means of concentric cylinders or rings, as described by Leithead (1950). Water was added periodically to the inner and outer cylinders to maintain a depth of 2 inches. An accurate record was kept of the amount added to the inner ring. The outer, or buffer ring, restricted the lateral flow from the internal compartment. Each test was continued for a 2-hour period.

Infiltration measurements were taken on tobosagrass sod, on buffalo and curly mesquitegrass sod and on bare ground. The three series of measurements were made within the radius of a 10-foot circle to keep soil variability to a minimum. A typical location for an infiltration test is shown in Figure 7.

Infiltration tests were made in 1950 on four different soil types in pasture C. These tests were repeated three times for each soil type at widely separated, randomized locations. During the summer of 1951 and of 1952, the tests were confined to Tobosa clay soils. Five tests were made on this soil type in pasture C. Infiltration tests also were made in 1951 on sideoats grama sod and on buffalo and curly mesquite sod in the Ozona clay exclosure in pasture D.

Data on infiltration of water are summarized in Table 1. Curves showing accumulated inches of water absorbed by the soil are given in Figure

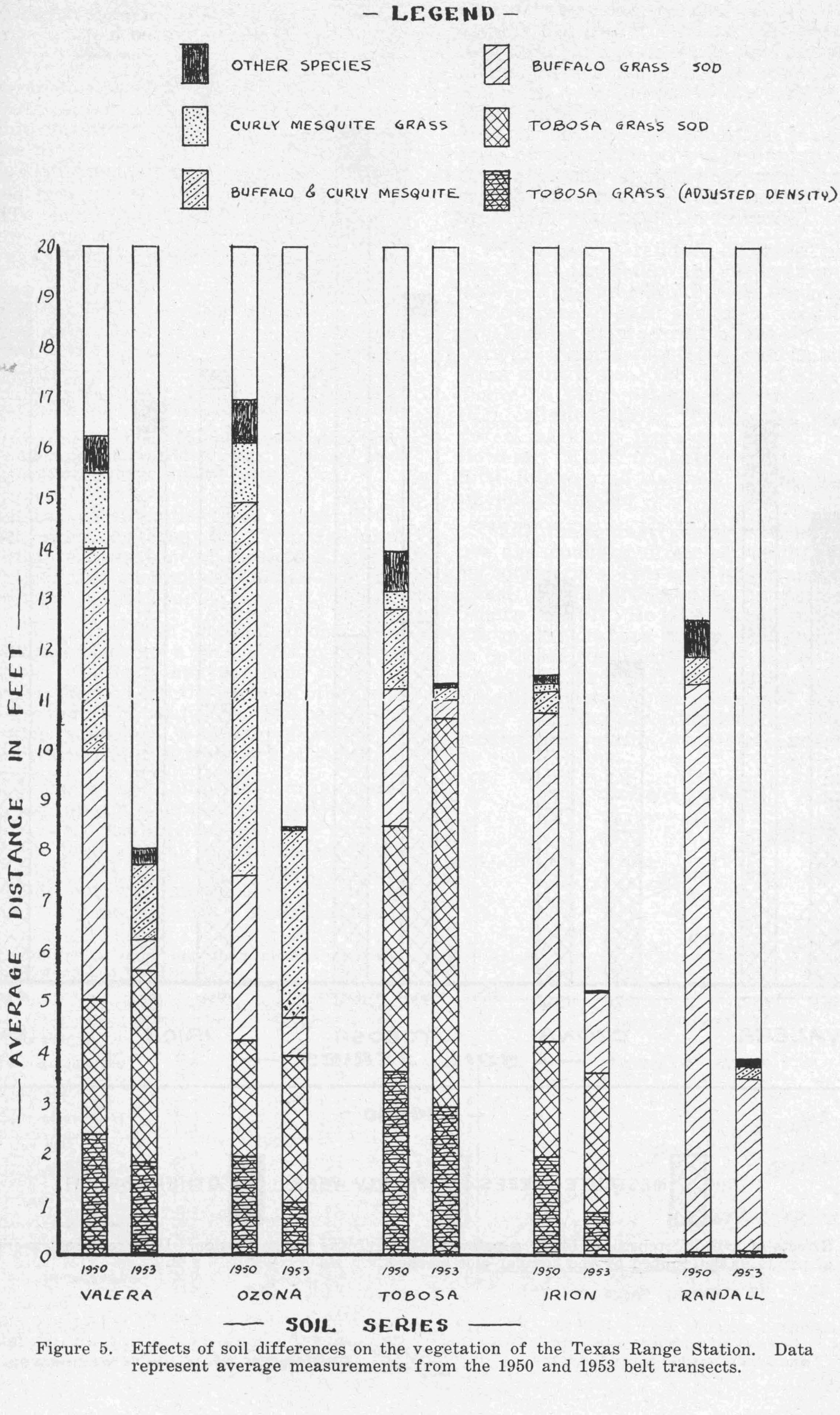

Figure 5. Effects of soil differences on the vegetation of the Texas Range Station. Data represent average measurements from the 1950 and 1953 belt transects.

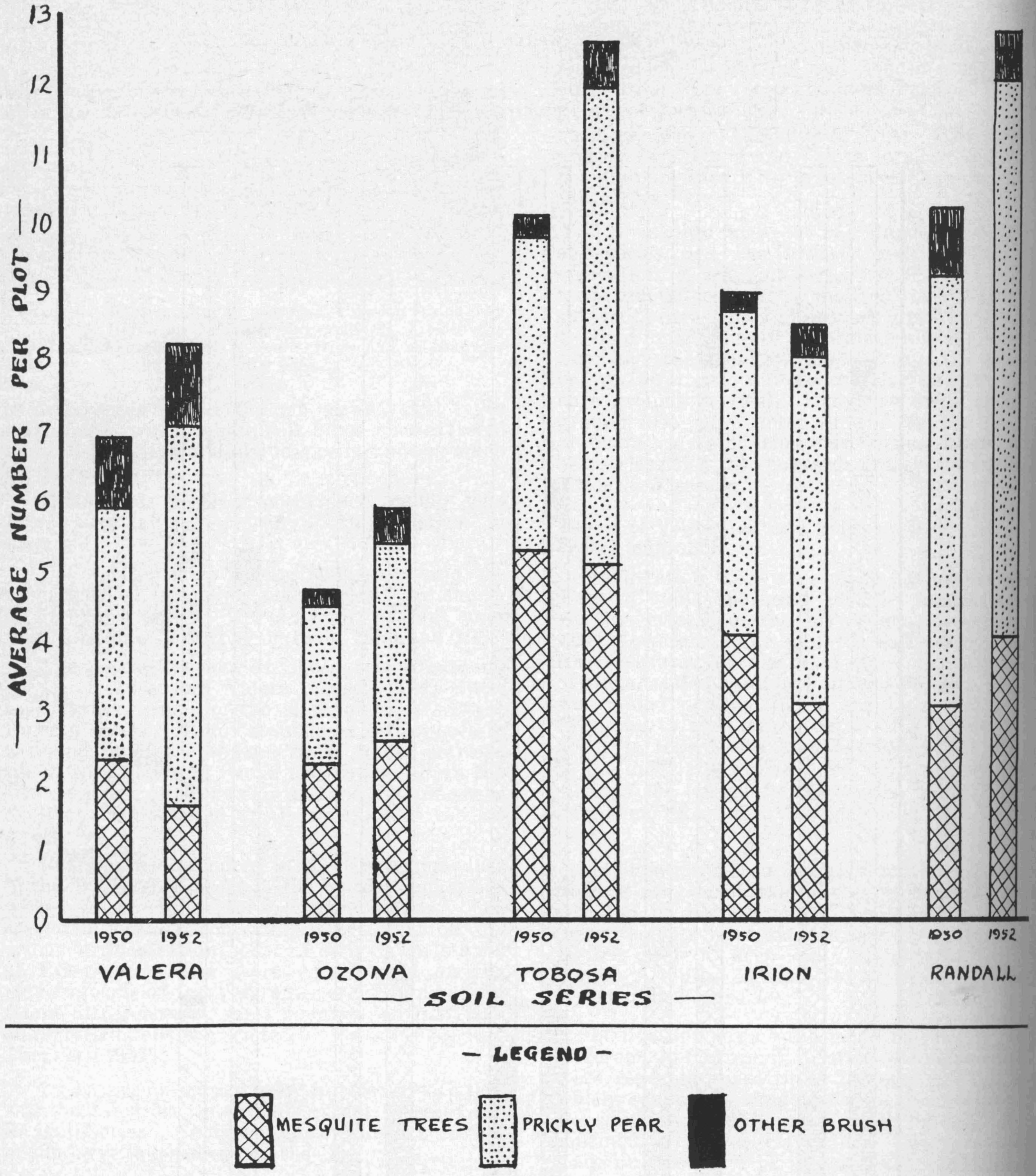

Figure 6. Effects of soil differences on brush population of the Texas Range Station. Data represent average number of plants as determined by the circular-plot method.

