MECHANISMS OF SECONDARY SUCCESSION
IN A TALL GRASS PRAIRIE

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CHAPTER I

INTRODUCTION

An ecological succession study was initiated in 1963 to determine what changes in plant composition, herbage production, and microclimate occurred in a northcentral Oklahoma tall grass prairie site affected by the treatments of fire, mowing, and plowing. The collection and interpretation of specific quantitative and qualitative data was intended to show both effects and causes of secondary succession during natural revegetation of disturbed sites. It was thought such information would prove valuable in theoretical consideration of secondary succession as well as possibly indicating new range management practices.

CHAPTER II

SITE DESCRIPTION

The site chosen for the investigation is located nine miles west and one mile north of Stillwater, Payne County, Oklahoma, and about one-half mile south of Lake Carl Blackwell. The topography of the area is characteristically a gently rolling plain. The site itself has a slight slope toward the northwest. The soils are primarily Kirkland silt-loam with patches of Kirkland slick-spots, i.e., patches where the surface layer of soil has eroded exposing the hard clay of the B horizon, and Renfrow silt-loam. Gray and Galloway described both soil types in 1959. The Kirkland topsoils are greyish-brown to brown friable silt loam, weakly acid and eight to 14 inches deep. Subsoils consist of compact clay and are brown, blocky and very slowly permeable. The Renfrow group has brown to reddish brown silt loam surface soils which are weakly acid and five to eight inches deep. Subsoils are derived from red clay beds or weakly consolidated shales which range from alkaline to calcareous. Both types are part of the Permian redbed plains. Although surrounded by the Postoak-Blackjack (*Quercus stellata*,[1] *Q. marilandica*) vegetation type of Duck and Fletcher (1945), Gray and Galloway indicate that both soils originally supported tall grass vegetation.

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[1]Scientific nomenclature according to Waterfall, 1963.

A review of the area's history revealed that the site had been protected for twelve years prior to the initiation of the study. During that time, a thick mulch cover had built up and little bluestem (Andropogon scoparius) had become the dominant species. As A. gerardi, Sorghastrum nutans, and Panicum virgatum dominate the climax prairie in central Oklahoma the site could be classified as either the subclimax of Smith (1940) or the perennial bunch-grass stage of Booth (1941). Both are followed by climax prairie.

Climatological records of the U.S.D.A. Outdoor Hydraulic Laboratory located near Lake Carl Blackwell show a 70 year average precipitation of 33.07 inches, about 25 inches of which falls during the growing season. Precipitation records kept at the study site showed somewhat less than 25 inches fell each of the 1964, 1965, and 1966 growing seasons (Figure 1).

The average length of the growing season around Stillwater is 207 days (U.S. Weather Bureau, 1966) beginning April 4 and lasting until October 28. In this study sampling was started after the last frost in the spring and terminated after the first frost in the fall.

The yearly mean temperature is 60.8°F, however during the summer months, especially July and August, there are frequently several consecutive days with maximum temperatures over 100°F (Figure 2).

Humidity is quite variable as can be seen in Figure 3.

