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Influence of Vegetation Management on Yield and Quality Surface Runoff

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Texas Water Resources Institute

Texas A&M University

1977 FINAL REPORT

TITLE II PROJECT C-6310

INFLUENCE OF VEGETATION MANAGEMENT ON YIELD AND QUALITY SURFACE RUNOFF

BY

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March 1977

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INTRODUCTION

Water requirements for the United States will triple by the year 2000 (Water Resources Council, 1968). In Texas and many western states about 75% of the total water used is from ground water and this source in many areas is rapidly being depleted. To meet future demands water will have to come from other sources (Runkles, 1972). A possible source is increased water yield from watersheds. The quantity and quality of this surface runoff is influenced by many factors which include precipitation pattern, vegetation-type, soil-type and land use. If surface runoff from watersheds is to be a potential water source, the impact of these factors on water quality and yield must be evaluated.

Forests, grasslands and shrublands cover vast watersheds in Texas and North America. Many watershed studies have been conducted in forested regions, but rangeland areas have received only limited attention, particularly in Texas. The significance of these latter types cannot be overlooked since 40% of the land surface in the United States and 60% of Texas support this type of vegetation.

The major use of rangeland is domestic livestock and wildlife production. The impact of this use on water yield and nutrient and sediment loss from watersheds requires investigation. The influence of various grazing systems and intensities must be determined in order to coordinate ranching practices with increased high quality runoff. The effect of brush control on runoff yield and quality has not been thoroughly investigated.

The purpose of this study was to determine the influence of vegetation characteristics, grazing systems and precipitation on surface runoff from rangeland on the Edwards Plateau region of Texas. Water yield, organic-N, NO_3^--N, NH_4^--N, NO_2^--N, total and ortho-P, Ca, Mg, K, pH, conductivity, total and calcium hardness, turbidity and suspended sediment load were quantitively evaluated.

Field sampling was conducted on small-gauged watersheds on the Texas A&M Agricultural Research Station at Sonora, Texas. These gauged watersheds, which have been established over the past 13 years by the Agricultural Research Service (ARS), represent a variety of grazing systems ranging from continuous heavy grazing with poor vegetation cover to four-pasture and seven-pasture deferred rotation systems with good cover. In addition several different techniques have been used for woody plant control on the watersheds. The Sonora Research Station, with over 25 years of grazing management research, provides a unique area for study of the effects of grazing management and brush control on surface runoff, nutrient load and sediment yield.

STUDY AREA

The Sonora Agricultural Research Station is located approximately 56 km south of Sonora, Texas and is within the Edwards Plateau Land Resource Area (Godfrey et al., 1970). The station consists of 1,403 ha located in Sutton and Edwards counties.

Edwards Plateau summers are relatively warm with an average July temperature of 30°C. The average January temperature is 9°C (Hardy et al., (1962). The growing season averages 235 days. Average annual rainfall at the Station is 56.7 cm. The highest annual rainfall recorded was 105 cm in 1935, the lowest was 16 cm in 1951. May and September are considered the wettest months averaging 7.9 and 8.0 cm, respectively (Long, 1962). Droughts are the rule rather than the exception with 53% of the years falling below the average annual rainfall (Thomas, 1959).

The Edwards Plateau is a partially dissected remnant of an uplifted plain capped chiefly by resistant limestones. The area is underlain by Cretaceous rocks which overlie a basement of Paleozoic rocks (Long, 1962). Topography is gently rolling and the average elevation is 735 m.

Soils on the Station are typical of the central area of the Edwards Plateau. Most of the Station is occupied by Tarrant stony clay soils which are a grayish brown color and vary from 15 to 30 cm in depth. These soils contain large amounts of limestone fragments, stones and gravel and are underlain by a hard limestone substratum that is usually fractured and porous. Slopes range from 0 to 8%. Tarrant silty clay soils are deeper than the stony clay soils and have fewer limestone fragments and stones in the surface and occur on nearly level to gently sloping sites (Carter et al., 1938). Low stony hill range sites cover the greater portion of the Station (Smeins, Taylor and Merrill, 1976).

Vegetation of the area has changed significantly under the impact of confined grazing pressure by domestic livestock and elimination of fires (Bray, 1906). Prior to 1900, up to 125 animal units per section grazed the study area (Youngblood and Cox, 1922) while from 1900 to 1948 approximately 70 animals units per section was common (Merrill, 1959). Early documents describe the area as grassland with scattered woody plants along drainages and on steep, rocky slopes (Havard, 1885; Bentley, 1898; Buechner, 1944). Today woody plants are a major component of the vegetation.

Herbaceous vegetation is characterized by a mixture of short and midgrasses with a great variety of forbs. Important grasses are common curlymesquite (Hilaria belangeri)*, Wright threeawn (Aristida wrightii), side-oats grama (Bouteloua curtipendula), vine mesquite (Panicum obtusum), Texas wintergrass (Stipa leucotricha), red grama (Bouteloua trifida), Hairy grama (B. hirsuta), and hairy Tridens (Erioneuron pilosum). Scattered throughout the herbaceous matrix are varying densities of woody plants which occur singly or in mottes (clumps). Live oak (Quercus virginiana), Vasey shin oak (Q. pungens var. vaseyana), Ashe juniper (Juniperus ashei), redberry juniper (J. pinchoti), and homey mesquite (Prosopis glandulosa var. glandulosa) are important woody species.

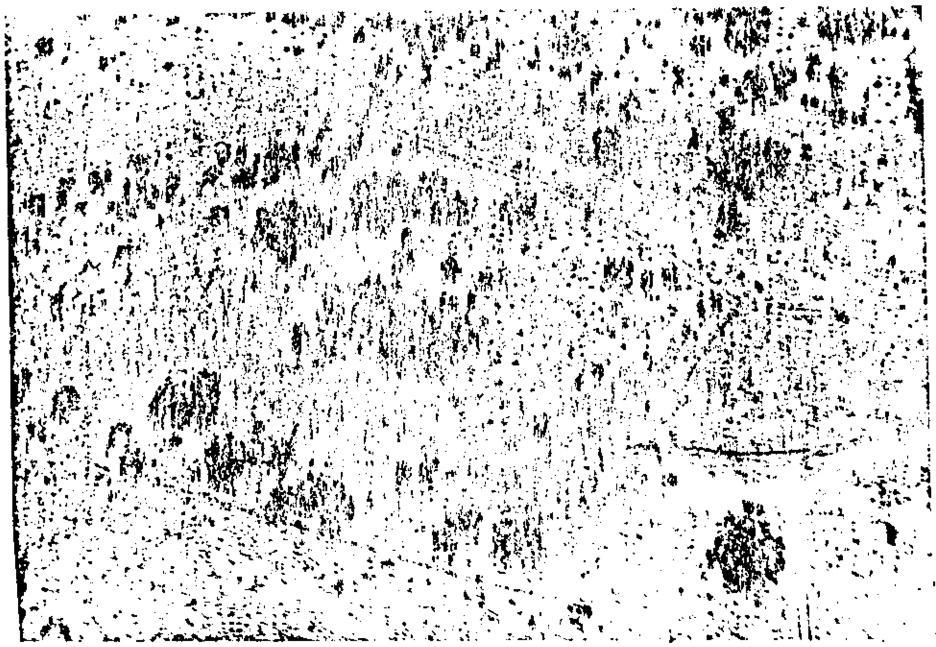
The Station is divided into several 32 ha pastures. Each pasture receives a specific grazing treatment and some pastures have had various chemical and mechanical brush control applied to them. Two pastures serve as exclosures for comparison with grazed pastures. One exclosure excludes all livestock and whitetailed deer while the other excludes livestock only.

Within seven pastures are located small (1.5-4.0 ha) watersheds which were established by the ARS for the purpose of evaluating water yield (Figs. 1 and 2). Each watershed has a gauging station equipped with a stage recorder and a calibrated H-flume (Fig. 3A). During 1974 the Texas Agricultural Experiment Station (TAES) established automatic sediment samplers (Fig. 3B) on two of the watersheds for the purpose of evaluating water quality and sediment yield. Since initiation of the current study two more watersheds have been equipped with sediment samplers.