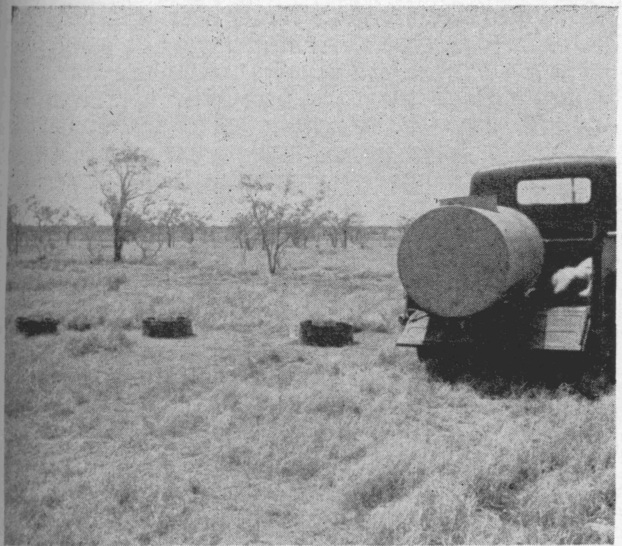

Figure 7. A typical location for water infiltration tests. Each set of concentric rings is located on a different type of ground cover.

8. Individual consideration was given initial infiltration rates, as computed from the first reading at an elapsed time of 2 minutes, and to total accumulative amount of intake for the 2-hour period.

The 1950 infiltration determinations were made in August following a period of 3 to 4 weeks without rain. Little if any available moisture remained in the soil at the time of the tests under all ground-cover conditions. The bare areas at this time supported a scattered stand of bitterweed which had died from lack of moisture.

Table 1 shows that initial infiltration rates were highest on tobosagrass sod, followed by buffalo and curly mesquite sod and bare ground. However, the total amount of infiltration at the end of 2 hours was greatest on tobosa sod and bare ground, but was significantly lower on buffalo and curly mesquite sod. Statistical treatment of these data by analyses of variance indicated a significant effect of the grass cover on both initial intake rates and total amount of water intake. These analyses also show a high variability in water intake within soils and no significant differences between any of the soil series. Most of the data were consistent in showing high rates of absorption at the beginning of the tests, then a rapidly diminishing rate until a fairly constant ultimate rate was obtained. These trends are shown graphically in Figure 8.

Table 1. Initial intake rates and total amount of water infiltration into the soil[1]

Soil and cover	Initial intake rate, inches per hour	Total infiltration, inches at the end of the 2-hour period
1950—Ozona clay soil		
Tobosa sod	31.8	22.2
Buffalo & Curly mesquite sod	12.6	7.1
Bare ground	11.5	9.9
1950—Tobosa clay soil		
Tobosa sod	37.7	11.8
Buffalo & Curly mesquite sod	26.7	2.3
Bare ground	15.8	12.7
1950—Valera clay soil		
Tobosa sod	47.7	12.7
Buffalo & Curly mesquite sod	21.6	4.7
Bare ground	12.4	14.1
1950—Irion clay soil		
Tobosa sod	42.9	7.3
Buffalo & Curly mesquite sod	35.7	5.3
Bare ground	17.2	15.9
1951—Tobosa clay soil		
Tobosa sod	37.5	12.6
Buffalo & Curly mesquite sod	21.0	3.3
Bare ground	15.5	7.2
1952—Tobosa clay soil		
Tobosa sod	19.0	5.1
Buffalo & Curly mesquite sod	14.0	2.4
Bare ground	14.7	7.2

[1]Data represent averages of all runs for 1950, 1951 and 1952.

No effective rainfall occurred in 1951 for 2 to 3 months before the infiltration tests were made. A general drouth was becoming increasingly severe in 1952 and there was no available moisture for plant growth at the time of the tests. Bare ground had supported scant annual weed or grass growth since the spring of 1950 and practically no plant litter remained on the ground. Data collected during these last 2 years did not differ markedly from those obtained in 1950. However, in 1952 the bare ground had the highest final intake rate as well as the highest total *amount of intake.*

With the concentric-ring method, the destructive and puddling effect of raindrop action was not considered. This is an important factor under actual rainfall conditions, as pointed out by Osborn (1950). However, at all times the water was muddy on bare ground and practically clear on both sod conditions. The relative positions of the curves for tobosa sod and buffalo and curly mesquite sod remained unchanged during all the tests. Analyses of variance indicated that differences from year to year were not significant,

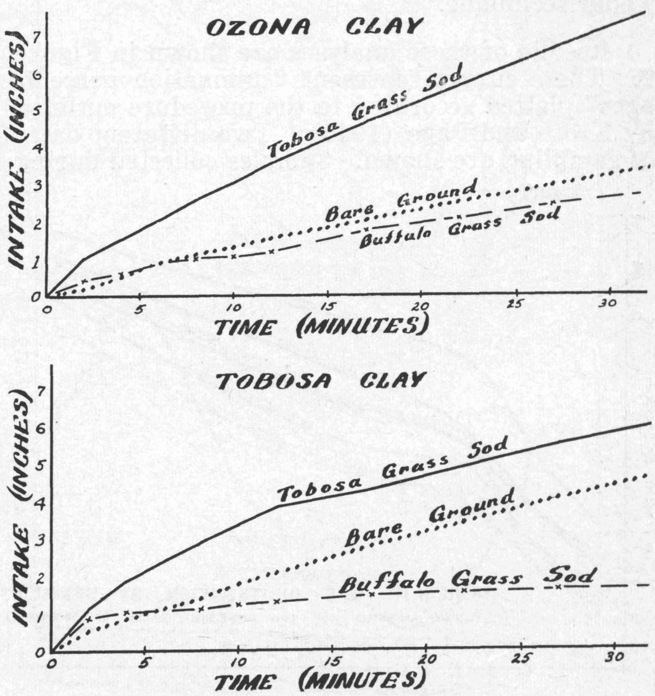

Figure 8. Typical curves showing accumulative amount of water absorbed by the soil under three different ground-cover conditions.

although they were close to the 5 percent level. The slowest rates under all conditions occurred when the drouth was most severe.

The rapid rate of water intake under both sod types tested in the exclosures indicated that grazing is a factor in affecting infiltration. Sod-forming grasses tended to develop a bunch-like appearance under protection from grazing and there was a heavy accumulation of plant litter.

From the measurements of soil height it was found that the soil level under a cover of tobosagrass was one-half to 2 inches higher than the soil level on areas occupied by buffalograss, curly mesquitegrass or annual weeds. The accumulation of litter and increased soil porosity under tobosa sod undoubtedly contributed to the increased rate of water infiltration as compared with the infiltration rate of the turf grasses. Also, the extent of soil aggregation and the stability of these soil aggregates have influenced the results obtained.

Effects of Vegetation on Soil Aggregation

Laboratory studies on the nature and distribution of soil aggregates were made on soil samples of Ozona clay collected on the Texas Range Station in 1950, 1951 and 1952. Determinations were made on samples of the upper 6 inches of soil taken at random in pastures C. and R. Three ground-cover conditions were represented: tobosagrass sod, mixed buffalo and curly mesquite sod and bare ground.

Comparisons of aggregate size distribution were made for the three ground-cover conditions by wet-sieve analysis, using a modification of the Yoder technique.