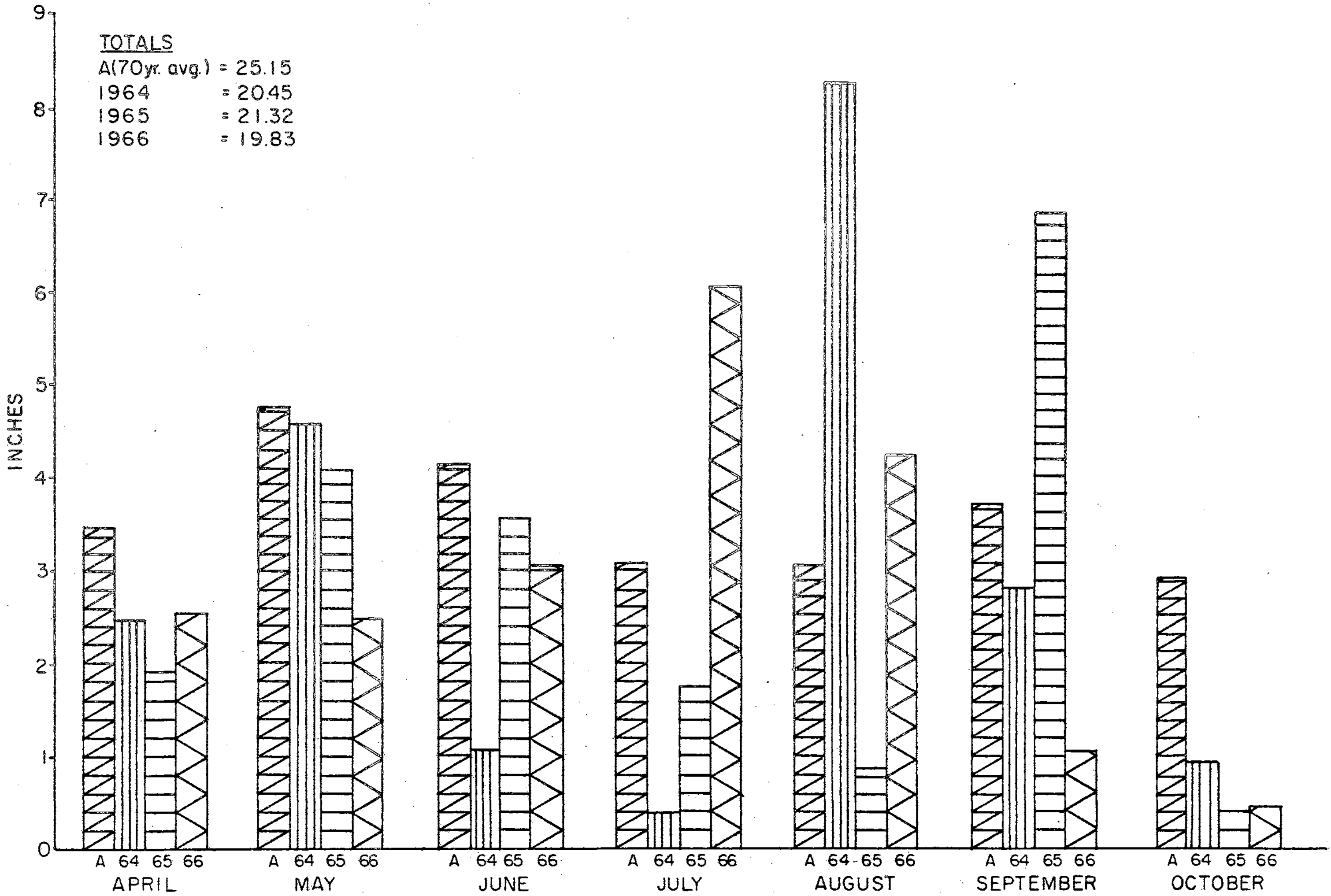

Figure 1. Precipitation

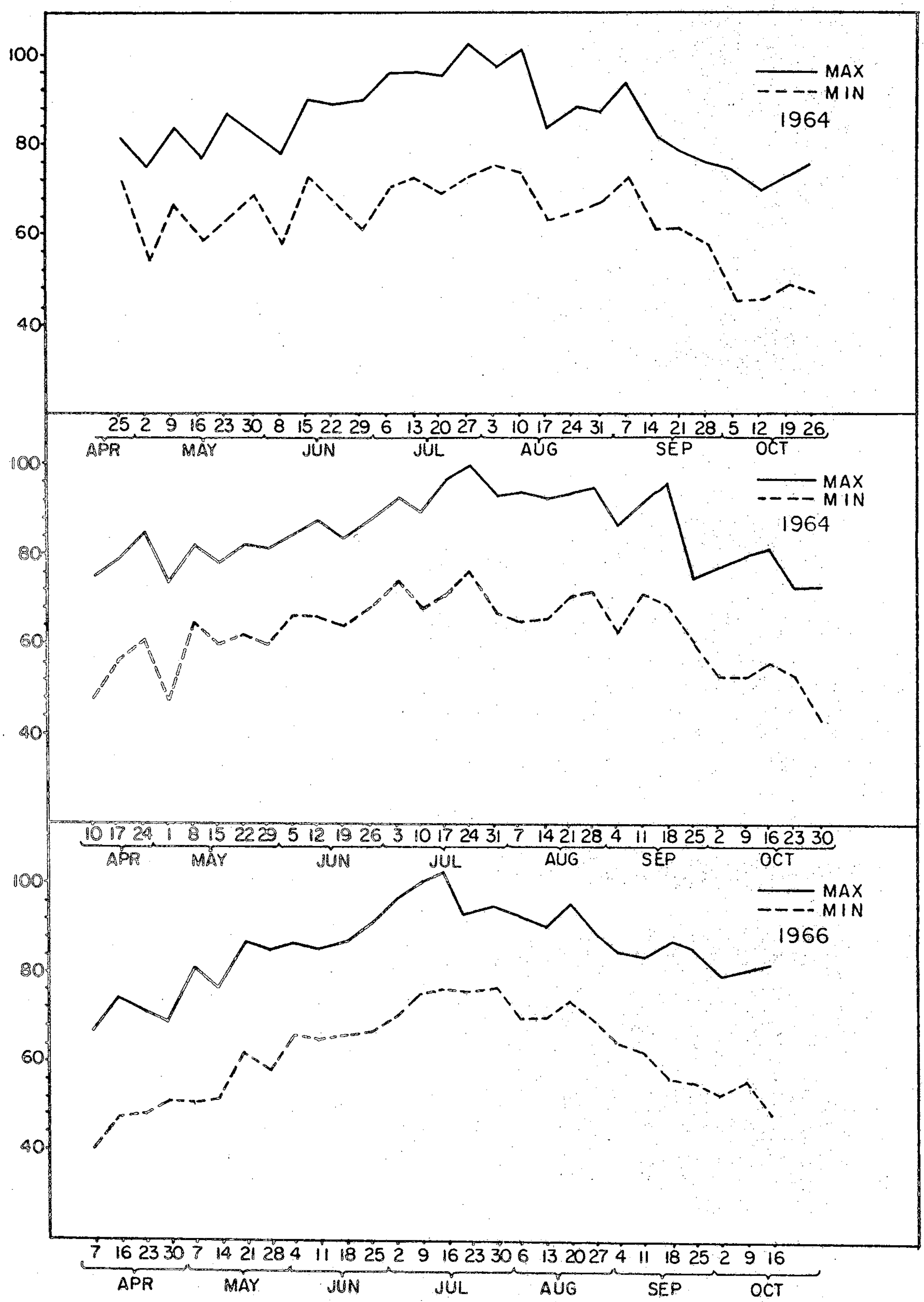

Figure 2. Average Maximum and Minimum Temperature

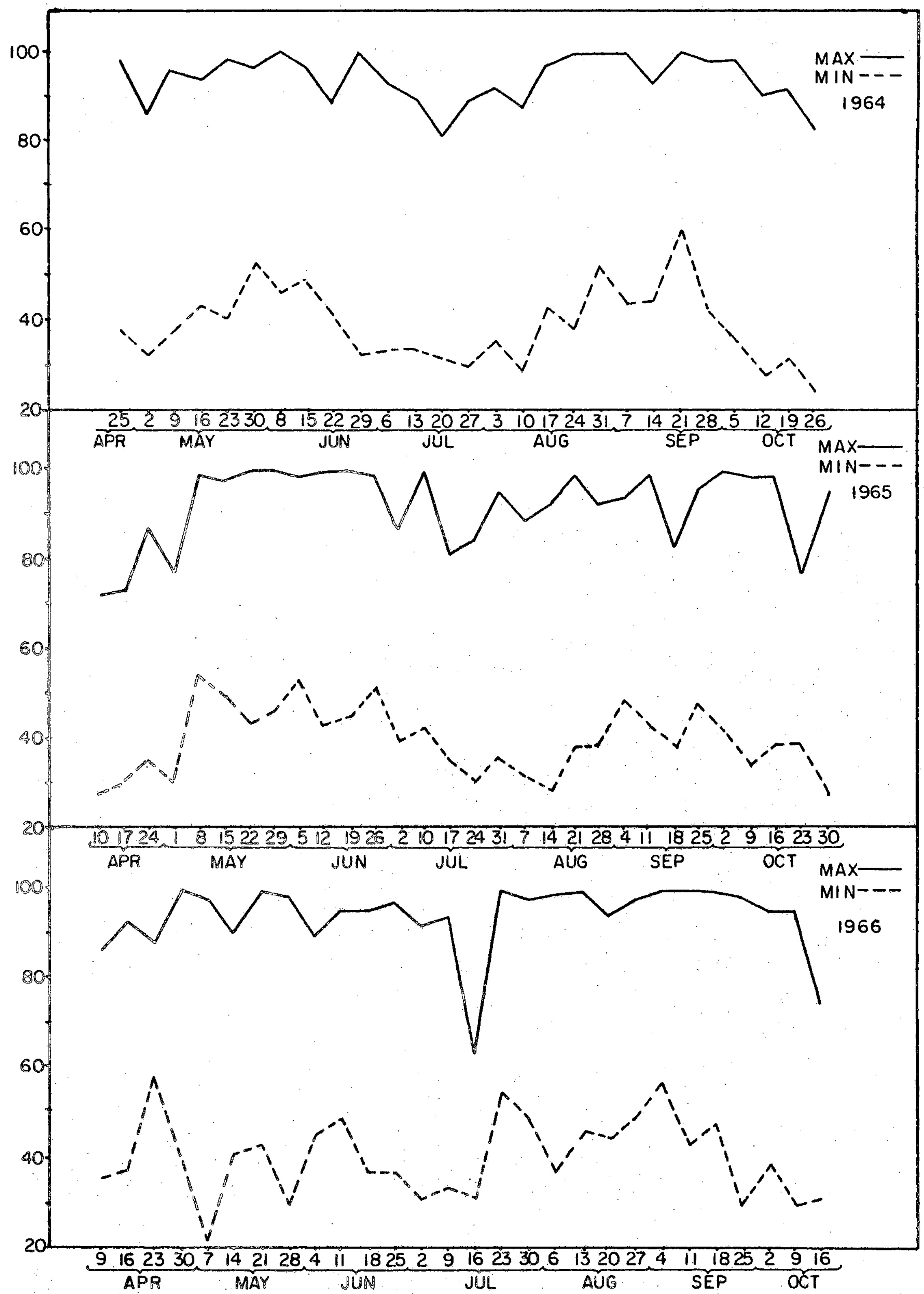

Figure 3. Average Maximum and Minimum Relative Humidity

CHAPTER III

METHODS AND PROCEDURES

In 1963 the study site was divided into 18 experimental plots, each 60 feet by 60 feet, and fire lanes 12 feet wide were plowed between them (Figure 4). Six treatments were assigned to the plots using the completely random design of Steele and Torrey (1960). The treatments included: mowing and removing the vegetation each year; burning in the early spring before vegetative growth had begun; burning in the late spring after vegetative growth had begun; plowing once at the beginning of the study; plowing each year of the study; and protected plots left as controls. Each treatment had three replications.

Vegetational analyses were made using the point-centered-quarter method of forest sampling (Cottam and Curtis, 1956) which was modified by Dix (1961) for use in grasslands. Although sampling was meant to indicate relative proportions of major species and not to represent exact stand composition, this method was selected because it is fairly rapid and according to Dix, "... is thought to be highly efficient in detecting slight differences between closely related stands or vegetal changes in time within a stand due to treatment or climatic shifts." Twenty quadrats were taken per plot for a total of 60 quadrats per treatment. Results are expressed in terms of both species composition and species density. Density is defined as aerial shoots per unit area. Sampling was done during July; the first sample being made in 1963.

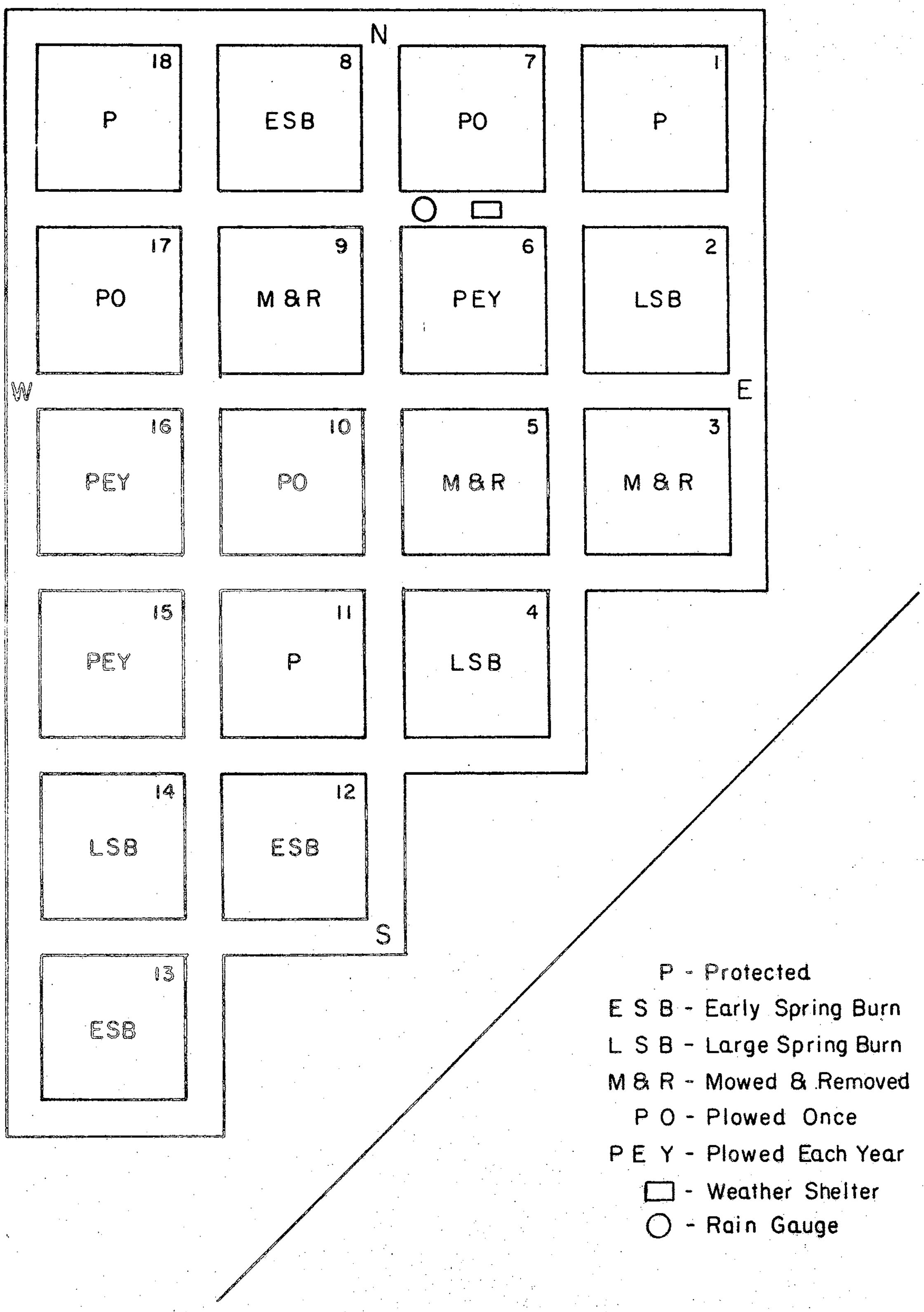

Figure 4. Plot Design

A standard weather bureau rain gauge and weather bureau shelter were placed near the north central edge of the study site. Maximum and minimum thermometers were kept in the shelter and were read weekly. Air temperature and humidity were continuously recorded by a hygrothermograph kept in the shelter. Precipitation was measured and recorded shortly after any had fallen.

Microclimatic data were gathered from six plots, one representing each treatment, in the northeast section of the study site. A Livingston white, spherical, porcelain atmometer bulb was installed in the center of each of these plots to measure evaporation. All bulbs were nine inches above the ground and were read weekly.

Palmer dial soil thermometers were placed near the center of each of the six plots and the probes were installed horizontally at a depth of six inches. Weekly maximum and minimum readings were taken.

Per cent soil moisture values were obtained using a geotome and taking soil samples from each of the six plots at depths of zero to six inches, six to 12 inches, 12 to 24 inches, and 24 to 36 inches. All samples were weighed, oven dried, then reweighed, and calculations were made according to the procedure outlined by Weaver and Clements (1938). The sampling was carried out biweekly early and late in the growing season and weekly in mid-season when higher temperatures prevailed and moisture stress on the vegetation was greatest.

Phytomass was calculated using the clip-quadrat method (Weaver and Clements, 1938). Ten two-tenths square meter quadrats per plot were clipped for a total of 30 quadrats per treatment. Only living vegetation was sampled and this was divided into six categories; *Andropogon gerardi*, *A. scoparius*, *Sorghastrum nutans*, Other Grasses, Legumes, and

Forbs. Results were expressed as pounds per acre, oven dry weight. Clipping was done first in 1963.

All burning was done into the wind which created an extremely hot fire. Fire was spread by means of rakes to cause a fairly even burn. Early spring burns were done in the last week of March while the vegetation was still dormant. Late spring burns were carried out the last of April or the first of May after the growing season had begun. The first burning was done in 1965, therefore plots eight, twelve, and thirteen, the early spring burn, and plots two, four, and fourteen, the late spring burn, were under protection during 1964.

Mowing was done while the vegetation was dormant and plots were raked to remove all loose vegetation and litter.

CHAPTER IV

LITERATURE REVIEW

Considering the magnitude of this investigation and the numerous facets involved, the sum of reports of related studies is relatively small. Literature concerning the effects of burning, while sparse, is nevertheless, greater than that for plowing or mowing.

Mowing

Principle studies on the effects of mowing include that of Launchbaugh (1955) who concluded that mowing after vegetation has reached maturity has no harmful effect on species composition. Penfound (1964) reported no significant change in vegetative composition although he found a greater number of species and higher initial phytomass in mowed plots than controls. Penfound inferred that this was due to the removal of mulch which had prevented establishment of invading species. By the fourth year of his study, however, phytomass in the mowed plot had fallen below that of the control. Neiland and Curtis (1956) found that densities of *Andropogon gerardi*, *A. scoparius*, *Panicum virgatum*, and *Sorghastrum nutans* decreased as a result of clipping. They attributed the decrease to reduction in stored carbohydrates in the roots.

Crockett (1966) reported virtual elimination of mulch and increased basal area, but only minor changes in relative composition of dominant species after three years of mowing of a previously relict prairie in northcentral Oklahoma. He stated that the increased basal area probably indicated a corresponding increase in herbage.

Plowing

Booth (1941) outlined the steps in the revegetation of abandoned fields in Oklahoma as follows: a weed stage lasting about two years; an annual grass stage of nine to 13 years duration; a perennial grass stage of undetermined length; and finally, a fully developed prairie. Booth reported that after 30 years, a field that he examined had not yet approached the final stage. Tomanek, Albertson, and Riegel (1955) found that an abandoned field in western Kansas had not reached climax after 33 years.

Studies by Rice and Penfound (1954) showed perennial forbs and grasses to be dominant the first year after plowing. Ambrosia psilostachya was the most important dominant. At the end of the second year all dominants in the control were prominent in the plowed plots. Ambrosia psilostachya had practically disappeared and succession was proceeding more rapidly than in previously reported studies. Plowed plots contained more moisture in the spring than the controls, but during mid-summer the reverse was true, so that for the season, average soil moisture was less in the plowed plots. Phytomass was higher in the plowed plots than in the controls. This was attributed to an increase in available minerals brought about by the decomposition of organic matter which had been plowed under initially.