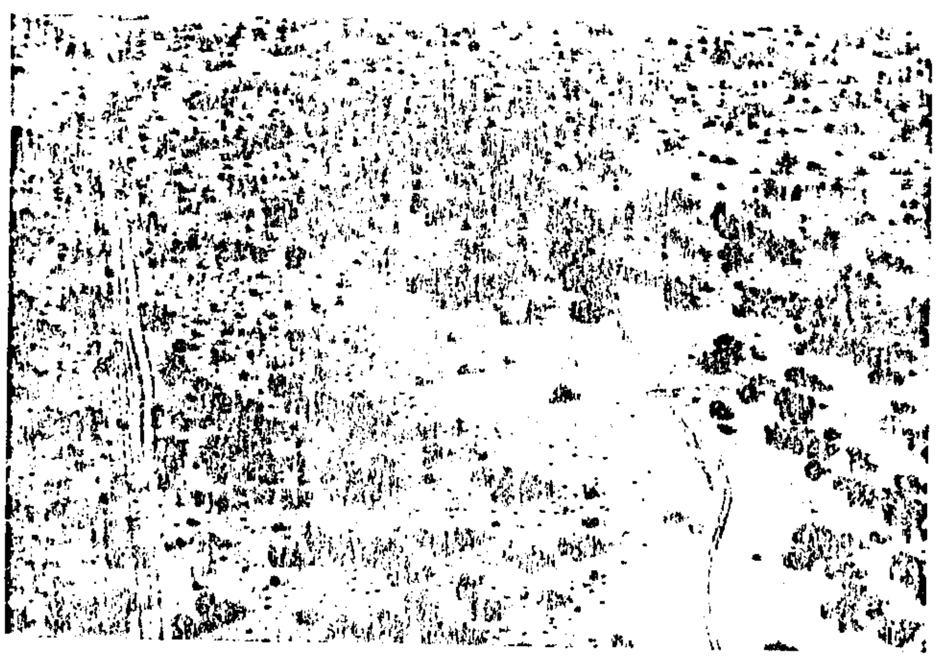
The four watersheds equipped with sediment samples (Figs. 1 and 2) are within pastures that represent either continuous heavy grazing or a 4-pasture deferred rotation grazing system. In the 4-pasture system all four

*Taxonomic nomenclature follows Gould (1975).

Figure 1. Aerial view of experimental watersheds located on the Sonora Research Station, Sonora, Texas. Two, 4-pasture, deferred rotation pastures and their included watersheds are shown. The upper photograph (A) is pasture 7 and the lower (B) is pasture 1.



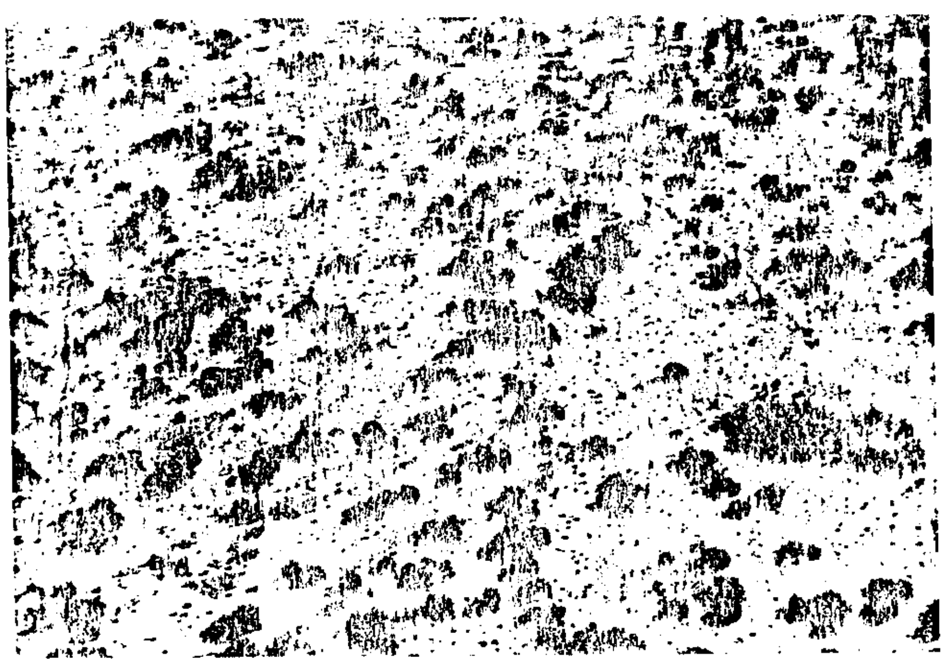
A



B

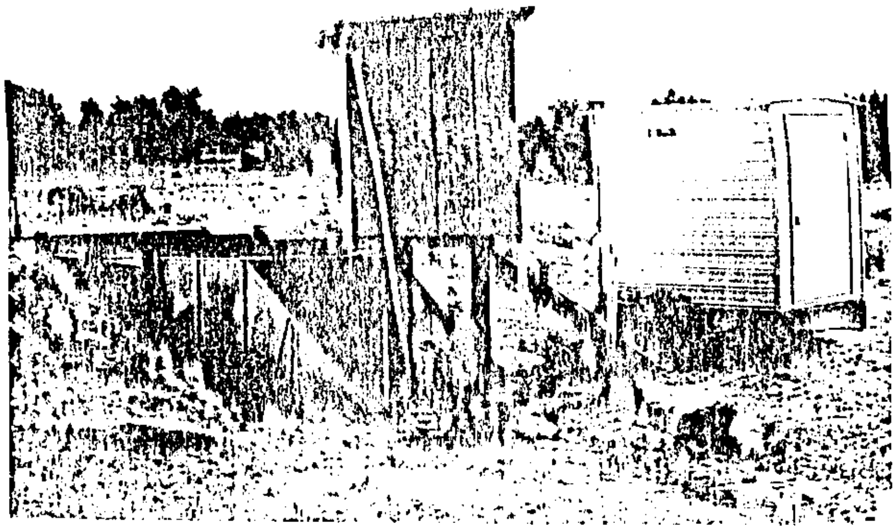
Figure 2. Aerial view of experimental watersheds located on the Sonora Research Station, Sonora, Texas. Two, continuously heavily grazed pastures and their included watersheds are shown. The upper photograph (A) is pasture 4 and the lower (B) is pasture 5.

A

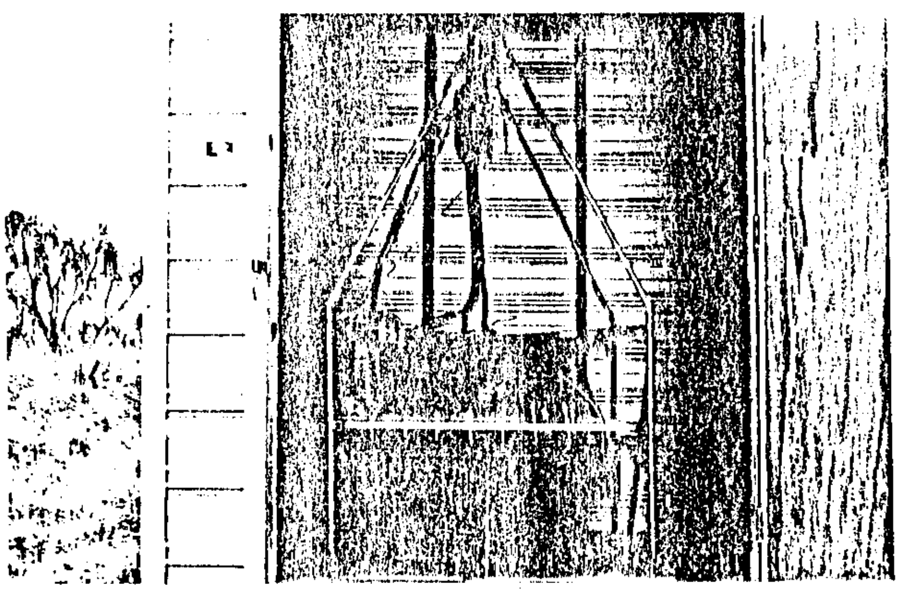


B

Figure 3. Flume, stage recorder and sediment sampler (A) and close-up of sediment sampler (B) on the watershed located in the continuously heavily grazed pasture number 4 on the Sonora Research Station, Sonora, Texas.