Results of these analyses are shown in Figure 9. These curves represent "summation percentages" plotted according to the procedure outlined by Kroth and Page (1946). Two different dates of sampling are shown. Samples collected during

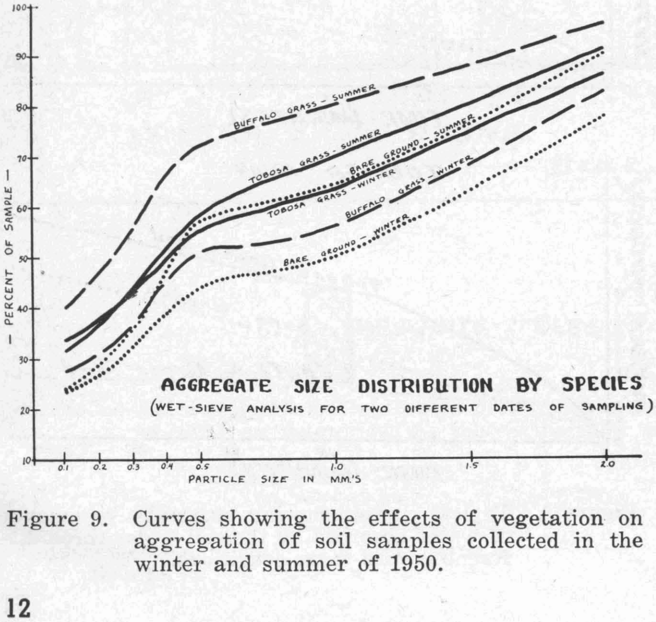

Figure 9. Curves showing the effects of vegetation on aggregation of soil samples collected in the winter and summer of 1950.

the winter had a higher percentage of large aggregates in each type of ground cover. The distribution pattern of aggregates was similar in soil samples from the three ground-cover conditions at both dates of sampling. The maximum percentage of large aggregates occurred in soil from bare ground but total aggregation was greatest under tobosagrass sod.

Wet-sieve aggregation tests also were made on large clods of soil. These clods were slaked in water for 1 hour and were wet-sieved for 1 hour instead of the standard 30 minutes. At the end of this time, the clods were completely broken down to particles less than 5 millimeters in diameter. The aggregate distribution patterns again were very similar to those shown in Figure 9. These results suggest a characteristic distribution pattern of aggregates for the soil type and indicate that the aggregates are very stable.

Effects of Vegetation on Soil Temperatures

The amount and kind of vegetation have a direct influence on soil temperature. In the studies of soil temperatures conducted on the station, striking differences in temperatures were observed under tobosagrass sod, buffalograss sod and bare ground. Typical curves showing soil temperatures at 3 and 6 inches under sod and bare ground are plotted in Figure 10.

Soil temperatures under a tobosagrass cover were lower in the day and higher at night than temperatures measured at similar depths under bare ground. Thus, tobosagrass reduced the maximum temperatures and increased the minimum temperatures, causing a more uniform soil temperature.

At increased soil depth, temperatures lagged further behind the air temperatures. Figure 10 shows that soil temperature at a 3-inch depth under bare ground on June 29, 1952 reached a maximum 2 hours later than the outside air temperature (measured in the shade). At a depth of 6 inches, the lag behind air temperature was 6 hours.

Observations of soil temperature were made in 1950 under favorable moisture conditions, and also in the following 3 years of drouth. These observations showed that the effects of vegetation on soil temperature were reduced as the soil became dry. The lag of soil temperature behind air temperature also was less pronounced under drouth conditions.

EFFECTS OF RAINFALL ON VEGETATION

Relation of Rainfall to Available Forage

The general relationships between the density of forage on the Texas Range Station and the amount of rainfall for the 16-year experimental period are shown in Figure 11. Total rainfall for the year was plotted against the number of hits as measured by the point-contact method of analysis. The point-contact measurements were usually made about the middle of April. In most years, the vegetation had "greened up" by this time and plant identifications were not too difficult. This period also was considered the most desirable time to record the abundance of bitterweed, although growth of this plant often occurs in the late fall.

The number of hits recorded by the inclined-point-contact method, as used in this study, is considered as a measure of the amount of available forage on the experimental pastures. Since these chartings were made in pastures being grazed by livestock, they reflect plant growth, density of ground cover and amount of forage utilized by the grazing animals.

Several general observations are evident from the relationships shown in Figure 11. Available forage of all plant species studied is closely related to the amount of rainfall. Most species show a lag in available forage of from 1 to 2 years behind years of high or low rainfall. This effect was noted in previous studies by Nelson (1934), Craddock and Forsling (1938) and Clawson (1950).

The graph giving total density of all plant species, both annual and perennial, shows a significant correlation between available forage on Ozona clay and the rainfall of the preceding year. This relationship is indicated by the large correlation coefficient, r=.637. This means that the maximum response of vegetation to rainfall under constant stocking rates is not immediate but requires a delay of about 1 to 2 years. The more variable vegetation on Tobosa clay shows a smaller but significant correlation coefficient, r=.603.

A close relationship was obtained also between the rainfall of the preceding year and the density of buffalograss. For this species, the value of r=.635 on Ozona clay was very close to significance on the 1 percent level. This correlation coefficient indicates that about 36 percent of the year-to-year variability in available forage is associated with rainfall during the previous year.

The nature of the soil has influenced the amount of variability in the density of vegetation. For example, the lakebed areas of the Randall and Irion soils series had greater fluctuations in the amount of vegetation than the other soils. Most species of plants showed a more stable density on the ridgetop soils of the Ozona series.

Tobosagrass showed the least amount of year-to-year fluctuation in density with variation in rainfall. This grass was the most depandable of all species for livestock forage during years of low rainfall. However, when rainfall conditions were favorable it did not increase in abundance as rapidly as buffalograss or curly mesquite grass. A highly significant correlation coefficient, r=.651, was calculated for the density of tobosagrass on Tobosa clay soil and rainfall of the previous year. A value of r=.610 also was calculated for the relationship of rainfall and tobosa density 2 years later.

A greater lag in growth following rainfall was noted for the three-awn grasses than for the other species. This lag, which amounted to 2 years in many instances, may have been due partially to the low palatability of these grasses resulting in a carryover of forage from year to year.

Variation in growth due to climatic factors was greatest in the annual weeds. This fluctuation is demonstrated by the 16-year record of bitterweed density presented in Figure 11. Bitterweed growth is more closely related to seasonal distribution of moisture than to the total annual rainfall. This poisonous range plant grew profusely in bare areas when there was sufficient late fall and early spring moisture. In contrast, annual broomweed germinated late in the spring and was not abundant during years with scant late-spring rains.

Figure 11 indicates that vegetation response following years of low rainfall is slower than

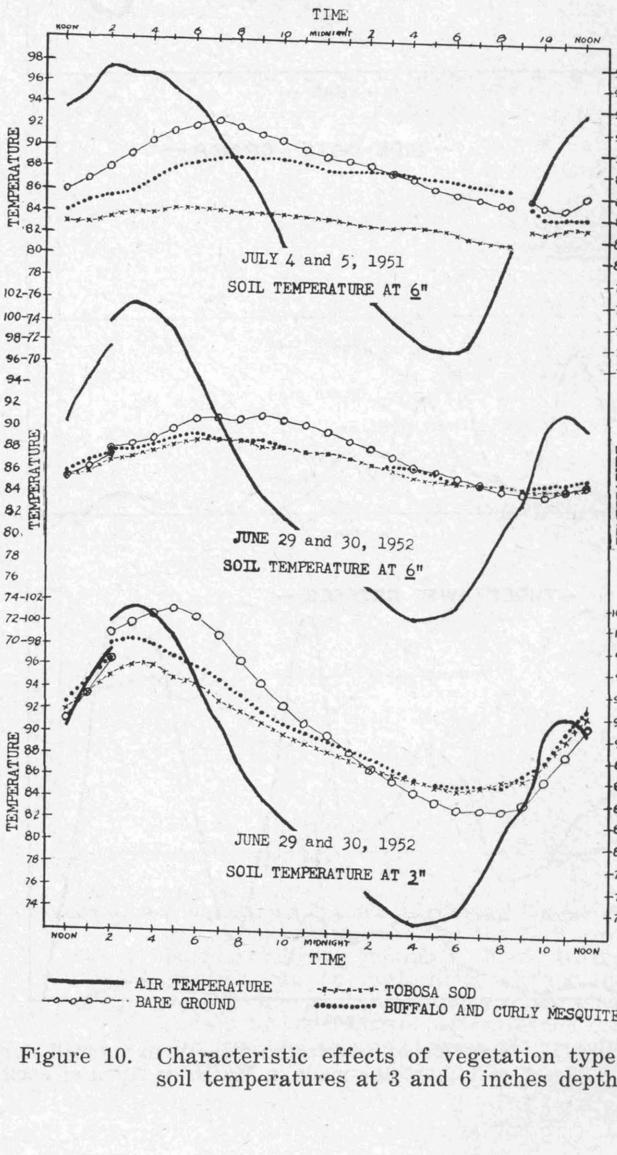

Figure 10. Characteristic effects of vegetation type on soil temperatures at 3 and 6 inches depth.

the response to years of high rainfall. This points up the danger of restocking immediately after periods of drouth.

Effects of Rainfall on Floristic Composition

Fluctuations in the percentage composition of tobosagrass and the turf grasses, buffalo and curly mesquite during 1938-53 are shown in Figure 12. Percentage composition was calculated by dividing the average number of hits of each species by the total number of hits for all plant species.