Penfound and Rice (1957a) recorded the effects of annual plowing over a five year period. At the conclusion of the first growing season original dominants, Andropogon gerardi, Andropogon scoparius, Panicum virgatum, and Sorghastrum nutans were present in reduced numbers although P. virgatum remained a dominant along with Leptoloma cognatum and A. psilostachya. After three years of plowing, Panicum virgatum had diminished and Leptoloma cognatum and Helianthus annuus dominated the plots. After five years no original dominant remained. Leptoloma cognatum, H. annuus, Setaria lutescens, Digitaria sanguinalis, and Salsoli kali were the prevalent species. Changes in species composition were attributed to burial and destruction of propagules by plowing of the original dominants.

In another study reported the same year (Penfound and Rice, 1957b), a greater number of plant species was found in control plots during the first two years after plowing, but the third and fourth years brought a virtually equal number of species. This was due primarily to a reduction in species in the control which the authors attributed to the effects of competition.

Burning

One of the earliest and most comprehensive burning studies was that of Aldous (1934) near Manhattan, Kansas. Aldous noted that plant population was greatest on plots burned in late fall rather than late spring and that plots burned in late fall and early spring had greater populations than unburned plots. Yield was decreased no matter what the date of burning but was least after a fall burn. Anderson (1964) summarized results of burning investigations at Manhattan as reducing herbage regardless of the time of burning though plots burned in late spring produced more than those burned earlier. In 1967, Owensby and

Anderson admitted that under certain conditions, such as large accumulations of mulch, burning may temporarily increase herbage yield by removing the choking litter. Additionally, they found that some late spring burned plots yielded equally with unburned plots while spring burns did not. Weed yields were reduced by late spring burns, but there was little difference in weed yields between early burned plots and unburned controls. Anderson (1961) reported that late spring burning is detrimental to forbs, but winter and early spring burns may show forb increases. Elwell, Daniel, and Fenton (1941) found that fire reduced herbage yield between 40 and 60 per cent near Guthrie, Oklahoma, and that annual plants replaced much of the perennial vegetation.

Ehrenreich and Aikman (1963) noted increased yields on spring burned plots in Iowa while Dix (1960) found herbage to be less on burned plots in western North Dakota.

In the southeastern states, burning apparently increases yields. Duvall (1962) reported that late winter and early spring burning significantly increased grass production in central Louisiana. Green (1935) and Wahlenberg, Green, and Reed (1939) found improved composition and quality of vegetation together with increased yields of forage in Mississippi as a result of burning. They attribute these effects to the removal of pine litter and dead grass by fire. Owensby and Anderson (1967) believed that the 58 inches of precipitation received in these areas each year contributed to the increases in yield, also.

Results of studies by Curtis and Partch (1950), Ehrenreich and Aikman (1957), and Hadley and Kieckhefer (1963) showed that seed stalk production of *Andropogon gerardi*, *A. scoparius*, and *Sorghastrum nutans* increased after fire. Dix and Butler (1954) recorded increases in seed stalk production for A. gerardi and A. scoparius following fire but S. nutans showed a reduction. Hensel (1923) noted an increase in Andropogon scoparius after burning. McMurphy and Anderson (1965) recorded an increase in A. gerardi after a late spring burn. However, certain investigators have found that A. gerardi decreases as a result of continued burning (Hensel, 1923; Kelting, 1959; Hadley and Kieckhefer, 1963).

Apparently the effect of burning on soil moisture varies with the amount of precipitation received in the study area (Owensby and Anderson, 1967). Generally, however, most investigators agree that burning reduces soil moisture. Aldous (1934) found this to be true in the upper three feet of soil. Anderson (1965) declared that soil moisture was reduced at all depths after burning but the reduction was greater in deeper soil layers. Hanks and Anderson (1957) and Kelting (1957) discovered that despite regrowth of vegetation after burning, soil moisture was reduced throughout the growing season.

Bieber and Anderson (1961) noted that after rains moisture levels tend to fluctuate more in the upper two feet of soil of burned plots than unburned. The fluctuation is also more than at greater soil depths. They also found no significant difference in soil moisture between late burned and unburned plots. Penfound and Kelting (1950) reported no significant change in soil moisture after a winter burn. Green (1935), in Mississippi, found little difference in moisture in the upper foot of soil between burned and unburned plots after eight years of observation. Others than Bieber and Anderson, though, have noted that time of burning affects soil moisture levels. Kelting (1957) found lower soil moisture after winter burning. Aldous (1934) and

Anderson (1965) recorded greater reduction in soil moisture after early spring burns than late spring burns.

Anderson (1961) attributed reduced soil moisture in burned plots to the removal of mulch which allows surface soil to puddle during rains causing increased runoff and decreased infiltration. In 1965, Anderson found that soils tended to be warmer earlier on burned plots thereby promoting early rapid plant growth resulting in a reduction in soil moisture. Ehrenreich and Aikman (1963) postulated that reduced soil moisture in burned plots was due to higher soil temperature and increased evaporation and transpiration.

There is little disagreement regarding the effect of burning on soil temperature. Hensel (1923), Penfound and Kelting (1950), Kelting (1957), Ehrenreich and Aikman (1963), and Anderson (1965) found maximum soil temperatures to be higher on burned plots. Hensel also noted that minimum temperatures were frequently lower than unburned controls in March and April.

TABLE III

ABSOLUTE COMPOSITION: STEMS/METER^2: PROTECTED VERSUS MOWED AND REMOVED

Species	Protected				Mowed and Removed			
	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon scoparius	112.4	95.4	123.2	115.1	209.2	135.3	274.5	284.7
Andropogon gerardi	23.7	21.7	21.8	28.0	-	8.4	1.6	4.6
Sorghastrum nutans	8.8	8.5	14.0	25.1	9.8	11.8	8.3	50.7
Sporobolus asper	6.2	6.2	16.1	19.9	2.2	3.4	3.3	17.2
Panicum oligosanthes	5.2	7.8	5.7	10.5	4.3	7.6	5.0	31.9
Andropogon saccharoides	5.3	7.0	1.0	-	3.3	9.2	-	9.4
Andropogon ternarius	-	-	-	2.1	-	-	-	20.9
Aristida oligantha	-	0.8	-	1.1	-	-	11.6	11.6
Eragrostis intermedia	-	0	-	-	-	-	-	2.3
Eragrostis spectabilis	7.0	-	-	1.1	4.3	-	-	-
Leptoloma cognatum	0.9	-	-	0.5	-	-	-	-
Other Grasses	14.0	6.2	-	6.3	2.2	5.0	1.6	-
Legumes	-	0.8	2.8	5.2	-	0.9	1.7	7.0
Achillea lanulosa	5.3	0.8	3.8	1.1	8.6	-	11.6	4.6
Ambrosia psilostachya	3.5	12.4	24.7	22.0	7.6	15.1	51.3	71.0
Aster ericoides	4.4	7.8	3.8	7.3	1.1	0.9	14.9	17.2
Carex spp.	7.9	7.0	5.9	4.2	6.5	3.4	5.0	4.6
Other Forbs	2.0	3.8	4.8	2.1	1.1	0.9	6.6	11.6
	207.6	186.2	227.4	251.6	260.2	201.9	397.0	549.3

TABLE IV

PRODUCTIVITY: LBS./ACRE: PROTECTED VERSUS MOWED AND REMOVED

Species	Protected				Mowed and Removed			
	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon gerardi	201.0	190.8	213.3	192.2	-	-	-	-
Andropogon scoparius	646.5	329.3	318.3	295.2	1022.2	483.7	544.1	704.8
Sorghastrum nutans	77.5	121.5	145.0	150.7	154.5	39.0	129.3	306.0
Other Grasses	309.5	208.0	165.5	253.3	109.5	98.8	73.7	239.0
Legumes	3.7	16.2	23.2	-	10.8	3.7	4.7	10.8
Forbs	59.0	182.3	304.7	288.5	72.3	110.0	176.0	183.3
Total	1292.2	1048.1	1170.0	1179.9	1369.3	735.2	927.8	1443.9

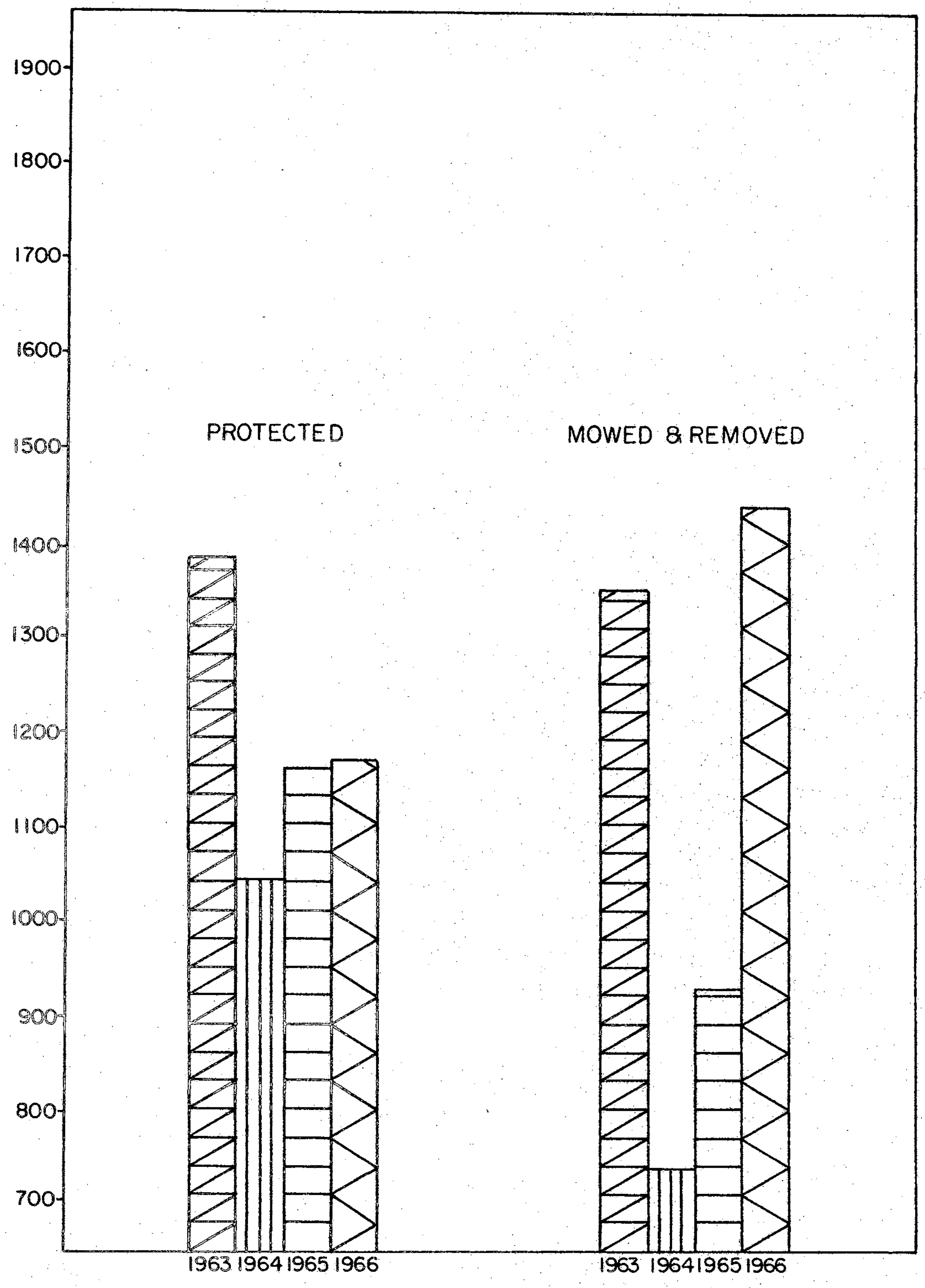

Figure 5. Total Productivity: Lbs./Acre: Protected Versus Mowed and Removed

Hence, moisture availability would be most essential during this period. June and July of 1964 were especially dry with less than two inches of precipitation compared to the normal average of seven inches.

The increase in forb productivity can be attributed largely to an increase in Ambrosia psilostachya. The fire lanes plowed between the plots supported a large population of this forb and probably created a seed source, which effected its spread into adjacent plots.