A



B

pastures are of approximately equal grazing capacity. The proper stocking rate of all four pastures is divided into three herds. Three pastures are grazed while one is deferred. The major objective is to provide one full year of rest out of every four years for each pasture and for each pasture to be deferred for four months during three different times of the year. In other words, a pasture does not receive a full years rest at one time but rather is grazed twelve months, rested four months, grazed twelve, etc., and in so doing over a four year period it receives one years rest and is rested four months during three different times of a year. In the continuously grazed pasture livestock are kept on the pastures continuously for 12 months.

Of the four pastures equipped with sediment samplers, two are under the heavy continuous grazing system while the other two have a 4-pasture, 3-herd deferred rotation grazing system (Table 1). They have all been grazed with a 60:20:20 ratio of cattle, sheep and goats since 1969. Three have a current stocking rate of approximately 55 animal units per section while the fourth (pasture 1, Table 1) is stocked at 40 animal units per section.

All pastures have a fine sandy clay loam soil which is shallow and rocky. They all have gentle slopes with the maximum slope (6%) in pasture 5 (Table 1). Soil depths are variable within any one watershed but as indicated by the range site classification (Table 1) some watersheds have generally deeper soils than others. Organic matter content and bulk densities are quite similar for all pastures. Vegetation of the pastures is very different in both species composition and biomass (Fig. 4, Table 2).

Selection of these four pastures for installtion of sediment samplers

Figure 4. General view of the vegetation of deferred rotation pasture number 7 (A) and continuously heavily grazed pasture number 4 (B) on the Sonora Research Station, Sonora, Texas.

A

B

Table 1. Grazing history, current use and selected site characteristics of the four experimental watersheds investigated for water yield and quality on the Sonora Research Station, Sonora, Texas.

	PASTURE DESCRIPTION			
	4-Pasture, Deferred Rotation (Pasture 1)*	Heavy Continuous Graze (Pasture 4)	Heavy Continuous Graze (Pasture 5)	4-Pasture, Deferred Rotation (Pasture 7)
Grazing History				
1948-1969	moderate continuous grazing with a 50:50 ratio of cattle and goats at 32 animal units per section	heavy continuous grazing with a 50:25:25 ratio of cattle, sheep and goats at 48 animal units per section	heavy continuous grazing with sheep at 48 animal units per section	light continuous grazing with a 50:50 ratio of cattle and goats at 16 animal units per section
1969-present	4-pasture, 3-herd deferred rotation grazing with a 60:20:20 ratio of cattle, sheep and goats at 40 animal units per section	heavy continuous grazing with a 60:20:20 ratio of cattle, sheep and goats at 56 animal units per section	heavy continuous grazing with a 60:20:20 ratio of cattle, sheep and goats at 56 animal units per section	4-pasture, 3-herd deferred rotation grazing with a 60:20:20 ratio of cattle, sheep and goats at 54 animal units per section
Site Characteristics				
Range Site	Shallow Upland	Shallow Upland	Low Stony Hill	Deep Upland
Size (ha)	2.9	1.8	2.8	2.7
Soil Texture	Fine sandy clay loam	Fine sandy clay loam	Fine sandy clay loam	Fine sandy clay loam
Slope (%)	2	2	6	2
Organic Matter (%)	5.4	5.3	4.9	5.8
Bulk Density (g/cc)	1.2	1.3	1.4	1.2

*Numbers assigned to the pastures on the Sonora Research Station.

e 2 ove) erb us woc lai li , s anc ck tot bov ounc rba us biomass (kg/ha) for watersheds in pasture 4 (heavy continuous grazing), pasture 5 (heavy continuous grazing) and pasture 7 (4-pasture deferred rotation grazing) for July 1974*.

Species	4-Pasture Deferred Rotation (Pasture 7)	Heavy Continuous Graze (Pasture 4)	Heavy Continuous Graze (Pasture 5)
	PERCENT COVER		
Herbaceous			
Curlymesquite (*Hilaria belangeri*)	16.6	10.6	20.8
Hairy tridens (*Erioneuron pilosum*)	0.8	3.8	3.2
Red grama (*Bouteloua trifida*)	1.1	2.4	2.0
Threeawns (*Aristida* spp.)	5.6	0.4	-
Texas wintergrass (*Stipa leucotricha*)	3.6	0.7	-
Other grasses	3.6	0.2	2.7
Forbs	0.1	0.4	0.3
Total Herbaceous Species	31.4	18.5	29.0
Woody			
Live oak (*Quercus virginiana*)	**	7.7	1.5
Shin oak (*Quercus pungens*)		2.4	8.9
Redberry juniper (*Juniperus pinchoti*)		3.5	8.4
Ashe juniper (*Juniperus ashei*)		0.8	-
Other Woody Species		1.7	1.9
Total Woody Species	20.1	16.1	20.7
Litter	34.9	28.3	0.5
Soil	10.9	20.5	19.3
Rocks	2.7	16.6	30.7
	BIOMASS (kg/ha)		
	2500	1200	1000

*Vegetation data not collected for pasture 1

**Individual woody species data not available for this watershed was based on 1) their relative closeness to one another which reduces precipitation variation, 2) their grazing treatments which permitted 2 replications of 2 grazing treatments, and 3) their relative similarity in site characteristics.

Data will be presented in this report for only three of the four watersheds equipped with sediment samplers. The reason for this is that one sediment sampler was damaged in transit and by the time it was replaced and installed much of the time period of this project had passed. Also, due to mechanical problems with the remaining sampler, the fourth sampler was used to furnish parts to keep the others operational.

PROJECT PERSPECTIVE AND PERSONNEL

This project, which is designed to evaluate the yield and quality of surface runoff from Edwards Plateau rangeland, is coordinated with other studies that are being conducted on the Sonora Research Station. The overall objective of research on the Station is to study various grazing systems and to evaluate their impact on ecological conditions of this rangeland and to ascertain the most efficient system for livestock and wildlife production. This work, conducted by Dr. Leo B. Merrill, forms the framework within which other studies may be pursued.

The ARS until recently has evaluated water yield from selected pastures. They transferred their equipment to TAES in January 1976 and water yield data continue to be collected. At the time of initiation of this OWRT project some work had commenced to determine quality of surface runoff. This project has enabled the quality analysis portion of the total research effort to be expanded and has provided the resources needed to begin an evaluation of the critical area of nonpoint pollution from rangeland.

Several other projects have developed which operate in conjunction with this project and which are partially supported by the OWRT grant and TAES. Studies that have been at least partially supported by this grant are:

1. Nitrogen cycle of herbaceous vegetation of two semi-arid grasslands under two long-term grazing systems - Ph.D. dissertation study by Mr. James F. George.
2. Nitrogen cycle and biomass dynamics of shin oak and live oak on a semi-arid grassland under two grazing systems - M.S. thesis study by Mr. Bradley M. Kohls.

3. Infiltration rate and sediment production of Edwards Plateau rangeland as affected by soil characteristics and grazing management - M. S. thesis study by Mr. W. Allan McGinty.

These investigations along with the main study of surface runoff yield and quality, which is being conducted by the principal investigator, will hopefully provide a rather complete understanding of nitrogen cycling and hydrologic properties of Edwards Plateau rangeland. Certain portions of these studies that have been completed will be included in this report.

METHODS

Precipitation

Standard U.S. Weather Bureau rain gauges (Spec. No. 450.2301) are located near the flume of each watershed. This provides a measure of precipitation quantity as well as a sample for chemical analysis. During rainfall events additional collectors are set out to collect samples for quality analysis. Chemical analyses are the same as described for runoff water (see below).

Water Yield

Water yield was determined from small 2 to 4 ha watersheds equipped with calibrated H-flumes and stage recorders.

Runoff Water Quality

Water samples were collected by PS-69 pump samplers constructed by the Federal Inter-Agency Sedimentation Project, St. Anthony Falls Hydraulic Laboratory. These samplers are attached to the H-flumes of the watersheds. They have the capability of automatically collecting a total of 72, 1 - liter samples. The time interval between samples is approximately three minutes. Each time a sample is taken the hydrograph is marked for later coordination of chemical variables with flow rates.