These data show that tobosagrass made up the bulk of the forage during years of low rainfall. Buffalograss and curly mesquitegrass, however, show a higher relative coverage than tobosagrass in most years.

The graphs showing percentage composition of the above grasses for the 11-year period, 1938 to 1948, might readily lead to an erroneous conclusion. The apparent trend toward a predominance of tobosagrass is largely a reflection of rainfall. Tobosagrass in 1948 actually had the lowest density observed. The fact that the density of

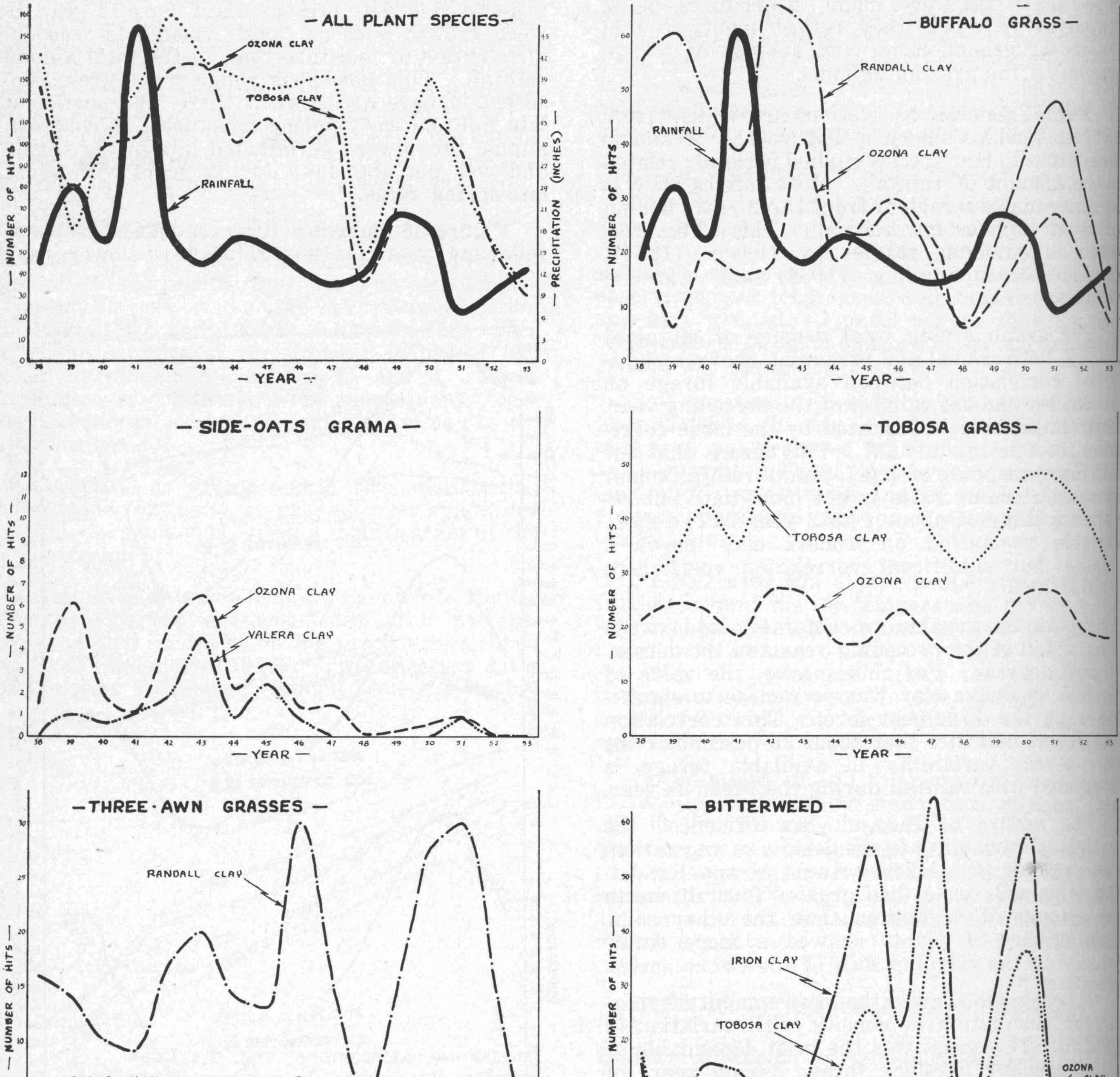

Figure 11. Relation of vegetation density to rainfall during 1938-53. Vegetation density was measured by point-contact chartings made in March or April of each year.

the short grasses was reduced even more than that of tobosa accounts for the apparent shift in dominance.

Composition trends shown in Figure 12 also point out some of the hazards involved in the interpretation of grazing effects from the vegetational survey of a single year. Studies of plant composition during dry years may suggest different grazing effects than similar studies during years of adequate rainfall.

Forage Production

The forage produced in the temporary exclosures was determined from clippings made in August and December of 1951, 1952 and 1953. These yield data are shown graphically in Figure 13.

Forage production was extremely low from 1950 to 1953 because of the shortage of rainfall. The highest production during this period was obtained during the spring and summer-growing seasons of 1952. It amounted to only 738 pounds of air-dry forage per acre of tobosagrass and 449 pounds of mixed buffalograss and curly mesquitegrass. Buffalograss produced 369 pounds of forage per acre in the lakebeds during the same period. All clippings were made in dense sod areas which should produce much more forage under normal rainfall conditions.

On the Ozona clay soils, tobosagrass consistently produced more forage per unit of sod area than the turf grasses, buffalo and curly mesquite. Buffalograss, on the lakebed soils of the Randall series, produced more forage in 1953 than the other grasses. However, only a limited area was occupied by this grass at this time.

Forage production was limited during the fall-growing seasons for all species of grass. From August to December 1952, the production was insufficient to measure. Normally, forage growth in the fall cannot be depended on to furnish feed for the winter. It is, therefore, essential for the livestock operator to save some surplus forage from spring and summer growth so that the livestock may survive the winter with a minimum of supplemental feed. This practice also will help to maintain the vigor of the grasses.

These data on forage production reflect the intensity of the drouth during the period of this investigation. They also indicate the importance of adjusting stocking rates to conform to low rainfall conditions.

Effects of the Drouth on Vegetation

As shown by the rainfall records, Figure 2, a severe drouth has prevailed at the Texas Range Station since September 1950. The rainfall for 1951-53 was considerably below the average for the area. A large proportion of the recorded rainfall occurred in light showers that were ineffective for plant growth. This shortage of moisture affected the forage production and caused a marked reduction in plant density.

It has been difficult to separate the effects of the prolonged drouth from the effects of heavy grazing. Many of the changes in the vegetation that have taken place can be attributed to a combination of both drouth and heavy grazing. However, the changes in the exclosures, as shown in Figure 14, were caused by the drouth.

Tobosagrass was the most drouth resistant of the forage grasses. Only slight changes in total sod area were recorded for this species. Some reduction in foliage density occurred due to death loss within the sod areas, but this reduction was smaller than that of the other grass species.

High death losses occurred in both buffalo and curly mesquitegrass. Figure 14 shows the reductions in sod area and in foliage density that occurred in one of the exclosures on the station

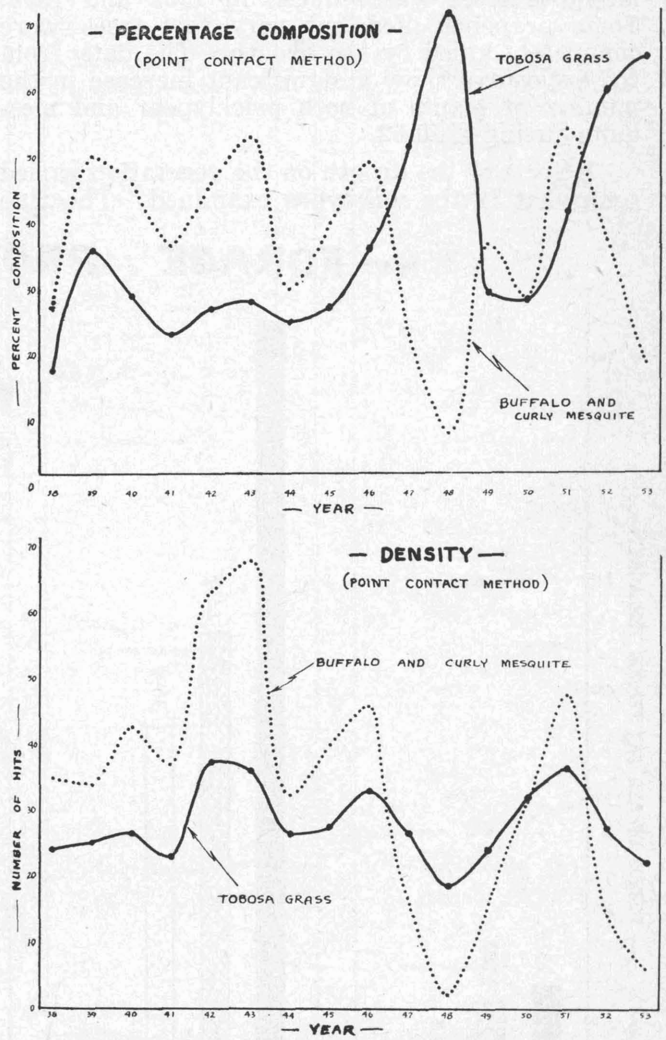

Figure 12. Fluctuations in floristic composition and average density of tobosa and the turf grasses, buffalo and curly mesquite. Percentage composition can be misleading without taking density into account. Composition changes caused by the rainfall pattern should be recognized and separated from changes due to grazing.

from 1950 to 1953. Curly mesquite appeared to have been affected by the drouth conditions more than buffalograss.