In the three years that soil temperature was recorded, the general pattern was the same (Figure 6). From a low at the beginning in April, a peak was reached sometime in July and a gradual decrease occurred until sampling was stopped in October. Soil temperature can be correlated well with air temperature in pattern of change.

Evaporation for the three years shows two distinct peaks; one occurring the last of April and the other occurring toward the last of July or the first of August (Figure 7). Also, there appears to be a slight third peak occurring in October. The first of these peaks can be explained partially by the rise in temperature and the growth lag which occurs before vegetation has developed enough to protect the soil from moisture loss early in the spring. Also contributing to the first peak are low relative humidity and precipitation during this period. The second peak in July or August occurs due to a number of factors including low relative humidity, soil at maximum average temperature for the season, and low precipitation. Evaporation can be more closely correlated with average relative humidity than other factors, however. The slight third peak can be attributed again to low precipitation and relative humidity and perhaps partially to the reduction of herbage, hence cover, that Penfound (1964) noted after mid-August.

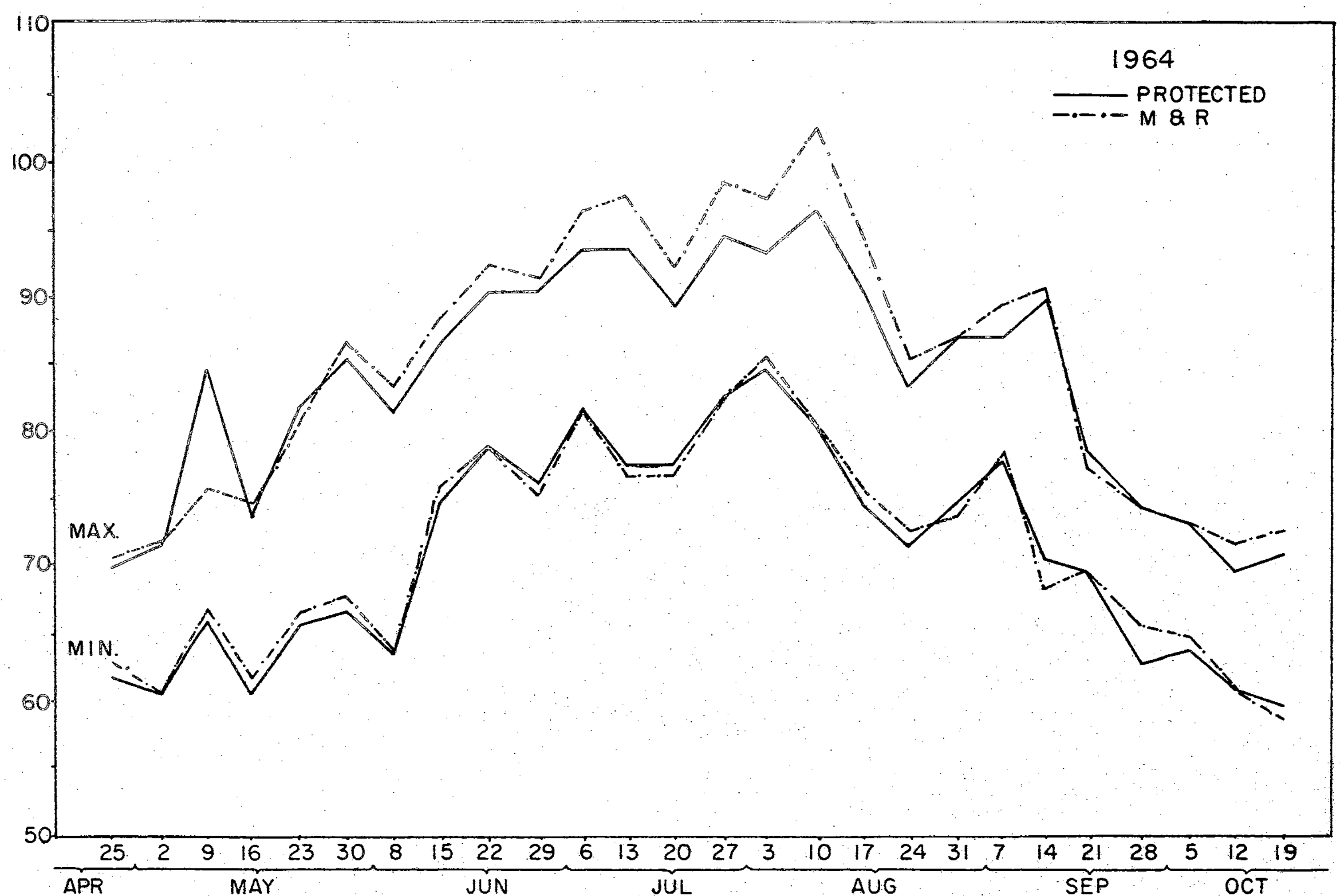

Figure 6. Soil Temperature: Protected Versus Mowed and Removed

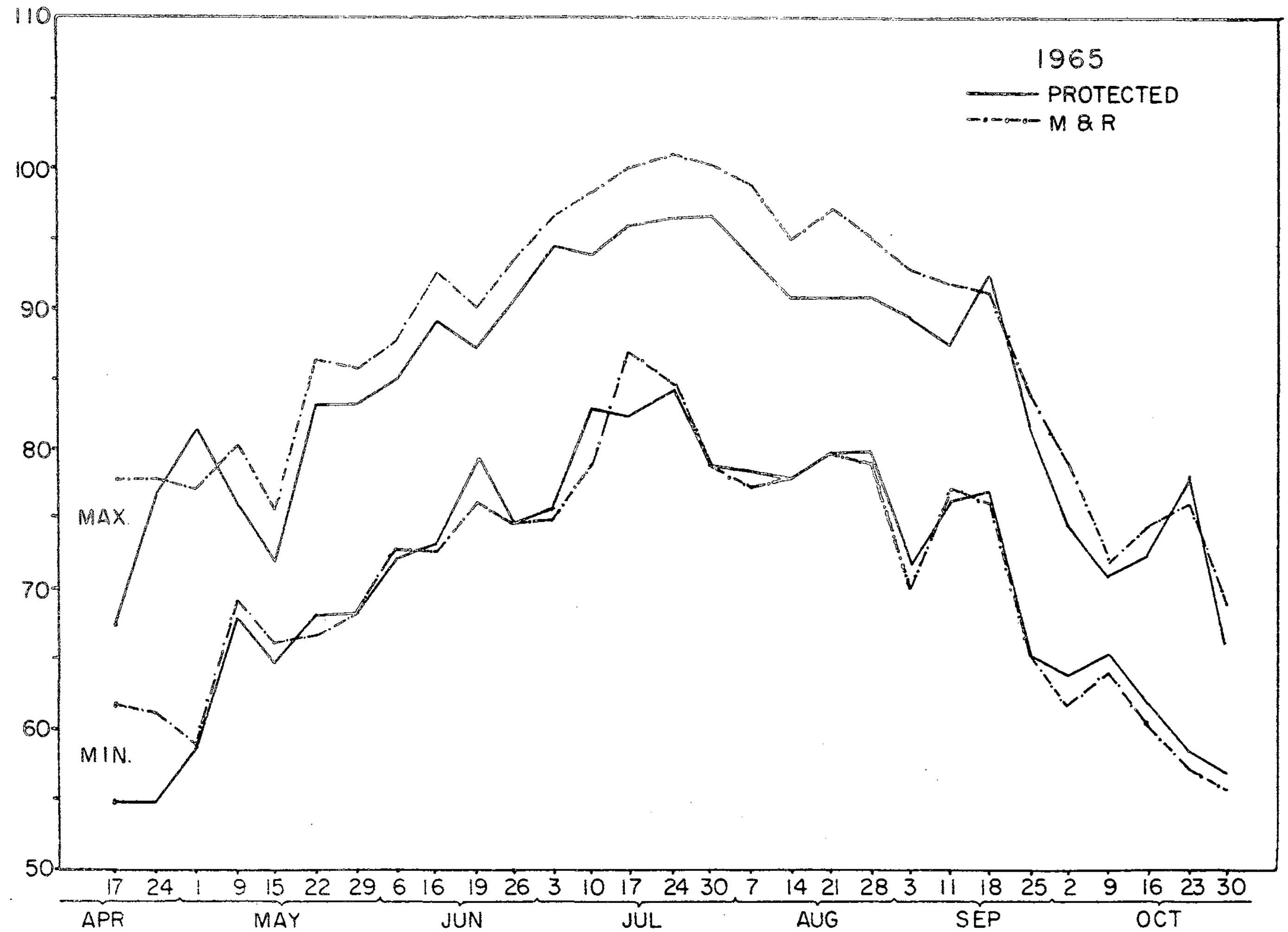

Figure 6. (Continued)

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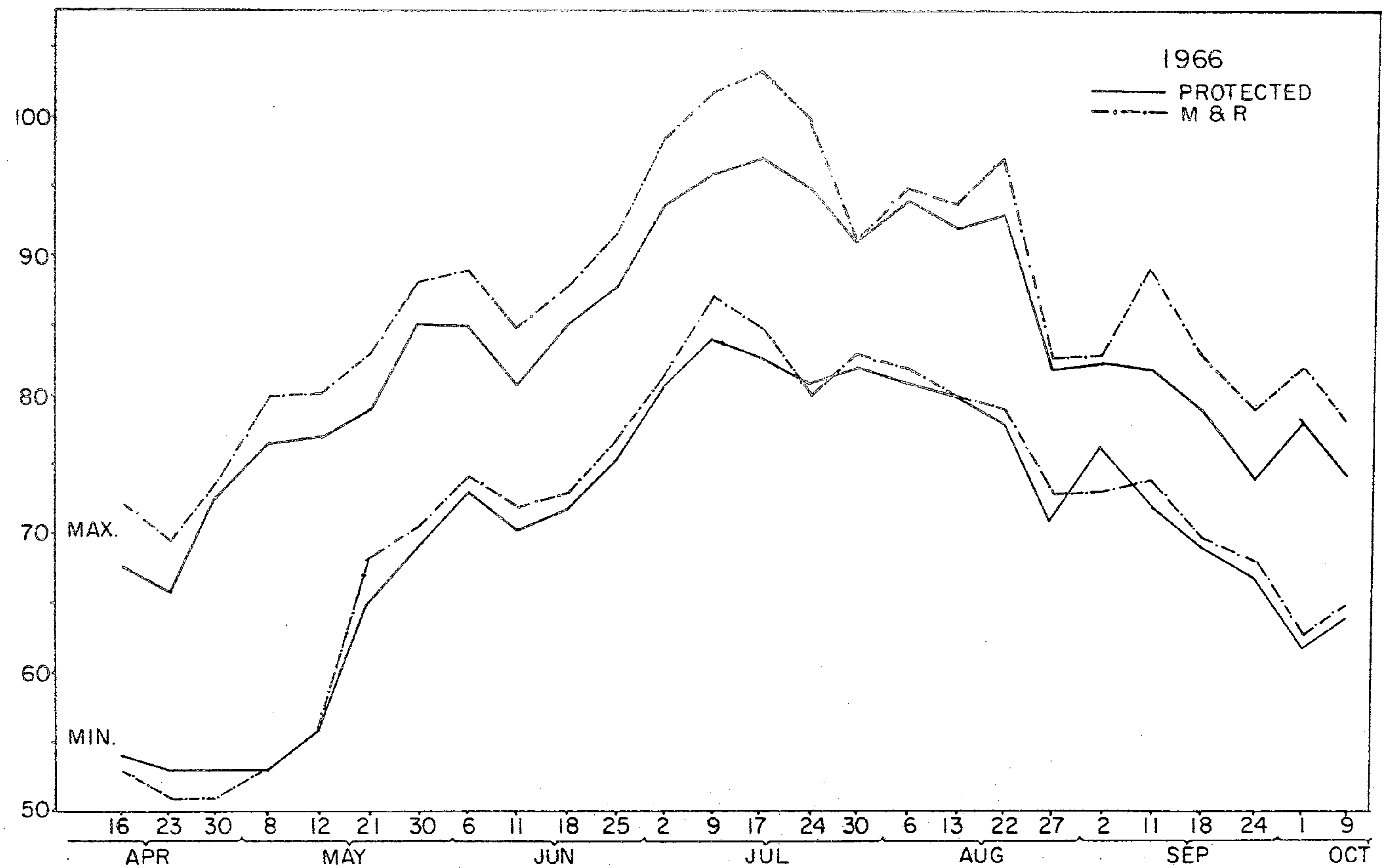