Water samples are removed from the samplers and immediately frozen for storage. They are then transferred to the laboratory for analysis. They are thawed and brought to room temperature. Electrical conductivity is determined with a Hach Chemical Co., Model 2511 conductivity bridge and pH with a Chemtrix Type 40 pH meter. The samples are then filtered through Type HA millipore filters (0.45 μm). The following analyses are then conducted:

Filtrate

Nitrate and nitrite nitrogen:

Autoanalyzer as described by the EPA (1971)

Ammonia nitrogen:

Nesslerization process as described in APHS (1971)

Kjeldahl - nitrogen:

Kjeldahl process described by the EPA (1971)

Total and ortho-phosphate: EPA (1971)

Calcium, Magnesium and Potassium:

Perkin - Elmer Model 303 Atomic Absorption Spectrophotometer

Total and calcium hardness: Hach Chemical Co. DR-EL Kit

Turbidity:

Hach Chemical Company DR-EL Kit

Residue

Kjeldahl - nitrogen:

Kjeldahl process as described by EPA (1971)

Sediment:

weight of residue per volume of filtrate

Soil Analysis

Soil samples are periodically collected from a depth of 0-5 cm from pastures 4 and 7 (Table 1). These samples are frozen, delivered to the laboratory, dried at 60°C for 24 hours. They are then passed through a 2 mm soil sieve before extraction of exchangeable nitrogen with a solution of 2N KCl. The extracted aliquot is refrigerated until analyzed for ammoniacal-nitrogen using the Orion Ionalyzer ammonia probe. Nitrates and nitrites are determined using an autoanalyzer and methods described by EPA (1971). Residual soil is passed through a 150 micron soil sieve and stored in plastic bags until analyzed for total nitrogen by the micro-Kjeldahl method described by Bremner (1965). Soil moisture was determined by gravimetric procedures. The collected samples were weighed in the field, transferred to the laboratory, oven-dried at 110°C for 24 hr and re-weighed.

Plant Analysis

Herbaceous plant samples are clipped at ground level within 1/8 m^2 quadrats by species and dried to a constant weight at 60°C for determination of above-ground biomass within pastures 4 and 7 (Table 1). Litter present on the soil surface is also collected. Curlymesquite grass (*Hilaria belangeri*), the dominant herbaceous species, was separated into live and dead components. All standing plant material and litter on the soil surface were ground to pass a 0.5 mm screen using a Wiley mill grinder. These samples are analyzed for Kjeldahl nitrogen using the micro-Kjeldahl procedure of Bremner (1965).

Branch clippings are taken from the 0-2.5 m level in Live oak and Shin oak mottes. Clippings from several trees within a motte are pooled to obtain samples. Samples are separated into leaves, new stems, and old stems in the laboratory. They are dried at 60°C for 24 hours and then the leaves and new stems are ground in a Wiley mill to pass a 0.5 mm screen. These samples are analyzed for Kjeldahl nitrogen using the micro-Kjeldahl technique of Bremner (1965).

Infiltration

Infiltration rates were compared on two different systems and on an area protected from grazing. Infiltration trials were run on three sites in each pasture. The three sites represent deep, intermediate and shallow soil depths, and were selected on their visual homogeneity and similarity.

Infiltration rates were determined using a drip infiltrometer described by Blackburn et al. (1974). An application rate of 15.25 cm/hr was used to insure that the infiltration rate was exceeded at all sites. Infiltration rates were measured as the difference between application rate and measured runoff rate. Runoff was measured gravimetrically for each 5-minute interval during the treatment period. Runoff was calculated by dividing the volume by the time increment.

Fourteen variable plot frames were set out at each site in such a manner as to allow two plots to be run at the same time. These plots ranged from 0.35 to 0.45 m^2 in area. The area of the variable plot frames were determined by placing a 1.0 m^2 grid divided into .01 m^2 sections over each plot. The variable plot frames were then plotted on graph paper and planimetered to determine the area of each.

Infiltration trials were run on 14 plots at each site with soil moisture at antecedent levels, then 24 hours later the same 14 plots were rerun with soil moisture at field capacity. The first run constitutes a dry run, the second a wet run. All dry runs lasted for 1 hour, wet runs were for 1 hour or until such time that the terminal infiltration rate was obtained.

A soil sample was taken just outside each plot frame before each wet and dry run for determination of soil moisture. The samples taken at the 0-5 cm depth, with soil moisture being determined gravimetrically by oven drying at 105^{o}C for 24 hours.

At the end of each infiltration trial, both wet and dry, a 900 ml sample of the runoff was taken for determination of sediment loss by erosion. The samples were filtered and converted to kg/ha of sediment loss.

With a steel probe, soil depths were taken at random locations within each plot frame to determine a mean soil depth for each plot.

After the plots had been allowed to dry, a 0.25 m^2 quadrat was used to clip the standing vegetation within each plot to ground level. Litter within each plot was also collected.

RESULTS

Precipitation

Monthly and annual records for 1974, 1975 and 1976 show precipitation to be seasonally and annually variable (Table 3). A total of 99.5, 66.7 and 84.1 cm of rain fell in 1974, 1975 and 1976, respectively. All three years exceeded the longterm average of 56.7 cm. Typically May and September are peak rainfall months. However, rainfall patterns for the past three years do not follow the longterm averages. For example, July is normally a relatively dry month, but in 1976 it was the wettest month of the year (Table 3).

Measured chemical characteristics show most factors to be in low quantity (Table 4). Few precipitation samples have been collected and analyzed, and thus interpretations of these data are somewhat limited and speculative at this time. If the nitrogen values for 6-11-75 (Table 4) are related to average annual precipitation, the amount of organic-N, ammonia-N and nitrate-N would be 1.99, 1.20 and 0.74 kg/ha/yr, respectively. This is a total of 3.93 kg/ha/yr which is within the limits generally measured for nitrogen in precipitation (Stevenson 1965).

Table 3. Monthly and annual precipitation (cm) for 1974, 1975 and 1976 and longterm averages for the Sonora Research Station, Sonora, Texas.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Longterm Average												
2.74	2.61	2.59	4.37	7.92	7.57	5.12	4.88	8.00	5.74	2.34	2.82	56.70
1974												
0.58	0.0	3.12	8.00	13.15	3.12	3.17	29.83	18.44	11.27	3.27	5.42	99.46
1975												
2.74	8.07	0.0	8.89	12.95	3.73	13.84	1.35	3.22	4.47	6.96	0.43	66.65
1976												
0.20	0.25	1.73	8.61	7.11	2.41	27.81	7.62	9.52	14.07	1.80	2.97	84.10

Table 4. Chemical characteristics of precipitation samples.

	ppm									(μmhos/cm)
Date	Organic-N	NH_3-N	NO_3-N	NO_2-N	Total-P	Ortho-P	Ca	Mg	Total Hardness	Electrical Conductivity
8-30-74	*	0.15	0.10	<0.05	0.001	0.008	0.35	0.18	6.0	8.4
6-11-75	0.35	0.21	0.13	<0.05	**	**	3.10	0.04	*	*

*not measured
**not detectable

Water Yield

Water yield is reflective of variations in amount, intensity and duration of precipitation and of variations in watershed characteristics such as vegetation cover, slope and soil storage capacity. As with precipitation, runoff is seasonally and annually variable (Table 5). While all three years of study had more than normal rainfall, only two had significant amounts of runoff and then from only one of the three watersheds (Pasture 5) (Table 5).

In 1974, the 4-pasture deferred rotation pasture lost as runoff, 6 percent of incoming precipitation while the heavy continuous grazed pastures, pastures 4 and 5, lost 9 and 19 percent, respectively. In 1975 no significant runoff occurred from any of the three watersheds, while in 1976 runoff was 1, 2 and 12 percent for the deferred rotation pasture and the two continously heavily grazed pastures, respectively. When single storm events are evaluated, considerably higher runoff percentages may be obtained. For example, the storm of July 11, 1976 produced 8.4, 7.4 and 7.4 cm of precipitation for pastures 7, 4 and 5, respectively. Runoff from the pastures for this storm was 0.16, 0.48 and 2.91 cm, respectively, which is 2, 7 and 39 percent of incoming precipitation.