Density measurements of side-oats grama, obtained in the shortgrass exclosure in pasture D, showed that some death loss occurred during the same period. Marked reductions in vine mesquite grass were observed in the lakebed exclosure in pasture D. Severe losses were noted for purple three-awn in the exclosures and in the grazed pastures.

The drouth apparently facilitated an increase in the density of brush species. Pricklypear seemed to die back temporarily but recovered rapidly following rains. New plants of this species often originated from the breaking up of the old plants by drouth. Plants of cholla cactus became severely desiccated during dry periods but survived the drouth very well. Foliage density of mesquite trees was reduced in 1952 and 1953. Some branches died but very few trees were completely killed by the drouth. The data from the exclosures show a significant increase in the number of plants of both pricklypear and mesquite during 1950-52.

Effects of the drouth on the vegetation varied somewhat in the soil types examined. The fine textured soils in the low areas dried out and became very loose. Sod grasses on these soils died back more than those on the ridgetop soils. Because of the reduction in the vegetation cover, wind erosion was evident on all soils.

RESPONSE OF VEGETATION TO GRAZING

History of Grazing Use

Detailed records have been maintained since 1938 of the kinds and numbers of livestock grazed on the various pastures of the Texas Range Station. These records were used to analyze the effects of grazing on the vegetation.

The area now occupied by the Range Station was privately operated before 1938. Little information is available on stocking rates and practices used during that period. Available evidence indicates, however, that the area was heavily grazed by both sheep and cattle.

Since 1938, the pattern of stocking has varied. All pastures have been subjected to some grazing by both sheep and cattle. Certain pastures have been used in both rotation grazing and continuous grazing management. Stocking rates for all classes of livestock have been changed sev-

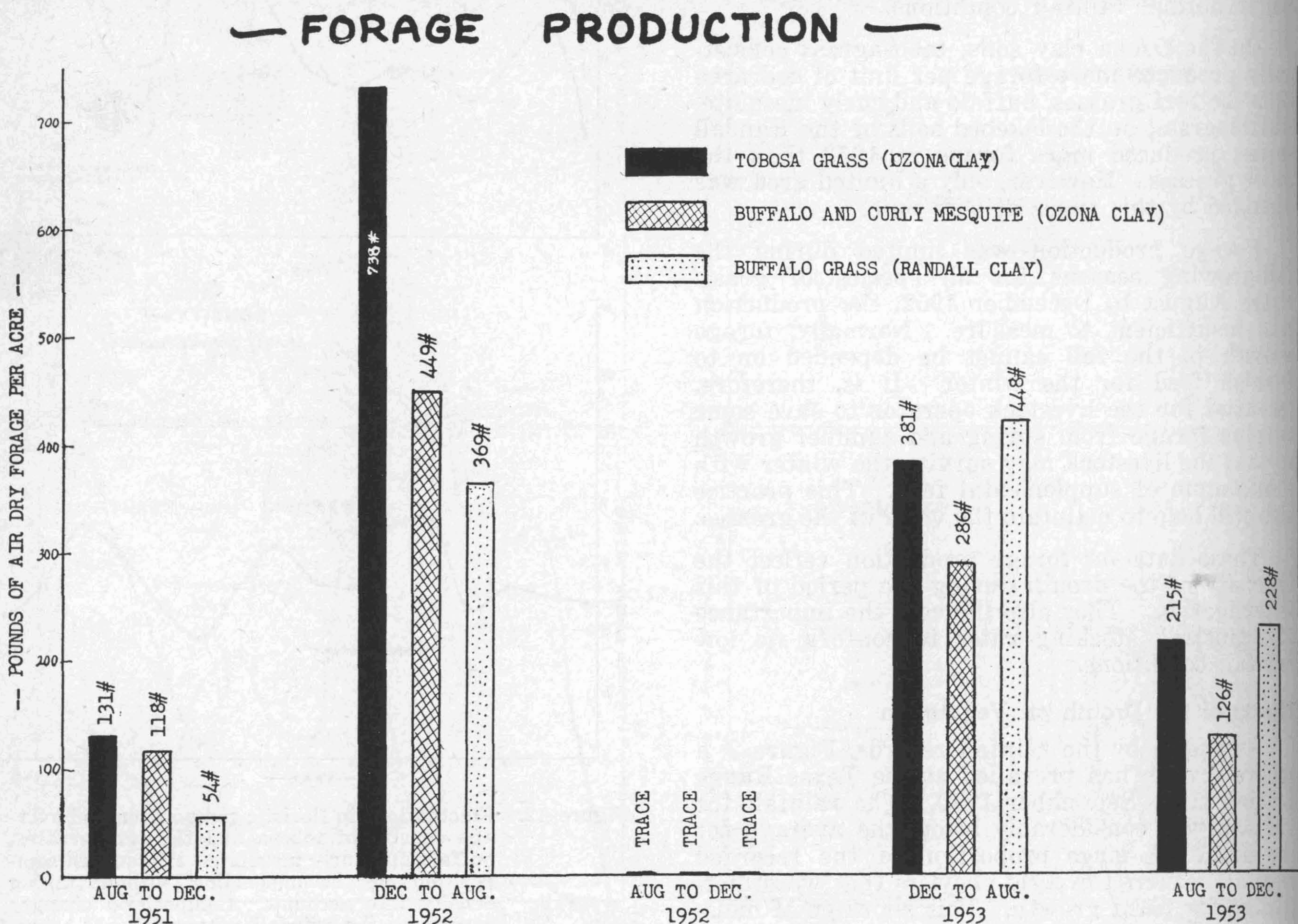

Figure 13. Forage production during the drouth of 1951-53. The bulk of the forage comes from spring and early summer growth. Forage produced in the fall usually is not adequate to carry livestock through the winter.