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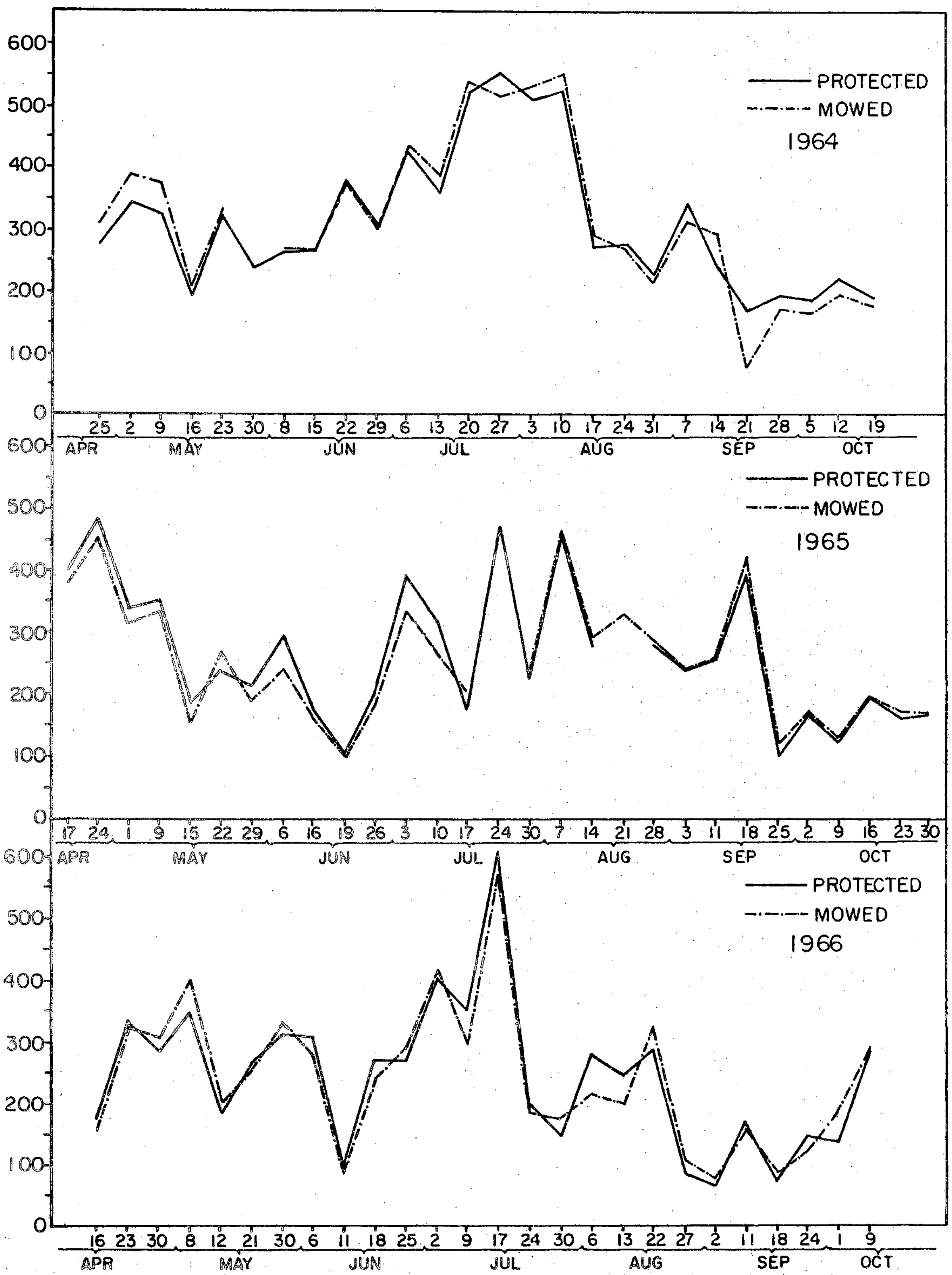

Figure 7. Evaporation: Protected Versus Mowed and Removed

In 1964, soil moisture at each of the four sampling levels showed a gradual change of less than 2.5 per cent between any two months on all but one occasion (Table V). For the year, there was less moisture in the first foot of soil than the second and third feet. In 1965 and 1966, soil moisture was greater and fluctuated more in the upper foot of soil than in the lower two feet. The increased soil moisture in the upper foot of soil was undoubtedly due to increased precipitation in 1965 and 1966. The greater fluctuation was probably due in part to the decrease in mulch on the plot because of decreased productivity in 1964 and 1965.

Mowed and Removed

The dominance as measured by absolute composition, relative density, relative frequency, and productivity of Andropogon scoparius on plots three, five, and nine prior to mowing was greater than on the protected sites in 1963 (Tables I, II, III, IV). Other species of relatively minor importance were Sorghastrum nutans, Panicum oligosanthes, Ambrosia psilostachya, and Achillea lanulosa. Despite the greater dominance of A. scoparius, relative density and relative frequency for grasses, forbs, and legumes were virtually the same on both protected and mowed plots. Phytomass was not significantly different from the protected plots (Figure 5).

After the first mowing in 1964, the relative density of A. scoparius declined about 13 per cent. This drop was followed by an insignificant increase in 1965 and by a significant decline of approximately 17.5 per cent in 1966. In three years of mowing, relative density of A. scoparius decreased about 29 per cent and relative frequency decreased 20 per cent. Absolute composition of the species

TABLE V

SOIL MOISTURE: PROTECTED VERSUS MOWED AND REMOVED

Month	Depth "	1964 Protected	1964 Mowed and Removed	1965 Protected	1965 Mowed and Removed	1966 Protected	1966 Mowed and Removed
Apr	0-6			16.2	19.0	21.2	14.6
	6-12			18.1	21.0	21.0	22.2
	12-24			16.7	18.0	14.6	23.0
	24-36			8.7	13.0	13.5	13.6
May	0-6			17.5	14.0	15.4	14.2
	6-12			18.2	18.8	18.5	18.8
	12-24			16.0	18.4	16.5	14.5
	24-36			13.6	14.9	13.1	13.2
June	0-6	10.5	7.4	17.3	14.0	13.6	12.5
	6-12	10.4	13.7	17.0	13.9	17.2	19.6
	12-24	17.0	16.7	14.7	17.2	16.1	17.8
	24-36	16.1	14.0	16.3	12.9	10.8	16.6
July	0-6	9.3	5.6	10.5	6.2	9.2	11.0
	6-12	9.4	9.9	13.8	11.7	10.8	15.0
	12-24	11.8	12.1	12.3	14.1	11.4	16.1
	24-36	14.3	12.3	13.2	12.0	11.2	13.3
Aug	0-6	9.6	9.2	12.1	10.1	9.7	9.9
	6-12	10.9	11.4	12.5	12.9	14.7	14.9
	12-24	12.3	14.4	10.6	14.1	13.0	14.9
	24-36	12.2	12.1	12.0	12.0	9.3	12.0
Sept	0-6	11.7	10.8	16.6	18.1	15.7	10.0
	6-12	11.3	12.0	15.8	17.9	16.2	17.5
	12-24	12.0	16.9	13.7	16.4	13.8	15.2
	24-36	14.0	17.6	10.9	12.0	10.4	11.3
Oct	0-6	11.6	9.4	17.5	10.8	12.3	9.1
	6-12	11.4	12.0	16.2	16.2	13.7	13.2
	12-24	12.0	17.3	14.5	18.2	12.7	11.7
	24-36	15.0	13.0	10.4	13.9	9.6	9.3

declined 50 stems per square meter in 1964 to 135 but nearly doubled in 1965 and increased insignificantly in 1966. Herbage decreased about 550 pounds per acre in 1964 but thereafter showed increases until 705 pounds per acre were produced in 1966. The final figure represented a drop of nearly 30 per cent in yield of *A. scoparius* compared to 1963.

The minor dominants showed small increases in relative density and relative frequency with the exception of *Achillea lanulosa* which declined.

Phytomass decreased in 1964 probably due to decreased precipitation (Clarke, Tisdale, and Skoglund, 1947; Smoliak, 1956), untimely mulch removal which allowed more evaporation from the soil, and lower soil moisture (Rogler and Hass, 1947) compared to 1965 and 1966.

Increases in phytomass in 1965 and 1966 were due to increases in total density and more vigorous growth of *A. scoparius*, *Sorghastrum nutans*, and several minor species because of mulch removal, increased precipitation, and higher soil moisture.

Soil Temperature

The maximum soil temperature of the mowed plot averaged 2.4, 1.9, and 3.6°F warmer than the protected plot in 1964, 1965, and 1966, respectively (Figure 6). In 1964 there were seven sampling dates when maximum temperature on the mowed plot was equal to or less than the maximum of the protected plot. In 1965 there were three dates and in 1966, only one date. The trend is apparently toward a consistently higher maximum temperature on the mowed site than the control, and an increasing difference in annual maximum averages of both treatments. The greatest difference in soil temperatures on the two treatments came when air temperature was the warmest, usually in July.

The minimum averages for the three years were never greater than 0.6°F apart.

The most important causes of the warmer maximum temperature on the mowed plot were undoubtedly the removal of mulch and standing vegetation which exposed the surface directly to the sun's rays. Vegetation eventually grew back, but the exposed soil surface was a major factor in allowing more heat radiation from the mowed treatment so that minimum averages on mowed and protected plots were virtually equal.

Sorghastrum nutans decreased in productivity in 1964, but increases in 1965 and 1966 almost doubled the yield of 1963. Other grasses followed the same pattern. Legumes, although never abundant, reacted in the same way except the yield in 1966 equalled that of 1963. Forbs increased in all years and finally produced about two and one-half times more phytomass in 1966 as 1963.

Average relative density of grasses remained the same after the first mowing, but a 13 per cent decrease was recorded in 1965 followed by an insignificant one per cent increase in 1966. Average relative frequency of grasses was 67 per cent, however a definite pattern of change is relatively difficult to ascertain since a 19 per cent drop in 1965 was followed by an eight per cent increase in 1966. Probably there is a downward trend in relative frequency but the degree of reduction is still in question.

Absolute composition for all species declined in 1964 by 50 stems per square meter. This was followed by an increase of nearly 100 per cent in 1965 and another increase of about 37 per cent in 1966. The 551 stems per square meter produced in 1966 is approximately double the count of 1963.

Total phytomass over the four years showed a drop in 1964 of about 600 pounds per acre followed by an increase of nearly 200 pounds in 1965 and another increase in 1966 of nearly 500 pounds. The 1966 herbage was about six per cent more than 1963.

The decrease in relative density and relative frequency of *A. scoparius* can be attributed to the removal of mulch which had prevented invasion (Penfound, 1964) and increase in population of other plant species.

Evaporation

Evaporation on the mowed plot averaged about four ml more per day then the protected plot through August 17, 1964 (Figure 7). Thereafter, the average was about five ml less. In 1965, evaporation averaged three ml less through July 10, and one ml more for the rest of the year. No pattern appeared in 1966 and evaporation averaged virtually the same although on some sampling dates the difference was fairly great. On the basis of these data, it would be difficult to predict a trend in evaporation.

Soil Moisture

A study of the soil moisture data reveals three general tendencies (Table V). The first is that moisture in the upper six inches of soil in the mowed plot averaged about two per cent less each month than moisture in the protected site during the three year period. The second tendency was for average moisture difference between the 0-6 inch depth and the 6-12 inch depth to be greater in the mowed plot than the protected control. In the three years, per cent difference in the mowed area was 3.3, 2.9, and 5.8. In the protected plot, the difference was 0.14, 0.90, and 2.30 per cent. A third trend, which appeared more specifically in 1965 and 1966, found soil moisture to be greater at each sampling depth with the exception of zero to six inches, in the mowed plot than the control. Mueller (1963), working in the same general area, found moisture at the 24-36 inch depth to be greater in mowed sites than protected. The first two phenomena can be explained by the exposure of the soil surface of the mowed plot by removal of vegetative cover. The third can be explained by increased interception of precipitation by the increased density, hence, aerial cover of vegetation and the subsequent increased penetration.