In general the continuously heavily grazed pastures have more runoff than the deferred rotation, but pasture 4 is only slightly greater than the deferred pasture while pasture 5 is considerably greater. The major difference appears to be a combination of site variables. The deferred rotation pasture (Pasture 7) has an excellent cover of vegetation, has relatively deep soils and a 2 percent slope (Fig. 4, Table 1). Pasture 4, which is under heavy continuous grazing, is similar to the deferred pas-

Table 5. Runoff dates and runoff amounts (cm) for three watersheds (Pastures 4, 5 and 7) for three years - 1974, 1975 and 1976 on the Sonora Research Station.

Date	4-Pasture, Deferred Rotation (Pasture 7)	Heavy Continuous Grazing (Pasture 4)	Heavy Continuous Grazing (Pasture 5)
		1974	
4-30	3.7706	5.6919	10.8516
5-1	0.0769	-	0.0185
5-3	0.0846	0.0256	0.2664
5-4	0.0043	-	0.0058
5-9	-	-	0.0139
7-26	-	-	0.0061
8-5	-	-	0.0066
8-12	-	-	0.3345
8-27	-	0.3091	record lost
8-29	-	-	0.1021
9-2	-	-	0.0457
9-17	0.8128	1.0183	3.7625
9-21	1.2347	1.8296	2.9888
10-28	-	0.1133	0.3129
Total	5.9839	8.9875	18.7152
		1975	
2-2	-	-	0.0107
2-3	-	-	0.0102
4-7	-	-	0.0043
4-28	-	0.1844	0.3635
5-9	-	-	0.0264
5-11	-	-	0.0221
5-24	-	-	0.0152
5-27	-	-	0.0066
5-29	-	-	0.1201
6-19	-	-	0.0541
Total	-	0.1844	0.6335

Continued

Table 5. (CONTINUED)

Date	PASTURE		
	4-Pasture, Deferred Rotation (Pasture 7)	Heavy Continuous Grazing (Pasture 4)	Heavy Continuous Grazing (Pasture 5)
		1976	
4-15	0.0005	0.0076	0.0041
4-19	-	-	0.0036
7-9	-	-	0.0023
7-10	-	-	0.0013
7-11	0.1585	0.4826	2.9141
7-12	-	-	0.1669
7-13	-	-	0.2654
7-15	-	0.0437	0.1760
7-17	-	-	0.5859
7-18	0.0099	-	0.0183
7-22	0.0478	0.2037	0.6726
8-30	-	0.0114	0.2672
8-31	0.0033	-	0.0015
9-19	0.0015	-	0.0005
9-27	-	-	0.0008
10-4	0.0003	-	0.0643
10-29	0.0546	-	0.9624
Total	0.2766	0.7419	6.1074

ture in that it has a 2 percent slope and has shallower yet relatively deep soil. It differs in having less vegetative cover and biomass than the deferred pasture (Table 1). Pasture 5, which is under heavy continuous grazing and has the greatest amount of runoff, is similar to pasture 4 in vegetation cover and biomass, but differs from both pastures 4 and 7 in that it has a 6 percent slope and has generally much more bare soil and rock cover.

While it is impossible to ascertain the exact factor or factor combination that causes pasture 5 to have greater runoff it appears that greater slope, a more open vegetation cover, low biomass and low litter cover are significant variables. Of course, the low vegetation cover, biomass and litter are directly related to the grazing regime applied to the pasture, which in this case is exceeding the capability of the vegetation to maintain itself in a healthy condition for either livestock production or watershed protection.

Runoff Water Quality

Concentrations of selected water quality parameters are presented in Tables 6, 7 and 8. Little variation existed in concentration across a hydrograph for any of the measured variables. Thus, only mean values for samples across an entire runoff event are presented. The significance of this relationship is that flow rate seems to have little influence on concentration.

Some samples were collected in 1974 prior to initiation of this study. Many of these samples were not properly preserved prior to analysis and thus may be subject to some error. Since values obtained from these samples were similar to properly handled samples which were collected later, they were included in this report.

In general, concentrations of most measured variables are very low. All forms of nitrogen are low with a range of means across all sample dates and pastures of 0.29-0.92 ppm for organic -N, 0.05-0.60 ppm for NH_3-N, 0.05-0.51 ppm for NO_3-N and 1.23-4.2 ppm for sediment -N. Nitrite -N values are always below the limits of detectability of the apparatus used or less than 0.05 ppm. Nitrate-N for most runoff events was low in concentration except for runoff events that followed long dry periods. Apparently some build-up of nitrate occurs when precipitation does not occur to either leach it or carry it off in runoff water. Even when these conditions do exist nitrate concentrations are comparatively low. The highest mean was 0.51 for April 19, 1976 (Table 6).

To obtain an estimate of total nitrogen losses, concentrations from the July 11, 1976 runoff event were related to volume of flow (Table 9). Mean concentration of the various forms of nitrogen were of the same magnitude across all pastures, however, due to greater amounts of runoff

Table 6. Concentration of nitrogen (ppm) of filtrate and sediment of surface runoff water from pastures 4,5 and 7 (P-4, P-5, P-7) on the Sonora Research Station, Sonora, Texas. All values are means of 10 or more samples.

	Organic-N			NH_3-N			NO_3-N			Sediment-N		
Date	P-7	P-4	P-5	P-7	P-4	P-5	P-7	P-4	P-5	P-7	P-4	P-5
						1974*						
8-29	-	0.29	-	-	0.05	-	-	0.27	-	-	-	-
9-17	0.44	-	-	0.06	-	-	0.24	-	-	-	-	-
9-21	0.44	0.64	-	0.12	0.05	-	0.20	0.30	-	-	-	-
10-28	0.24	-	-	0.09	-	-	0.43	-	-	-	-	-
						1975						
						No Data Collected						
						1976						
4-19	-	-	0.76	-	-	0.61	-	-	0.51	-	-	1.23
7-11	0.67	0.59	0.55	0.26	0.43	0.37	0.17	<0.05	<0.05	2.78	3.42	4.16
7-13	-	-	0.92	-	-	0.40	-	-	<0.05	-	-	2.95
7-15	-	-	0.50	-	-	0.21	-	-	<0.05	-	-	4.42
7-17	0.63	-	0.49	0.50	-	0.30	0.12	-	<0.05	2.21	-	3.40
7-22	0.51	-	-	0.34	-	-	0.10	-	-	2.70	-	-
8-30	-	-	0.61	-	-	0.60	-	-	0.20	-	-	2.94

* All 1974 samples were collected before initiation of this project and the samples were not always properly frozen and stored before analysis. Analyses performed on these samples give values similar in magnitude to those collected at later dates and which were properly handled. Thus, the data are included but they may include some error, particularly the various components of nitrogen which may have changed form.

Table 7. Phosphorus, Calcium, Magnesium and Potassium concentrations (ppm) of the filtrate of surface runoff water from pastures 4, 5 and 7 (P-4, P-5, P-7) on the Sonora Research Station, Sonora, Texas. All values are means of 10 or more samples.

Date	Phosphorus Total			Phosphorus Ortho			Ca			Mg			K		
	P-7	P-4	P-5	P-7	P-4	P-5	P-7	P-4	P-5	P-7	P-4	P-5	P-7	P-4	P-5
1974															
8-29	-	0.04	-	-	0.03	-	-	19.0	-	-	0.80	-	-	2.3	-
9-17	0.07	-	-	0.03	-	-	17.0	-	-	0.61	-	-	2.3	-	-
9-21	0.06	0.04	-	0.03	0.03	-	22.0	16.0	-	0.71	0.63	-	3.0	1.9	-
10-28	0.05	-	-	0.03	-	-	11.0	-	-	0.41	-	-	1.5	-	-
1975															
No Data Collected															
1976															
4-19	-	-	0.08	-	-	0.06	-	-	13.0	-	-	0.54	-	-	2.6
7-11	0.02	0.03	0.01	0.01	0.02	0.01	18.0	24.0	28.0	1.23	1.65	1.56	2.5	3.4	2.9
7-13	-	-	0.01	-	-	0.01	-	-	29.0	-	-	1.68	-	-	2.4
7-15	-	-	0.01	-	-	0.01	-	-	28.0	-	-	1.47	-	-	2.3
7-17	0.03	-	0.01	0.02	-	0.01	21.0	-	23.0	1.25	-	1.51	3.6	-	3.0
7-23	0.03	-	-	0.02	-	-	19.0	-	-	0.86	-	-	2.6	-	-
8-30	-	-	0.04	-	-	0.03	-	-	14.0	-	-	0.76	-	-	1.9

Table 8. Selected chemical and physical characteristics of surface runoff water from pastures 4, 5 and 7 (P-4, P-5, P-7) on the Sonora Research Station, Sonora, Texas. All values are means of 10 or more samples.