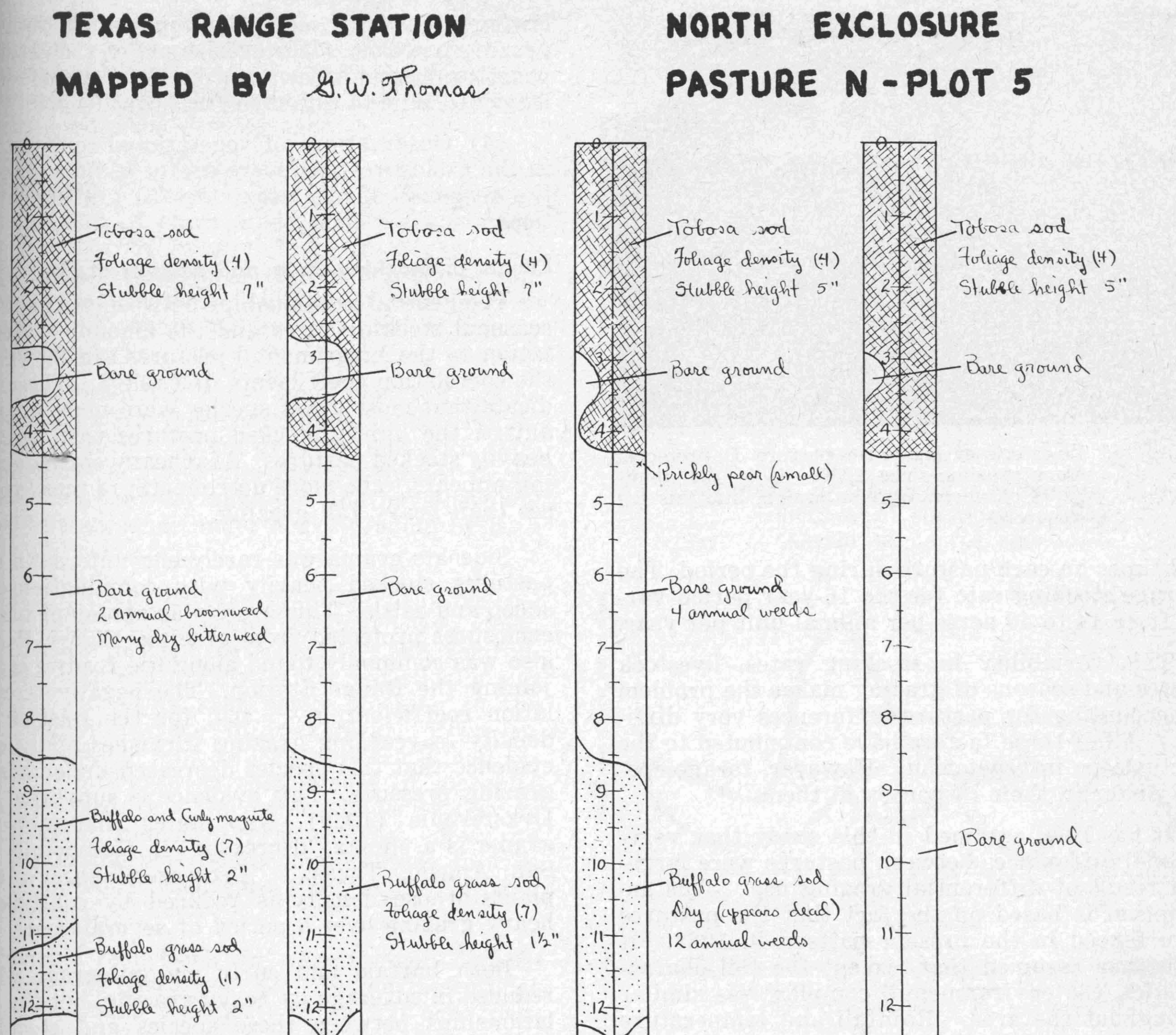

Figure 14. Vegetational change on a typical plot in the livestock exclosure (pasture N) showing the reduction in plant density due to the drouth.

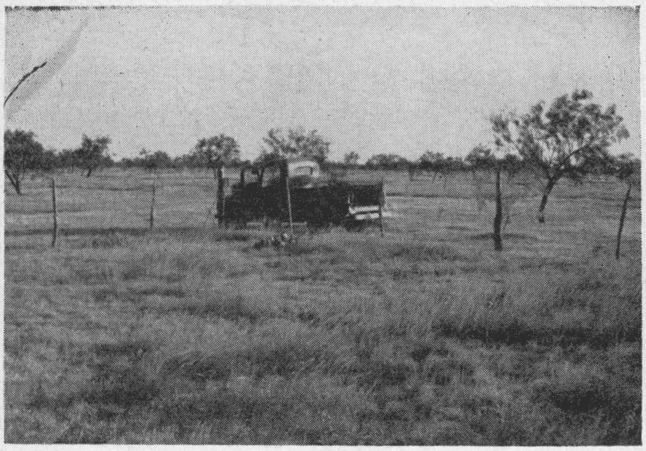

Figure 15. Livestock exclosure in pasture D protected from grazing since 1940. Note the abundance of sideoats grama coming into this exclosure.

eral times on each pasture during the period. The average stocking rate for the 16-year period varied from 14 to 40 acres per animal unit per year.

This variability in stocking rates, livestock classes and seasons of grazing makes the problem of accounting for pasture differences very difficult. All of these factors have contributed to the fluctuations in vegetation. However, forage species differ in their responses to them.

It has been assumed in this study that vegetational differences between pastures were largely a result of differential grazing use. This assumption is based on the fact that the pastures were fenced in the present pattern in 1938. It is further assumed that, except for soil characteristics, the environmental complex was similar throughout the area. Rainfall and temperature measurements taken at the ranch headquarters are believed representative of the entire area.

The response of the vegetation to grazing practices was determined in the following manner:

(1) Differences in the vegetation caused by soil factors were recognized and removed statistically by analyses of variance. Thomas (1950) showed that there were significant differences between individual pastures for most of the major plant species on the station after variability due to soils was removed. These differences were confirmed by a more complete vegetational survey in 1953.

(2) The amount of vegetation on each soil in each pasture was then compared with the past grazing history of the pasture. This was done by computing correlation coefficients relating grazing factors with the density of each of the plants or combinations of plants studied.

(3) These correlation coefficients were used as a basis for formulating hypotheses concerning the effects of grazing. The hypotheses were then checked by examining the past records and following trends in vegetation under the various grazing patterns. However, some of the grazing practices have not been continued for a sufficient length of time to establish final conclusions.

(4) Observations of vegetational composition in the exclosures also were useful in interpreting the response of the vegetation to grazing practices.

Effects of Stocking Rate and Season of Use

The general relationships between yearlong or seasonal stocking rates and the amount of vegetation on the experimental pastures are shown by the correlation coefficients in Table 2. These indicate that most grass species were more abundant on the lightly stocked pastures than on the heavily stocked pastures. Also heavy spring grazing appears to be more detrimental to most grasses than heavy fall grazing.

Sideoats grama was rarely encountered in the pastures stocked heavily with combinations of sheep and cattle. This grass was abundant in the exclosures protected from grazing, Figure 15. It also was commonly found along the roadways adjoining the Range Station. The negative correlation coefficient, $r = -.464$, for the relation of density to yearlong grazing furnishes additional evidence that this species decreased under heavy grazing pressure. This evidence is supported by Dyksterhuis (1949), who states that sideoats grama is a climax "decreaser" in the vicinity of San Angelo, Texas. "Decreaser" species are plants whose density is reduced by continuous heavy grazing over a period of several years.

Both buffalo and curly mesquitegrass were reduced in coverage by heavy grazing, but the relationships between these species and stocking rates are not very pronounced, Table 2. Buffalograss appears to be more resistant to heavy grazing than curly mesquitegrass. This may be due to the fact that the crowns of curly mesquitegrass

Table 2. Correlation coefficients showing the relationship between rate of stocking by livestock and the amount of vegetation on the Texas Range Station

Plant species	Stocking rate		
	Yearlong	Spring	Fall
Tobosagrass			
Sod area	.198	.327	—.136
Adjusted density	.333	.495	.021
Number of hits	.417	.042	.002
Buffalograss			
Sod area	.018	.027	.117
Adjusted density	—.200	—.232	.010
Number of hits	—.239	—.066	.145
Curly mesquitegrass			
Sod area	—.186	—.158	—.233
Adjusted density	.180	.224	.059
Number of hits	—.047	.026	.097
Mixed buffalo and curly mesquite			
Sod area	—.148	—.329	.255
Adjusted density	—.125	—.210	.191
Number of hits	—.076	—.065	.211
Sideoats grama (density)[1]	—.464	—.405	—.072
Purple three-awn (density)[1]	.333	.248	.146
Annual broomweed (number)[1]	—.274	—.266	—.264
Mesquite trees under 4 feet (number)	—.102	.082	—.248
Pricklypear (number)	.406	.353	.522[2]

[1] From 1950 survey.
[2] Indicates significant relationship on the 5 percent level.

are usually above the ground, whereas bullafograss grows very closely to the ground surface. Both of these sod-forming grasses have been damaged seriously by heavy grazing and drouth conditions during the past 4 years.

The correlation coefficients in Table 2 indicate that the pastures most heavily stocked with combinations of sheep and cattle have slightly more tobosagrass than the lightly stocked pastures. The relationship between number of hits (point-contact method) and rate of stocking also indicates that tobosa has increased on the heavily grazed pastures.

Vine mesquite, cane bluestem and green spangletop were more abundant in the lightly stocked pastures. These grasses rank with sideoats grama as climax "decreaser" species in the area. They are very palatable and have been reduced in abundance under heavy grazing by both sheep and cattle.

An apparent increase in pricklypear has occurred under yearlong and seasonal heavy stocking. The correlation coefficient, r=.522, for fall-stocking rate and pricklypear is statistically significant, indicating that heavy stocking in the fall caused an increase in pricklypear. However, rate of stocking (since 1938) apparently had little or no influence on the number of mesquite trees per pasture. Only trees under 4 feet in height were included in these analyses. Mesquite tree population was related more closely to soils and to previous occurence than to the grazing practices.