Early Spring Burn

During 1963 and 1964, the plots to be burned early in the spring were protected. *Andropogon scoparius*, the dominant species, was slightly more prevalent on these plots than on the controls (Tables VI, VII, VIII). Minor dominants during the two years were *A. gerardi*, and *Aster ericoides*. The ratio of grasses to forbs and legumes decreased in relative density by 13 per cent and in relative frequency by 15 per cent between 1963 and 1964 largely due to an increase in the forb *Aster ericoides*.

Phytomass on the pre-burn plots was about 15 per cent greater than the control in 1963 (Figure 8). Absolute composition in stems per square meter was slightly less than 60 per cent that of the control (Table VIII). The latter figure reflects the heavier mulch cover of the plots to be burned (Weaver and Rowland, 1952). In 1964, herbage

TABLE VI

RELATIVE DENSITY: PROTECTED VERSUS BURNED

Species	Protected				Early Spring Burn				Late Spring Burn			
	1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon scoparius	53.3	51.3	54.2	45.8	60.0	58.7	44.2	40.0	69.2	62.5	37.9	39.6
Andropogon gerardi	11.3	11.7	9.6	11.3	11.3	5.8	10.2	8.7	0.4	5.0	2.9	1.7
Sorghastrum nutans	4.2	4.6	6.3	10.0	3.3	0.4	0.8	3.3	7.1	3.7	10.8	13.3
Sporobolus asper	2.9	3.2	7.1	7.9	2.9	-	2.9	1.7	3.3	2.9	5.0	3.3
Panicum oligosanthes	4.6	4.2	2.5	4.2	1.3	1.2	2.9	1.7	3.7	5.0	6.7	8.7
Andropogon saccharoides	2.5	3.8	0.4	-	2.1	2.5	-	2.5	1.2	2.1	5.8	0.8
Andropogon ternarius	-	-	-	0.8	-	-	-	-	-	-	-	2.5
Aristida oligantha	-	-	-	0.4	-	-	-	3.8	-	-	0.8	4.2
Eragrostis intermedia	-	-	-	-	-	-	-	1.7	-	-	-	5.0
Eragrostis spectabilis	0.4	-	-	-	0.4	0.4	-	-	0.4	-	-	-
Leptoloma cognatum	3.3	-	-	0.4	4.6	-	-	-	2.5	-	-	2.9
Other Grasses	6.7	6.6	-	2.5	0.4	4.6	0.8	-	1.7	-	-	0.4
Legumes	-	0.4	1.3	2.1	-	0.4	2.1	1.7	0.8	-	5.8	4.2
Achillea lanulosa	2.5	0.4	1.7	0.4	5.4	4.6	1.7	0.8	2.9	-	0.8	-
Ambrosia psilostachya	1.7	6.7	10.8	8.8	1.3	3.8	12.1	12.5	0.8	7.9	4.2	5.8
Aster ericoides	2.1	1.2	1.8	2.9	2.9	12.0	13.8	12.9	3.7	5.8	10.4	7.1
Carex spp.	3.8	3.8	2.5	1.7	3.3	6.4	5.8	1.2	2.1	-	1.7	2.1
Other Forbs	0.8	2.8	2.1	0.8	0.8	0.4	2.5	2.9	-	5.0	4.6	1.2

TABLE VII

RELATIVE FREQUENCY: PROTECTED VERSUS BURNED

Species	Protected				Early Spring Burn				Late Spring Burn			
	1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon scoparius	39.7	38.3	43.1	35.0	46.1	44.0	35.3	30.0	50.9	45.6	26.7	31.7
Andropogon gerardi	6.6	10.9	7.8	9.4	7.8	5.6	7.5	6.1	0.9	5.3	4.2	2.8
Sorghastrum nutans	5.8	5.5	6.0	9.4	4.3	0.8	1.5	2.7	5.6	4.4	7.8	10.6
Sporobolus asper	4.1	3.9	9.5	8.6	3.5	-	3.0	2.7	6.5	5.3	5.6	4.2
Panicum oligosanthes	6.6	6.3	3.5	5.1	2.6	1.6	4.5	2.0	5.6	7.9	9.7	7.7
Andropogon saccharoides	4.1	3.9	0.9	-	4.3	2.4	-	2.7	2.8	3.5	6.3	1.4
Andropogon ternarius	-	-	-	0.9	-	-	-	-	-	-	-	2.8
Aristida oligantha	-	-	-	0.9	-	-	-	5.4	-	-	1.4	5.6
Eragrostis intermedia	-	-	-	-	-	-	-	2.7	-	-	-	7.7
Eragrostis spectabilis	0.8	-	-	-	0.9	0.6	-	-	0.9	-	-	-
Leptoloma cognatum	5.0	-	-	0.9	6.1	-	-	-	4.6	-	2.8	2.8
Other Grasses	7.4	6.3	-	2.6	0.9	6.4	0.8	-	2.8	-	-	0.7
Legumes	-	0.8	2.6	4.3	-	0.8	2.3	2.7	1.9	-	5.6	2.1
Achillea lanulosa	5.0	0.8	1.7	0.9	7.8	7.2	2.3	1.4	5.6	-	1.4	-
Ambrosia psilostachya	3.3	8.6	14.7	12.0	2.6	6.4	16.5	19.7	1.9	13.2	7.0	7.7
Aster ericoides	4.1	4.7	2.6	6.0	5.2	14.4	15.8	15.0	7.4	7.9	11.3	8.5
Carex spp.	5.8	7.0	3.5	2.6	6.1	7.2	6.8	2.0	2.8	-	2.1	2.1
Other Forbs	1.7	3.1	4.3	1.7	1.6	2.9	3.8	4.8	-	7.0	7.8	1.4

TABLE VIII

ABSOLUTE COMPOSITION: STEM/METER^2: PROTECTED VERSUS BURNED*

Species	Protected				Early Spring Burn				Late Spring Burn			
	1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon scoparius	112.4	95.4	123.2	115.1	74.6	90.0	128.6	143.0	180.5	155.0	90.3	104.0
Andropogon gerardi	23.7	21.7	21.8	28.0	14.0	9.0	30.3	31.8	1.1	12.4	6.9	4.4
Sorghastrum nutans	8.8	8.5	14.0	25.1	4.1	0.6	2.4	11.9	18.5	9.3	25.8	35.0
Sporobolus asper	6.2	6.2	16.1	19.9	3.6	-	8.5	6.0	8.7	7.2	11.9	8.8
Panicum oligosanthes	6.2	7.8	5.7	10.5	1.6	1.9	8.5	6.0	9.8	12.4	15.9	23.0
Andropogon saccharoides	5.3	7.0	1.0	-	2.6	3.8	-	8.9	3.3	5.2	6.3	2.2
Andropogon ternarius	-	-	-	2.1	-	-	-	-	-	-	-	6.6
Aristida oligantha	-	0.8	-	1.1	-	-	-	11.9	-	-	1.4	11.0
Eragrostis intermedia	-	-	-	-	-	-	-	-	-	-	-	-
Leptoloma cognatum	7.0	-	-	1.1	5.7	-	-	-	6.5	-	6.0	7.7
Eragrostis spectabilis	0.9	-	-	0.5	0.5	0.6	-	5.9	1.1	-	-	13.1
Other Grasses	14.0	6.2	-	6.3	0.5	7.1	2.4	-	4.4	-	-	1.1
Legumes	-	0.8	2.8	5.2	-	0.6	6.1	6.0	1.9	-	6.0	3.9
Achillea lanulosa	5.3	0.8	3.8	1.1	6.7	7.0	4.9	3.0	7.6	-	2.0	-
Ambrosia psilostachya	3.5	12.4	24.7	22.0	1.6	5.7	35.2	62.6	2.2	19.7	9.9	15.3
Aster ericoides	4.4	7.8	3.8	7.3	3.6	18.5	40.0	46.2	9.8	14.5	24.8	18.6
Carex spp.	7.9	7.0	5.7	4.2	4.1	9.9	17.0	4.5	5.4	-	4.0	5.5
Other Forbs	2.0	3.8	4.8	2.1	1.0	1.9	7.3	10.5	-	12.4	12.9	3.4
Totals	207.6	186.2	227.4	251.6	124.2	156.6	291.2	358.2	260.8	248.1	224.1	263.6

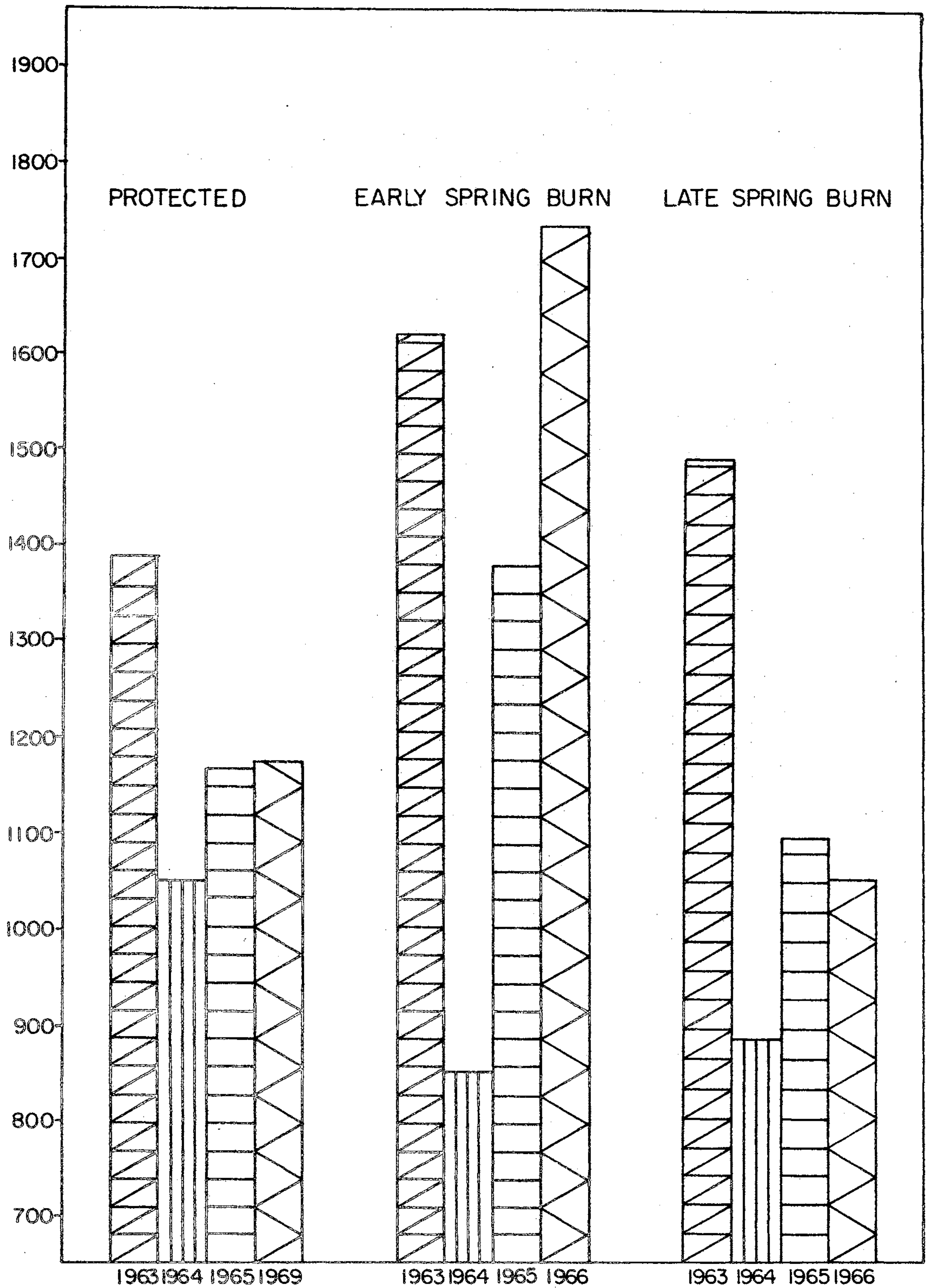

Figure 8. Total Productivity: Lbs./Acre: Protected Versus Burned

had fallen about 19 per cent below the control. Absolute composition, although 19 per cent greater than 1963, was still 18 per cent less than the protected plots. Most of the increase in absolute composition was in A. scoparius and A. ericoides. Much of the decrease in phytomass can be attributed to deficient precipitation which was nearly seven inches below average for April through July and about four inches less than 1963 (Mueller, 1964). The reason for the large decrease in productivity of A. gerardi and Sorghastrum nutans as compared to the control is not clear although it can be partially accounted for by the three per cent less moisture than the control in the upper foot of soil during July, the month before clipping (Rogler and Hass, 1947).