Date	Total Hardness (ppm)			Turbidity JTU*			Electrical Conductivity µmhos/cm			pH			Sediment (ppm)		
	P-7	P-4	P-5	P-7	P-4	P-5	P-7	P-4	P-5	P-7	P-4	P-5	P-7	P-4	P-5
								1974							
8-28	-	47	-	-	-	-	-	80	-	-	-	-	-	-	-
9-16	117	97	-	-	-	-	108	163	-	-	-	-	-	-	-
9-22	54	36	-	-	-	-	95	63	-	-	-	-	-	-	-
10-28	-	-	-	-	-	-	51	-	-	-	-	-	-	-	-
								1975							
								No Data Collected							
								1976							
4-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	233
7-11	96	102	116	19	32	43	136	126	184	7.3	7.2	7.4	485	428	578
7-13	-	-	125	-	-	39	-	-	194	-	-	7.1	-	-	240
7-15	-	-	117	-	-	41	-	-	180	-	-	7.2	-	-	221
7-17	-	-	118	-	-	25	-	-	171	-	-	6.9	635	-	214
7-23	-	-	-	-	-	-	-	-	-	-	-	-	634	-	-
8-30	-	-	42	-	-	34	-	-	93	-	-	7.4	-	-	866

*Jackson Turbidity Units

Table 9. Total nitrogen loss for a selected runoff event, July 11, 1976, from three watersheds (P-7, P-4, P-5) on the Sonora Research Station, Sonora, Texas.

	PASTURE		
	P-7	P-4	P-5
Organic-N			
ppm	0.670	0.590	0.550
kg/ha	0.011	0.029	0.173
NH_3-N			
ppm	0.220	0.430	0.370
kg/ha	0.004	0.021	0.108
NO_3-N			
ppm	<0.050	<0.050	<0.050
kg/ha	Trace	Trace	Trace
Sediment-N			
ppm	2.780	3.420	4.160
kg/ha	0.044	0.166	1.217
Total (kg/ha)	0.059	0.216	1.498

from pasture 5, total losses were greater from this pasture. Even the highest values, however, are still comparatively low.

Phosphorus, calcium, magnesium and potassium concentrations are relatively low (Table 7). Only calcium may be considered somewhat high but this would be expected in runoff water from limestone parent materials. Total hardness and conductivity values are both low and are indicative of relatively salt-free waters (Table 8). Turbidity values are also low and attest to the observable clarity of runoff water from these watersheds. The values of pH are neutral to slightly basic with a maximum of 7.4 (Table 8).

Sediment yield provides a measure of the erodibility of the soils of these watersheds. Concentrations vary from 221 to 635 ppm (Table 8). To determine total sediment loss, concentrations of sediment for the July 11, 1976 runoff event were related to volume of flow. For this date, sediment concentrations for pastures 7, 4 and 5 were 485, 428 and 578 ppm, respectively (Table 8). Calculated total losses were 8, 21 and 169 kg/ha for pastures 7, 4 and 5, respectively. Thus, pasture 5 has a much higher sediment loss than the other two pastures, but still has a relatively low sediment loss compared to losses from cropland (Kissel et al., 1976).

Soil Analysis

Soil samples were collected for nitrogen analysis to establish a baseline to relate to losses in runoff water. Samples were collected from herbaceous and woody (live oak and shin oak) communities within two of the study watersheds (pastures 4 and 7) (Tables 10 and 11).

Total nitrogen values for both pastures are relatively high, however, organic matter in these soils is also high (Table 1) and thus the values obtained were expected (Tables 10 and 11). Percent nitrogen was slightly higher for most dates in the continuously heavily grazed pasture (Pasture 4), although most values were similar. The range of values for herbaceous communities within the heavy continuous pasture is 0.32 to 0.39 percent, for live oak communities 0.58 to 0.84 percent and shin oak communities 0.79 to 1.14 percent. Comparable values for the deferred rotation pasture are 0.29 to 0.39 percent for herbaceous communities, 0.55 to 0.75 percent for live oak communities and 0.38 to 0.58 percent for shin oak communities. Woody plant communities in both pastures had approximately twice the total nitrogen compared to herbaceous communities. This is attributed to generally greater litter accumulation within the woody plant communities.

Nitrite nitrogen is generally negligible and nearly all values fall below 0.05 ppm which is the lower limit of detectability. Ammonia nitrogen is the most abundant form of exchangeable nitrogen. It has its highest values during periods of high soil moisture and high temperatures. Woody plant communities have much higher values of ammonia than do herbaceous communities. Most ammonia values fall in the range of 0.5 to 5.0 ppm but peaks of 20 or more ppm may be attained for short periods (Tables 10 and 11). Nitrate nitrogen values follow the same pattern of distribution as ammonia nitrogen, but its values are usually less than 1 ppm and

Table 10. Mean soil ammoniacal, nitrate-nitrogen (ppm) and total nitrogen (%) for three communities on pasture 4 located on the Sonora Research Station, Sonora, Texas. All values are an average of 5 or more samples.

Date	Continuous Heavy Grazing (Pasture 4)								
	Herbaceous			Live oak			Shin oak		
	Total-N	NH_3-N	NO_3-N	Total-N	NH_3-N	NO_3-N	Total-N	NH_3-N	NO_3-N
3-28-75	0.32	0.44	0.17	--*	--	--	--	--	--
5- 1-75	0.37	1.97	0.30	--	--	--	--	--	--
5-28-75	0.34	6.53	0.46	0.84	22.8	1.01	1.14	21.0	1.29
6-26-75	0.36	2.34	0.92	0.72	6.8	4.34	0.94	8.1	5.37
7-10-75	--	--	--	0.58	2.5	0.20	0.79	3.5	0.28
7-22-75	0.39	3.04	0.31	0.70	5.3	0.49	0.79	4.7	0.66
8-20-75	0.35	0.71	0.14	0.68	1.1	0.48	0.83	1.7	0.37
10- 3-75	0.36	0.46	0.14	0.66	3.0	0.65	0.87	3.4	0.57
11- 7-75	--	4.73	1.08	--	--	--	--	--	--
1-12-76	0.35	4.71	0.34	0.74	10.4	0.50	0.81	8.3	0.59
2-14-76	--	0.33	0.23	0.71	1.5	0.40	0.93	1.8	0.71
3-14-76	0.32	0.42	0.44	0.72	2.0	0.35	0.84	2.5	0.66
4-23-76	--	--	--	0.72	0.8	1.02	0.85	1.1	1.30
4-30-76	0.35	0.83	0.42	--	--	--	--	--	--
5-20-76	--	--	--	0.67	3.2	0.54	0.79	2.8	0.98
5-31-76	0.32	0.09	0.11	--	--	--	--	--	--
7-27-76	0.33	2.33	0.44	0.72	5.28	0.29	0.78	5.46	0.46
11- 4-76	0.39	1.90	0.94	0.79	5.01	0.42	0.84	5.93	0.36

* Data not collected

Table 11. Mean soil ammoniacal, nitrate-nitrogen (ppm) and total nitrogen (%) for three communities on pasture 7 located on the Sonora Research Station, Sonora, Texas. All values are an average of 5 or more samples.