Serious reductions in vegetational density were noted in pastures A and B under a seasonal rotation grazing system. These 172-acre pastures were stocked with 75 sheep and 10 cows for the 6-year period 1938-43. The dates of rotation were fixed at the same time each year. As a result, the vegetation in both pastures deteriorated

Table 3. Correlation coefficients showing the relationship between rate of stocking by cattle or sheep and the amount of vegetation on the Texas Range Station

Plant species	Stocking rate	
	Cattle	Sheep
Tobosagrass		
Sod area	—.181	.276
Adjusted density	—.023	.355
Number of hits	—.008	.034
Buffalograss		
Sod area	—.052	.123
Adjusted density	.170	.087
Number of hits	—.100	.043
Curly mesquitegrass		
Sod area	.139	.096
Adjusted density	.560[1]	—.202
Number of hits	—.495	—.115
Mixed buffalo and curly mesquite		
Sod area	—.188	.148
Adjusted density	—.308	.249
Number of hits	.156	.046
Sideoats grama (density)[2]	—.107	—.124
Purple three-awn (density)[2]	—.405	.676[3]
Annual broomweed (number)[2]	.281	—.528[1]
Mesquite trees under 4 feet (number)	.112	.139
Pricklypear (number)	.786	.085

[1] Indicates significant relationship on the 5 percent level.
[2] From 1950 survey.
[3] Indicates significant relationship on the 1 percent level.

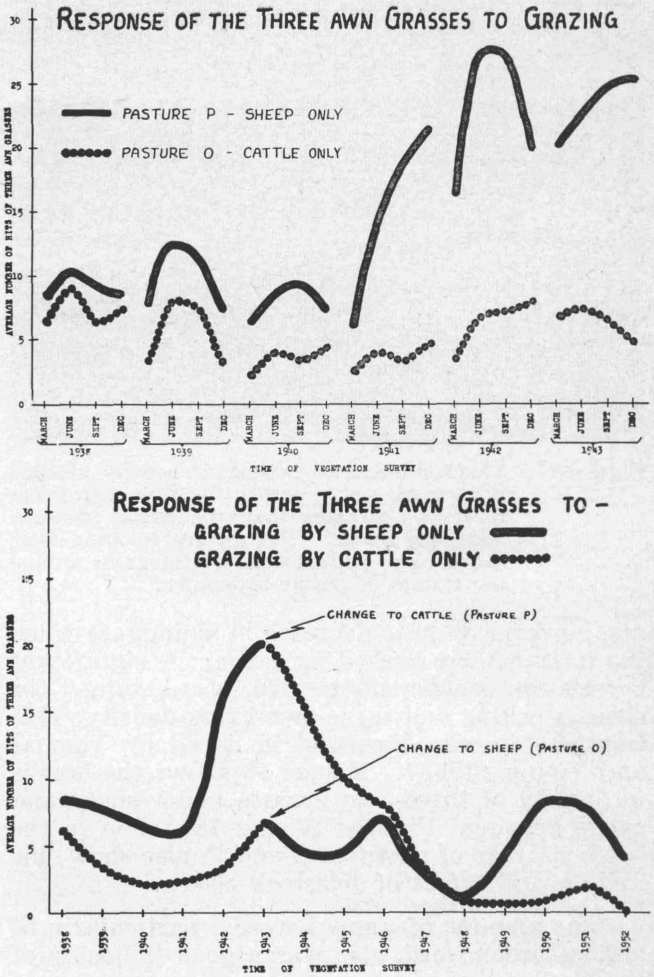

Figure 16. Response of the three-awn grasses to grazing by sheep and cattle. Note the rapid increase in these grasses when the pastures are grazed with sheep.

even though rainfall conditions were favorable. Pasture A, which was grazed each year during the spring-growing period, showed a serious reduction in most of the better grasses. Similar rotation grazing systems were tested on pastures I, K, L and M. In each case, the pastures that were heavily stocked during the spring-growing season deteriorated faster than those stocked during the other seasons. This evidence emphasizes the importance of a systematic deferment in the rotation design so that one pasture will not be grazed during the critical spring period every year.

Effects of Class of Livestock on Vegetation

Some differences in vegetation associated with grazing by sheep and cattle are indicated by the correlation coefficients in Table 3.

The relative abundance of three-awn grasses is one of the best indicators of the class of livestock grazing on the pastures. Pastures stocked at the highest rates with sheep had the largest amounts of these grasses. The three-awn gras-

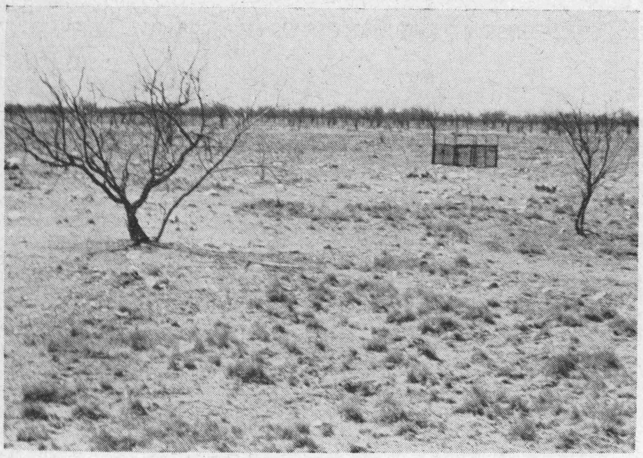

Figure 17. Lakebed area in pasture O heavily stocked with cattle only. Very little three-awn grass three-awn grasses than the cattle pastures but fewer weeds. This picture, taken in 1952, shows close utilization of buffalograss around the clumps of purple three-awn.

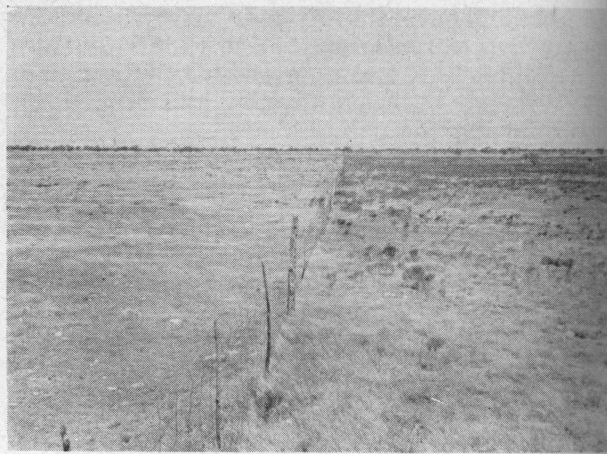

Figure 19. Fence line separating pasture B on the left from pasture C on the right. Differences are due largely to the presence of annual broomweed in pasture C, grazed by cattle, and purple three-awn in pasture B, grazed heavily by sheep.

ses, however, tend to decrease in abundance when the pastures are grazed by cattle. A significant correlation coefficient, r=.676, was obtained for sheep stocking and three-awn grass density. This relationship was discussed in detail by Thomas and Young (1953). Figure 16 shows the trends in density of three-awn grasses under sheep and cattle grazing. Figures 17 and 18, taken in the lakebed areas of pastures O and P, also show this differential effect of livestock class.

The amount of annual weeds, particularly of annual broomweed, also was a good indicator of the kind of livestock grazing on the pastures. In years of favorable rainfall, pastures stocked with cattle supported large amounts of annual broomweed. This species, nevertheless, was largely eliminated by heavy spring grazing with sheep. The negative correlation coefficient, r=−.528, shows a significant relationship between stocking rate by sheep and the number of annual broomweed plants per pasture. A typical fence-line contrast between pastures grazed by sheep and pastures grazed by cattle is shown in Figure 19.

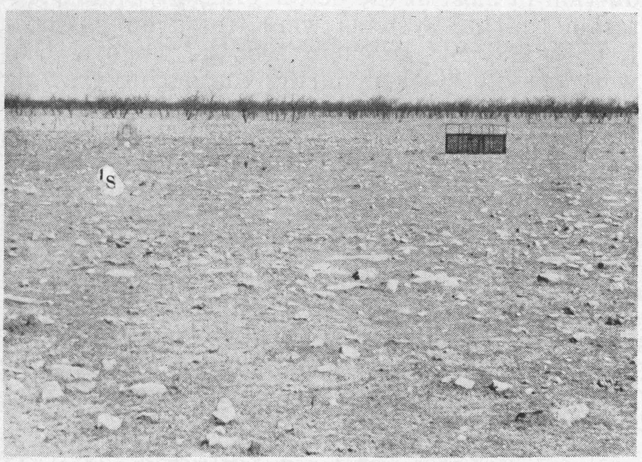

Figure 18. Lakebed area in pasture P heavily stocked with cattle only. Very little three-awn grass is present. This picture was taken in 1952 at the same time of the year as Figure 17.