The first early spring burn was accomplished the last week in March, 1965. Sampling data obtained that year showed that A. scoparius decreased about 14.5 per cent in relative density and about nine per cent in relative frequency. Absolute composition of the species, however, increased about 15 per cent due to the doubling of absolute composition for all species over the previous year (Table VIII). Productivity of A. scoparius was up 17 per cent (Table IX).

All minor dominants increased in relative density, relative frequency, and absolute composition except Achillea lanulosa which declined markedly. Ambrosia psilostachya increased significantly to a dominant position. Grasses, as a group, decreased in relative density 11.5 per cent and relative frequency 8.8 per cent.

Productivity of each species and sampling group increased also, but forbs showed the most significant gain of nearly 100 per cent. Total productivity rose 38 per cent. The increase in yield probably can be attributed to removal of growth retarding mulch (Owensby and

TABLE IX

PRODUCTIVITY: LBS./ACRE: PROTECTED VERSUS BURNED*

Species	Protected				Early Spring Burn				Late Spring Burn			
	1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon gerardi	201.0	190.8	213.3	192.2	490.3	130.8	184.3	471.8	-	-	0.2	0.8
Andropogon scoparius	646.5	329.3	318.3	295.2	709.7	415.5	497.5	703.5	905.0	445.8	457.3	556.0
Sorghastrum nutans	77.5	121.5	145.0	150.7	93.5	4.0	76.2	58.8	272.5	71.2	193.0	122.0
Other Grasses	309.5	208.0	165.5	253.3	201.3	48.8	109.8	92.8	198.2	168.0	207.3	245.5
Legumes	3.7	16.2	23.2	-	-	12.5	22.8	14.3	10.2	3.3	16.9	5.8
Forbs	59.0	182.3	304.7	288.5	123.0	235.8	482.8	391.3	100.0	194.7	218.3	118.0
Totals	1297.2	1048.1	1170.0	1179.9	1617.8	847.4	1373.4	1732.5	1485.9	883.0	1093.0	1048.1

*First burn in 1965

Anderson, 1967) and increased precipitation (Clarke et al., 1947; Smoliak, 1956). Likewise, the increase in forbs can be assigned to the removal of mulch (Penfound, 1964) which had prevented their establishment and proliferation.

The second burn was completed the last week in March, 1966. According to sampling data, Andropogon scoparius again declined somewhat, so that after two burns its relative density had decreased about 19 per cent and relative frequency decreased approximately 15 per cent in relation to the two year pre-burn averages. Absolute composition for A. scoparius increased slightly over the previous year and productivity increased about 29 per cent so that it virtually equalled the 1963 level. Productivity of A. gerardi increased significantly so that it too almost equalled the 1963 total.

It is doubtful that the increase in productivity of A. gerardi and A. scoparius in 1966 to their 1963 level was due entirely to recovery of vigor lost as a result of deficient precipitation in 1964. More likely, the reason was that they increased in relative density; A. gerardi about 2.5 times and A. scoparius about two times due to the removal of mulch. Absolute composition of Sorghastrum nutans nearly tripled, yet productivity declined almost 40 per cent.

Absolute density for all species increased by about 19 per cent over the previous year, so that after two burns there were almost three times as many stems per square meter as in 1963. Total phytomass increased nearly 21 per cent over 1965 and showed a seven per cent increase over 1963. There was, however, an 18 per cent decrease in phytomass of forbs after the second burn although the figure still represented an approximate 60 per cent productivity gain after two burns.

Penfound (1964) discovered that peak productivity of _A. gerardi_ and _A. scoparius_ occurred in June in protected prairie while in denuded prairie the peak was between June 30 and August 7. Peak phytomass as an average for all species also occurred between the same dates. This could be partially responsible for the apparent increase in production on the burned plots as clipping was done around the first of August.

Penfound also noted that phytomass was some 31 per cent less from September 7 to October 12 than from June 30 to August 7 on the protected plot. The denuded plots produced about 50 per cent less during the same periods. Perhaps this partially explains why Aldous (1934) and others (Anderson, 1964) found reduced yields in early spring burns. Aldous' sampling was done in October.

Soil Temperature

Soil temperature data for the three year sampling period showed that the early spring burned plot, although still cooler on the average, was becoming warmer in comparison to the control (Figure 9). In 1964, before the first burn, the average difference between the two treatments was 3.7°F each sampling date. The control maximum was 3.6°F greater and the control minimum was 3.8°F greater. After the first burn, the average difference was 2.7°F. The control maintained a 2.8°F greater maximum and a 2.0°F greater minimum. The second burn reduced the average to 1.1°F greater on the control. The protected plot was 2.5°F warmer, but was 1.0°F cooler than the burned plot.

Evaporation

Evaporation always averaged less on the burned plot than on the

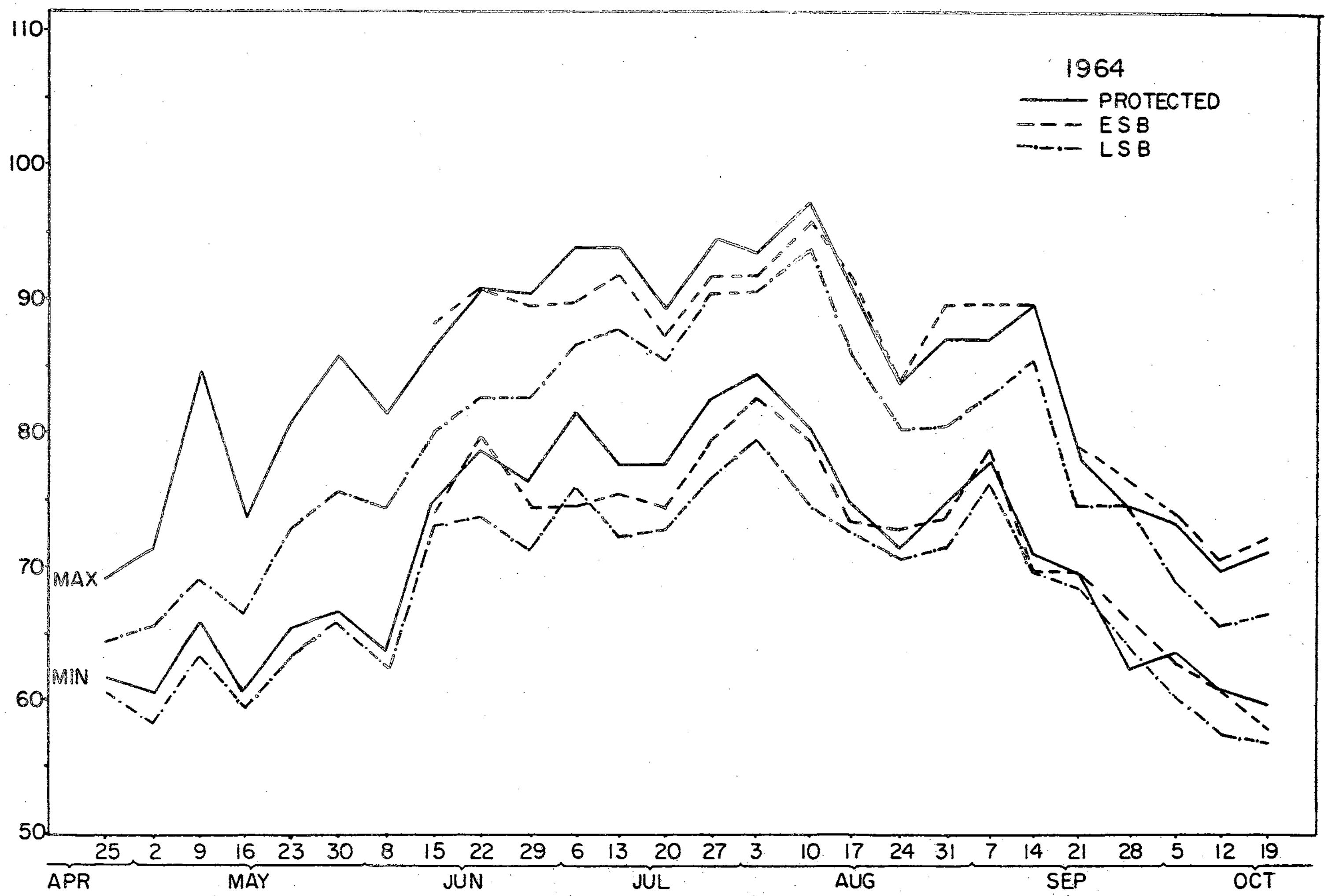

Figure 9. Soil Temperature: Protected Versus Burned

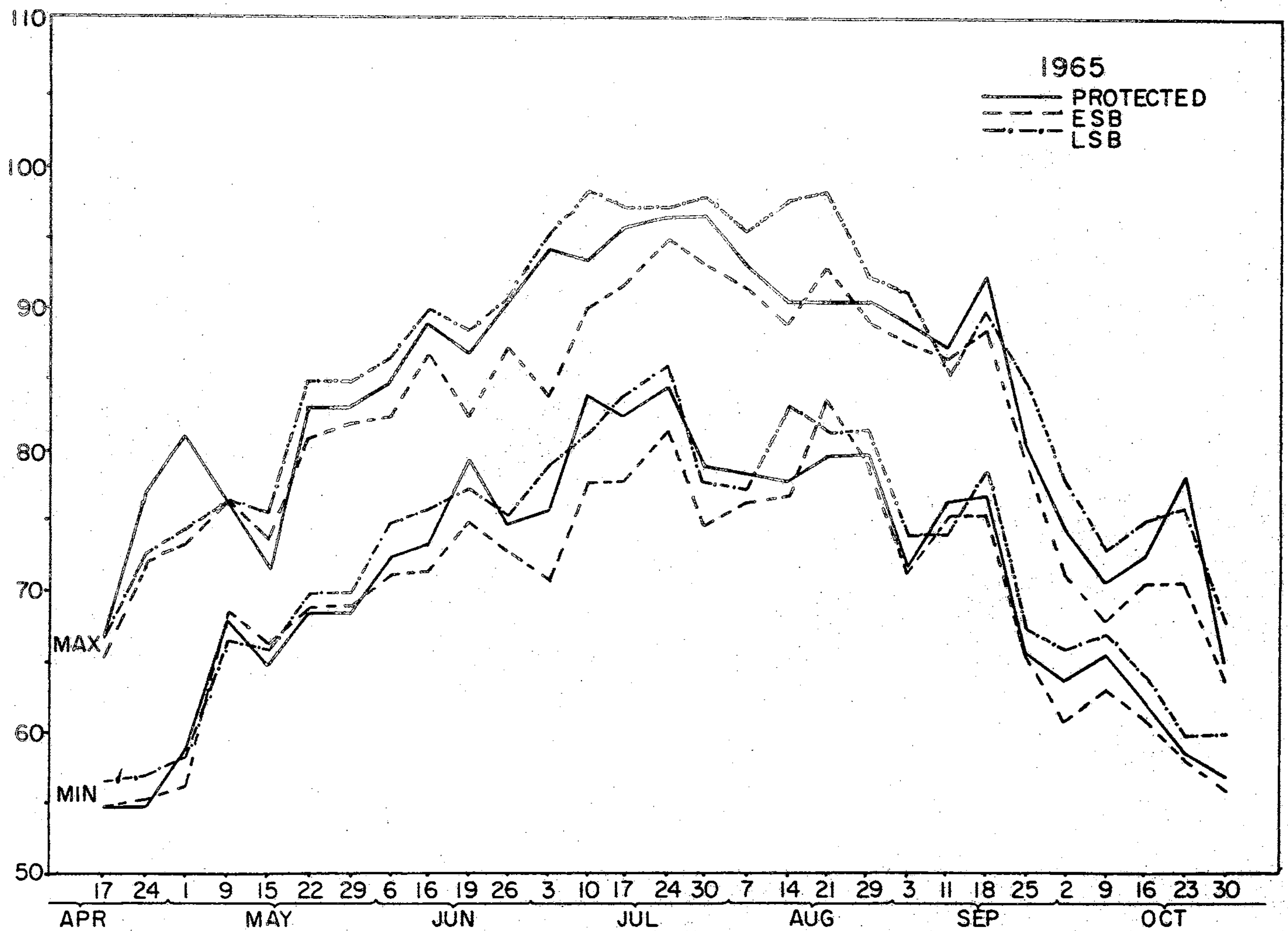

Figure 9. (Continued)