	Four-Pasture Deferred Rotation Grazing (Pasture 7)								
Date	Herbaceous			Live oak			Shin oak		
	Total-N	NH_3-N	NO_3-N	Total-N	NH_3-N	NO_3-N	Total-N	NH_3-N	NO_3-N
3-28-75	0.33	0.58	0.15	--*	--	--	--	--	--
5- 1-75	0.31	1.85	0.29	--	--	--	--	--	--
5-28-75	0.30	5.94	0.36	0.73	11.5	0.57	--	--	--
6-26-75	0.31	0.61	0.12	0.58	4.9	4.30	0.43	4.6	3.73
7-10-75	--	--	--	--	--	--	--	--	--
7-22-75	0.30	1.75	0.38	0.67	5.0	0.42	0.45	2.7	0.39
8-20-75	0.30	0.59	0.16	0.63	1.3	0.41	0.40	0.9	0.49
10- 3-75	0.33	0.76	0.20	0.65	3.3	0.45	0.41	1.6	0.38
10- 7-75	--	3.92	1.07	--	--	--	--	--	--
1-12-76	0.38	7.08	0.69	0.58	5.9	0.30	0.46	7.5	7.46
2-14-76	--	0.47	0.21	0.62	1.4	0.64	0.44	1.7	0.63
3-14-76	0.29	0.55	0.43	0.56	1.7	0.46	0.53	4.0	0.55
4-23-76	--	--	--	0.62	0.9	1.22	0.43	0.3	0.89
4-30-76	0.31	1.15	0.36	--	--	--	--	--	--
5-20-76	--	--	--	0.61	1.6	1.01	0.38	0.4	0.63
5-31-76	0.29	0.08	0.14	--	--	--	--	--	--
7-27-76	0.28	1.63	0.57	0.55	2.9	0.37	0.51	3.0	0.33
11- 4-76	0.39	2.19	0.72	0.61	4.0	0.60	0.58	3.6	0.85

* Data not collected

more commonly below 0.5 ppm (Tables 10 and 11).

It appears that both nitrate and ammonia nitrogen in the soil contribute little to nitrogen in surface runoff (Tables 6 and 9). At certain periods of the year these nitrogen forms are present in sufficient quantity in the soil to be removed by runoff water, however, even at maximum measured soil concentrations, the amounts removed would be quite low.

Plant Analysis

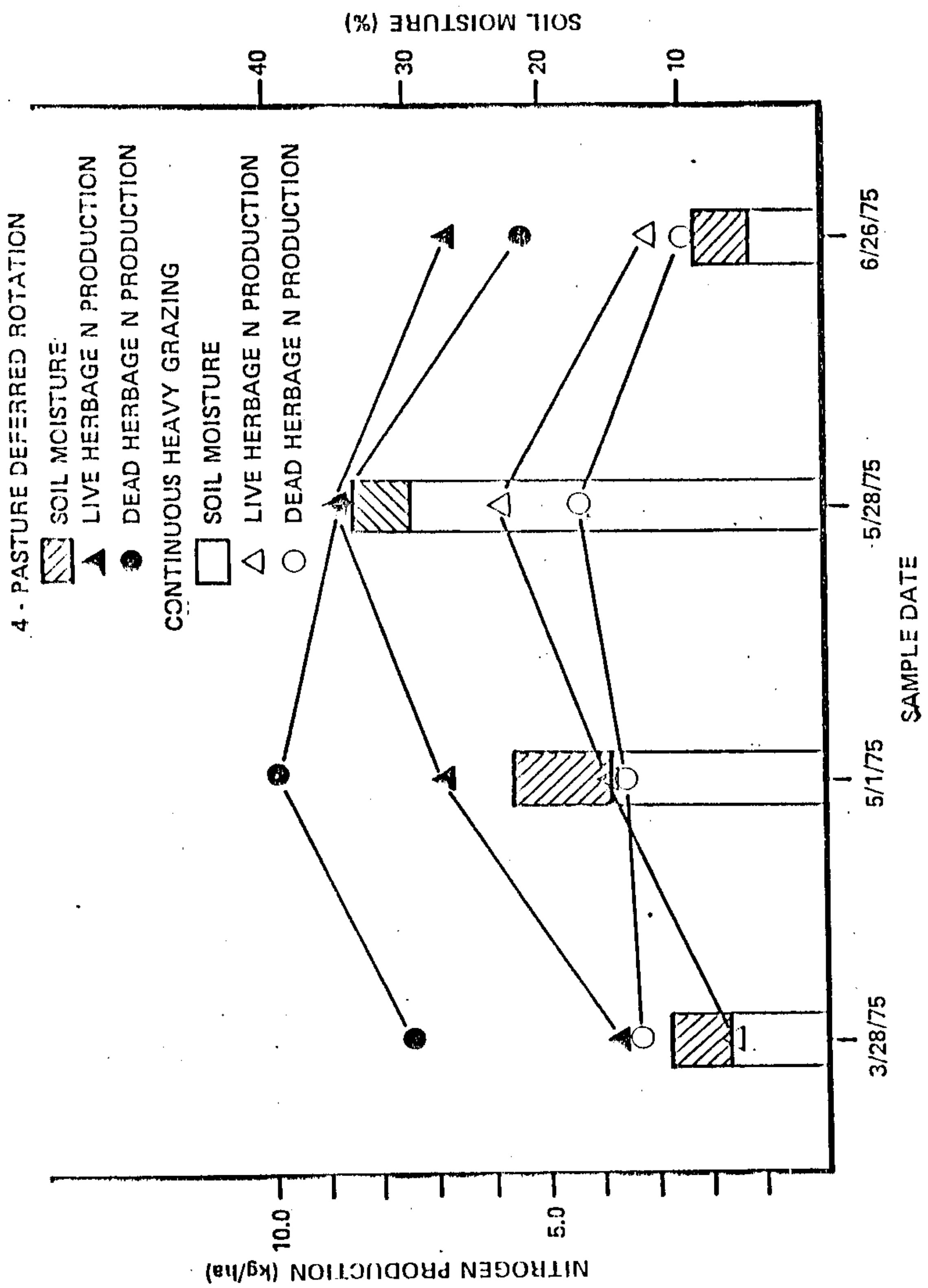
Periodically, biomass and nitrogen analysis is made of herbaceous plants on two of the experimental watersheds (pastures 4 and 7). Nitrogen analysis for the dominant grass (65-75% of total biomass), curly-mesquite, on both watersheds shows it to have a maximum of 17 kg/ha of nitrogen (Fig. 5). Of course, the amount of biomass present, the ratio of live and dead biomass and season of growth influence the nitrogen content. Generally, percent nitrogen of these plants is high but low biomass (ca. 2500 or less kg/ha) gives low weight per area values. Consequently, potential for nitrogen leaching from the plants to contribute to nitrogen in runoff waters is negligible.

Infiltration

Infiltration rates have been determined on a continuously heavily grazed pasture, a 4-pasture deferred rotation pasture (at the end of its 12-month grazing period) and an ungrazed exclosure (Fig. 5). The data show dramatically higher infiltration rates on the deferred rotation pasture and the exclosure as compared to the heavily grazed pasture which has approximately one-half the infiltration, or conversely twice the runoff potential, of the 4-pasture system and the exclosure. Major casusative factors in the difference are greater amounts of biomass and lower bulk densities on the better managed pastures.

Sediment production, while more variable than infiltration, also is less from the better vegetated pastures (Table 12). In particular, deeper soils have much greater sediment losses from poorly vegetated pastures as compared to those that have a good cover of vegetation. Overall sediment losses are less than 300 kg/ha for any pasture

Figure 5. Nitrogen production (kg/ha) of live and dead curlymesquite herbage and soil moisture (%) at four sample dates.



4 - PASTURE DEFERRED ROTATION
SOIL MOISTURE
LIVE HERBAGE N PRODUCTION
DEAD HERBAGE N PRODUCTION
CONTINUOUS HEAVY GRAZING
SOIL MOISTURE
LIVE HERBAGE N PRODUCTION
DEAD HERBAGE N PRODUCTION
SOIL MOISTURE (%)
40
30
20
10
NITROGEN PRODUCTION (kg/ha)
10.0
5.0
SAMPLE DATE
3/28/75
5/1/75
5/28/75
6/26/75

Figure 6. Infiltration rates for the field capacity soil moisture on three pastures representing heavy continuous grazing, 4-pasture deferred rotation grazing and an exclosure on the Sonora Agricultural Research Station during the summer of 1976. Each point on each curve is the average of 42 plots. Vertical lines at the end of each curve represents the 95% confidence limits for the mean. Lines followed by the same letter are not significantly different at the 95% level of confidence..