Heavy stocking by cattle evidently caused slight reductions in the amount of tobosagrass on the experimental pastures. This effect is indicated by the negative correlation coefficient in Table 3 and by the point-contact chartings shown in Figure 20. Sheep grazing caused a slight increase in tobosagrass. Since the point-contact chartings are influenced by the amount of utilization, these differences do not necessarily reflect an actual change in ground cover.

Under sheep grazing in pasture O, tobosagrass decreased in density on the Ozona clay soils and increased on the Tobosa clay soils.

The amount of buffalo and curly mesquitegrass apparently is not closely associated with the class of livestock on the pastures. Due to drouth, sod areas of both of these stoloniferous grasses were seriously reduced on all pastures. As a result, the effects of grazing by sheep and cattle have been difficult to evaluate.

The relationships between the amount of brush and the rates of sheep and cattle stocking are shown in Table 3. The numbers of mesquite trees apparently were not influenced by the class of livestock. However, the correlation between abundance of pricklypear and the rate of cattle stocking was highly significant, r=.786. Cattle grazing on pricklypear break off and scatter sections of these cacti. These sections, or "joints," take root under favorable moisture conditions and establish new pricklypear plants.

Utilization Studies

Studies of forage utilization by sheep and cattle were made in pastures O and P from August 1951 to August 1953. Forage available

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The caption to Figure 17, page 20, should read: "Lakebed area in Pasture O heavily stocked with sheep. This pasture has more of the three-awn grasses than the cattle pastures but fewer weeds This picture, taken in 1952, shows close utilization of buffalograss around the clumps of purple three-awn."

Table 4. **Forage available for livestock use in pasture O, heavily stocked by sheep, and pasture P, heavily stocked by cattle**[1]

Plant species and pasture	Forage available in pounds per acre				
	Aug. 1951	Dec. 1951	Aug. 1952	Dec. 1952	Aug. 1953
Tobosagrass					
Pasture O	1958	2098	1906	781	783
Pasture P	1237	790	917	192	348
Mixed buffalo and curly mesquitegrass					
Pasture O	1320	1104	381	187	200
Pasture P	252	Trace	182	37	168
Buffalograss					
Pasture O	1238	215	29	Trace	50
Pasture P	201	Trace	71	59	196

[1]Data represent averages of the forage clipped in the grazed areas.

for livestock was determined by comparisons of vegetation clippings made in the grazed areas with those made in temporary exclosures.

The data on forage available for livestock use in pastures O and P are presented in Table 4. These data show characteristic differences in the amount of forage available under sheep and cattle grazing. Both pastures were stocked at the rate of 20 acres per animal unit per year during the period of study. The pasture grazed by sheep consistently had more forage available than the cattle pasture. This difference was maintained as the drouth increased in severity. As a result, supplemental feeding of cattle became necessary

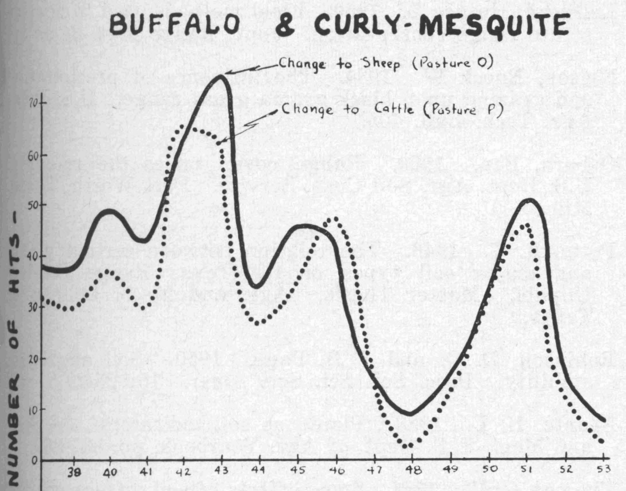

Figure 20. Response of buffalo, curly mesquite and tobosagrass to sheep and cattle grazing. Pasture O was grazed by cattle the first 6 years and has been grazed continuously by sheep since 1944. Pasture P was grazed by sheep for 6 years and by cattle since 1944. Both pastures have been stocked at an average rate of one annual unit per 18 acres yearlong.

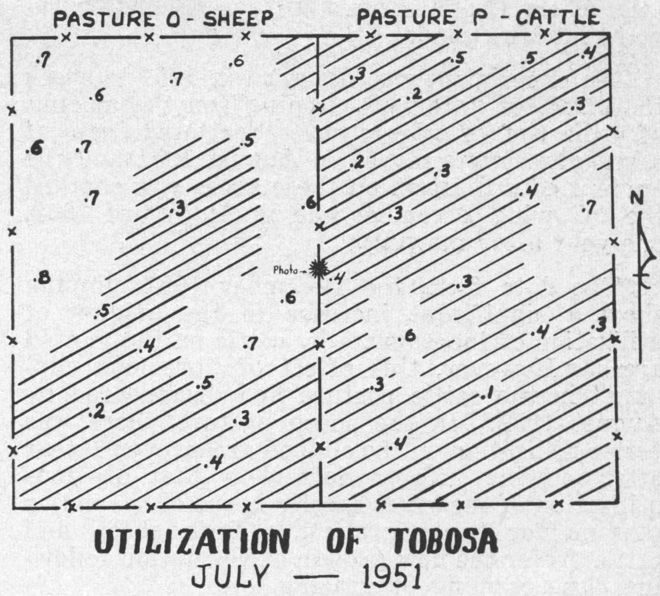

Figure 21. Utilization map showing stubble-height measurements of tobosagrass after grazing by sheep and cattle. The shaded area has been grazed to a stubble height below 6 inches.

at an earlier date than supplemental feeding of sheep.

This information indicates that a ratio of 6 sheep to 1 cow may be too low for the Texas Range Station. However, careful examinations of both the sheep and cattle pastures showed that sheep caused equally as much or more damage to the vegetation and soil as did the cattle. This was due to the habit of sheep to "spot graze." A utilization survey made in July 1951, shows some differences in the amount of utilization of tobosagrass by sheep and cattle at similar rates of stocking, Figures 21 and 22. The pattern of utilization of tobosa by sheep was strongly influenced by wind direction and soil condition. In grazing, sheep first concentrated on the ridgetop

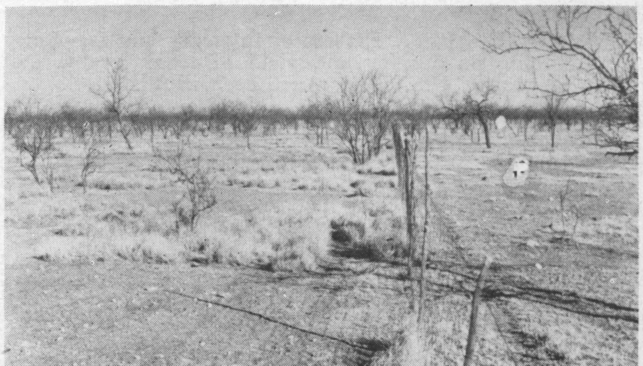

Figure 22. Picture taken at the location marked in Figure 21. Pasture O on the left has been grazed by sheep and pasture P on the right by cattle.

soils of the Ozona series and then drifted southward into the wind.

An experiment was designed in 1951 to check the effect of "previous clipping" on the amount of utilization of tobosagrass. Scattered areas of tobosagrass were moved in August 1951 and the amount of utilization on these areas was checked the following December and in August of 1952, one year after mowing.

The data from the December 1951 clipping show a significant increase in the amount of utilization of tobosagrass by cattle on the mowed areas. However, this effect of "previous clipping" in the cattle pasture had disappeared by August 1952. In the sheep pasture, there was better utilization on the clipped areas, even 1 year after mowing. These data show that previous utilization of the grass species is one of the major reasons for "spot grazing." Both sheep and cattle prefer the new growth of vegetation following close clipping or grazing.

ACKNOWLEDGMENTS

The authors acknowledge the following men who assisted with certain phases of this project: W. H. Dameron (deceased) and W. T. Hardy, superintendents, Ranch Experiment Station, Sonora; L. B. Merrill, range specialist, Sonora, and E. J. Compton, University of Texas. Appreciation also is extended to V. L. Cory, formerly range botanist, and to other members of the Texas Agricultural Experiment Station who have assisted in the collection of field data and in the organization of this grazing experiment.

The contribution of the University of Texas in furnishing the land and other facilities of the Texas Range Station is gratefully acknowledged.

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