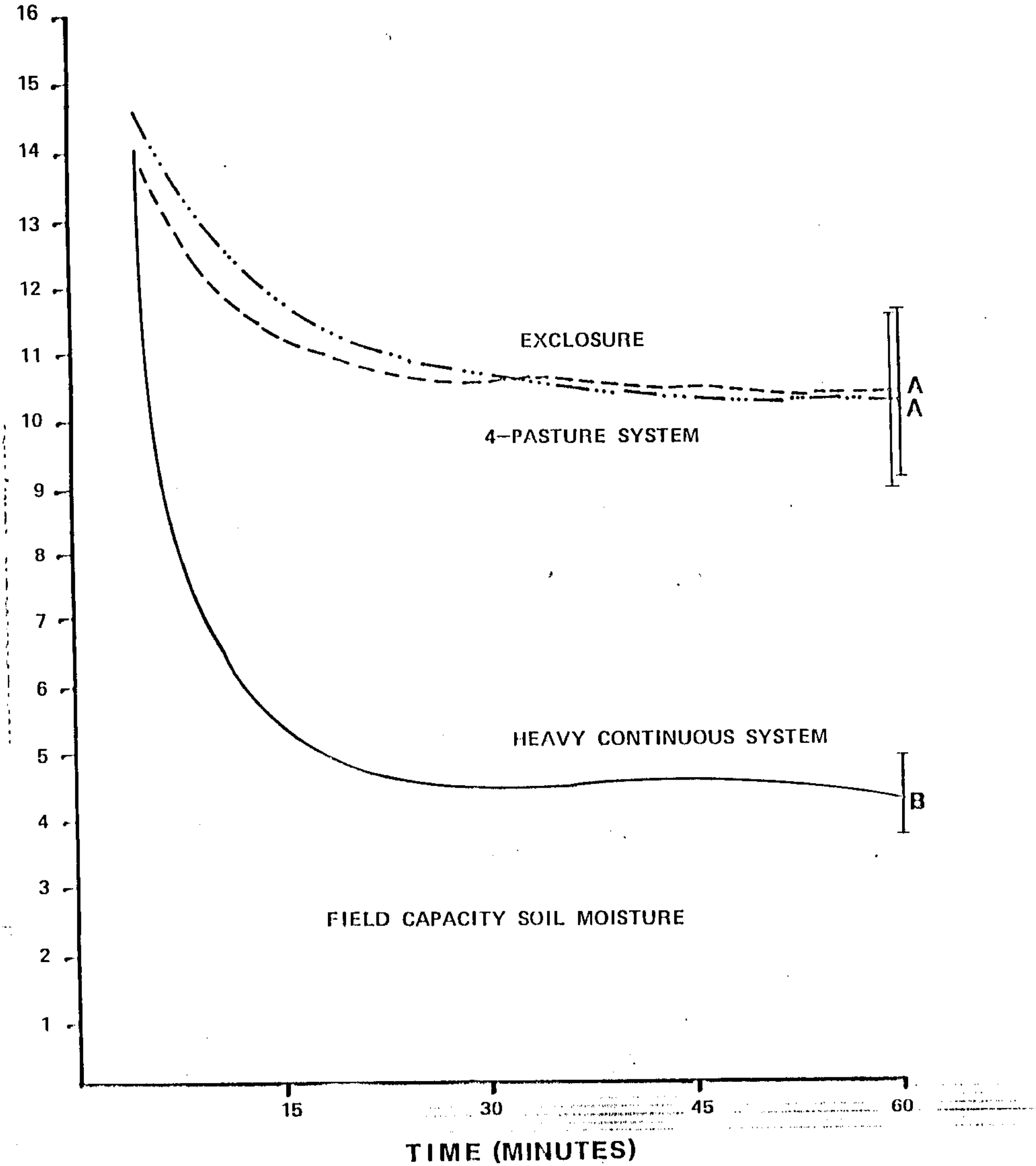

16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
EXCLOSURE
A
A
4–PASTURE SYSTEM
HEAVY CONTINUOUS SYSTEM
B
FIELD CAPACITY SOIL MOISTURE
15
30
45
60
TIME (MINUTES)

Table 12. Mean separation of sediment production (kg/ha) for wet and dry runs on shallow, intermediate and deep sites within three pastures (heavy continuous grazing, 4-pasture deferred rotation grazing and an exclosure). Mean differences are shown for pasture and site effects as well as pasture by site interactions.

Infiltration Run and Site	Grazing System: Heavy Continuous	4-Pasture	Exclosure	$\overline{X}$
Dry				
Shallow	256 a*	164 abc	122 bcd	181 Y
Intermediate	165 abc	165 abc	202 ab	177 Y
Deep	232 ab	58 cd	19 d	103 Z
$\overline{X}$	218 R	129 S	114 S	
Wet				
Shallow	236 ab	184 ab	274 a	231 Y
Intermediate	180 ab	171 abc	147 bcd	166 Z
Deep	219 ab	49 d	59 cd	109 Z
$\overline{X}$	211 R	134 S	160 RS	

*Means followed by the same letter indicated no significant differences at the 95% confidence level. Letters a through d indicate differences for pasture by site interactions, letters R and S are for pasture effects while letters Y and Z indicate site differences.

or site which is a low value compared to cropland and other sources of sediment production (Stevenson 1965). A detailed analysis of infiltration rates and sediment production is presented by (McGinty, 1976).

SUMMARY

A study was conducted on the Edwards Plateau of Texas (Sonora Research Station, Sonora Texas) to determine the yield and quality of surface runoff water as influenced by grazing management and site variables. The study was conducted during the period 1974 to 1976.

Water yield varied in relation to precipitation intensity and duration, and in relation to vegetation cover (which is directly influenced by grazing management), slope and soil storage capacity. On an annual basis the maximum runoff recorded was 12 percent of precipitation for a continuously, heavily grazed pasture in poor range condition. This same pasture had the highest runoff (39%) for a single rainfall event in July 1976. The significance of these results is that annually little runoff occurs, particularly from well-managed watersheds, but for selected single events significant amounts of runoff may occur, particularly from poorly managed areas. A large portion of the rangeland in this region is in poor to fair condition, thus considerable runoff occurs during short duration, high intensity runoff events. Good grazing management can help to reduce the amount of runoff.

Greater runoff correspondingly increases potential for greater sediment and nutrient loss. Since concentration of measured nutrient and sediment did not vary greatly from pasture to pasture, the major factor influencing nutrient and sediment loss is volume of flow. All forms of nitrogen have low concentrations. Sediment-N is the major contributor to nitrogen loss in runoff waters with values up to 4.2 ppm. Nitrite is always negligible, nitrate values vary from negligible to 0.43 ppm, ammonia ranges from negligible to 0.61 ppm and organic nitrogen is consistently higher than other forms but never exceeds 1 ppm. The

maximum measured nitrogen loss for any runoff event when adjusted to flow rate was 1.5 kg/ha on July 11, 1976 from the continuously heavily grazed pasture in poor condition. This is a comparatively low value and on other better condition rangeland is considerably less. Other nutrients evaluated also had generally low concentrations in runoff waters.

Soils have total nitrogen contents that range between 0.3 and 1.0 percent. Total nitrogen is relatively high, but exchangeable nitrogen is low. Ammonia nitrogen is the dominant form of exchangeable nitrogen, and most values fall between 0.5 and 5.0 ppm with periodic highs of 20 ppm. Nitrate values rarely exceed 1 ppm and are usually less than 0.05 ppm. Nitrite is always negligible. Overall exchangeable soil nitrogen available for movement into surface runoff water is relatively low and does not present a major problem. The exception may be rangeland in poor condition with significant sediment losses that may contribute sufficient organic and sediment nitrogen to potentially create water quality problems.

Infiltration and sediment production studies indicate that overall these rangelands have high infiltration rates and even those in poor condition have relatively low sediment losses. However, grazing management to maintain a good vegetation cover can definitely increase infiltration and reduce runoff and sediment losses.

The results of this investigation must be considered preliminary and should be interpreted with care. Limited data are currently available, and it is thus impossible to generalize. In order to properly ascertain the impact of grazing management and site variables on surface runoff yield and quality, several years of data will be needed. It is the intention of this investigator to continue research on this subject and to eventually provide the necessary data and recommendations for the proper management of these rangelands for livestock production, soil conservation and maintenance of high quality surface runoff waters.

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