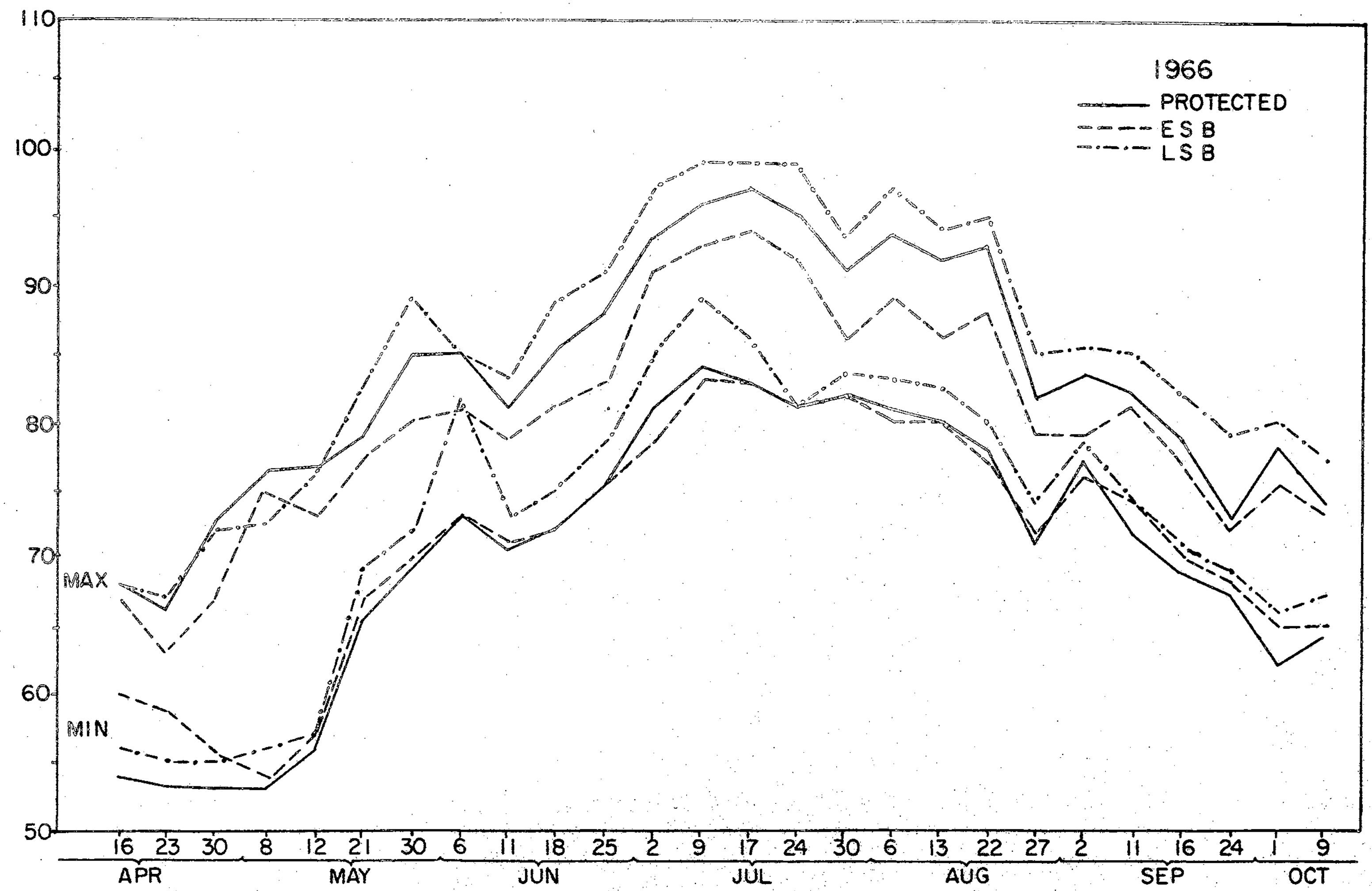

Figure 9. (Continued)

control although there was a definite trend towards equalization (Figure 10). Before burning, the average was about 11 ml less per day than the control. Plot eight was potentially more productive as was indicated by the heavier mulch cover, and although the absolute composition was less than the control, the grasses *Andropogon gerardi* and *A. scoparius* were much taller and more robust and protected the plot from evaporation. After the burning, the grasses were not as vigorous and the mulch cover was burned away. Hence, in 1965, the average difference in evaporation was seven ml and in 1966 it was six ml.

Soil Moisture

Before burning soil moisture in the pre-burning plot was usually always greater at all sampling depths than in the control. The average was two per cent greater each month. After the first burn, the average was 0.25 per cent greater May through October but moisture in the upper foot of soil was less. Moisture in the second foot of soil was 3.4 per cent greater than the control. In 1966 the second burn lowered the average to one per cent less than the protected plot. Again, moisture was less in the upper foot and only 0.6 per cent greater at the two feet level.

Although plot eight was potentially more productive than the control, as was indicated by initial sampling data, the effect of burning can be seen in the gradual equalizing of evaporation, soil temperature and soil moisture. It is thought that these trends will continue with continued burning.

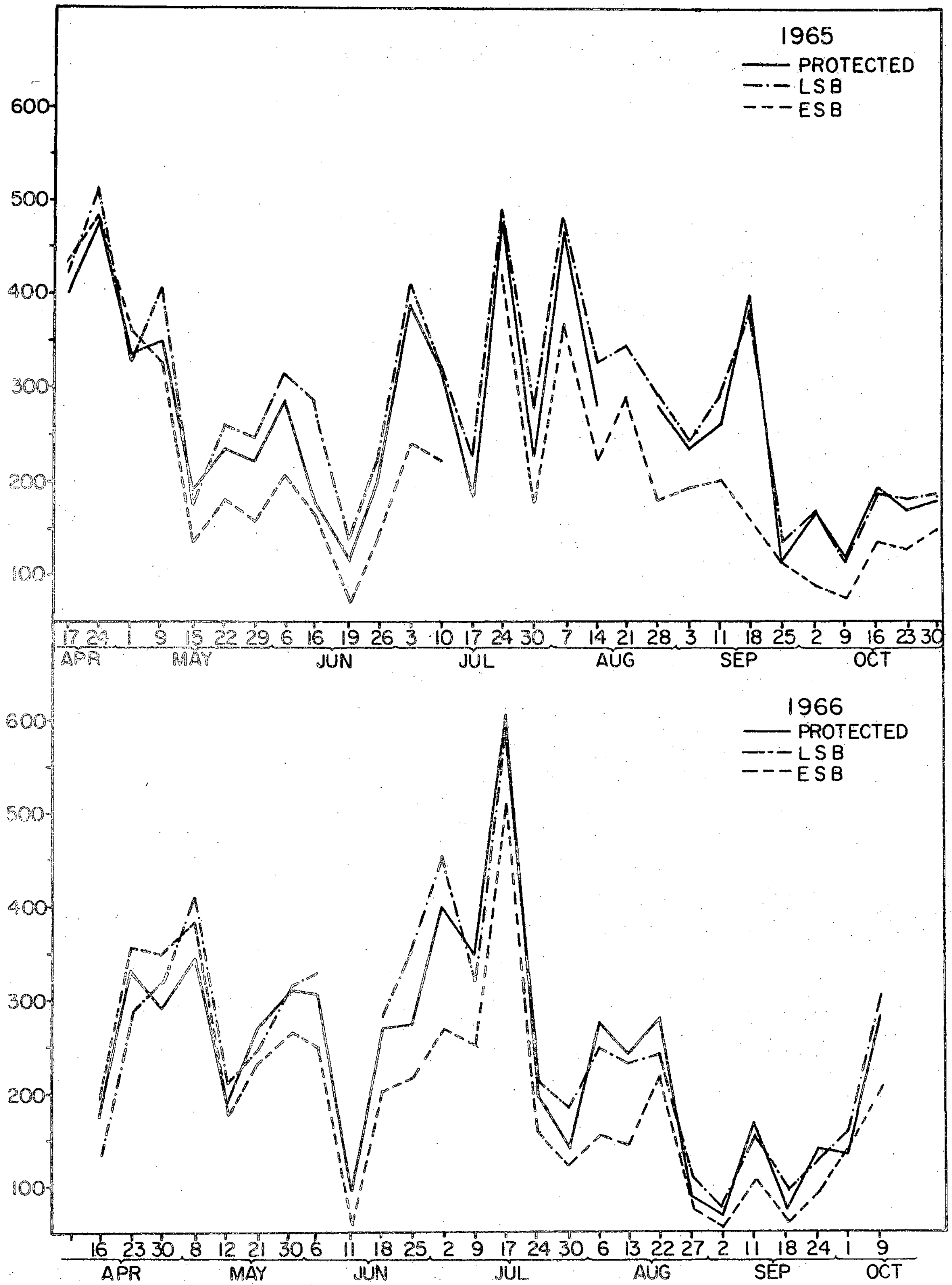

Figure 10. Evaporation: Protected Versus Burned

Late Spring Burn

Point-centered-quarter data for 1963 and 1964 clearly depicted the dominance of Andropogon scoparius on the plots to be burned late in the spring. Relative density (Table VI) of about 69 per cent decreased nearly seven per cent in 1964, while the plots were still protected. Relative frequency (Table VII) decreased from 50.9 per cent to 45.6 per cent during the same period. Absolute composition (Table VIII) also decreased during the two years. Other important plants were Sorghastrum nutans, Sporobolus asper, Panicum oligosanthes, Leptoloma cognatum, Achillea lanulosa, Aster ericoides, and Ambrosia psilostachya. These species also showed some fluctuation in relative density, absolute density, and relative frequency. The decrease of S. nutans and the increase of Ambrosia psilostachya were the most important of these changes. The relative density of grasses diminished 8.3 per cent and the relative frequency declined 8.6 per cent in 1964 due largely to the increase of the forb A. psilostachya, which was thought to be invading principally from the fire lanes. Absolute composition decreased insignificantly in 1964. Phytomass, however, declined drastically from 1,485 pounds per acre in 1963 to 883 pounds per acre in 1964 (Figure 8). Most of the decline can be attributed to the decreased precipitation discussed in connection with the early spring burning.

The late spring burns were made in late April or early May of 1965 and 1966. The sampling data for 1965 showed appreciable reductions of A. scoparius in all categories but productivity (Table IX). Relative density diminished by 24.6 per cent and relative frequency declined 18.9 per cent. Absolute composition declined about 58 per cent. Productivity increased, although insignificantly.

The minor dominant grasses increased in all categories while forbs, with the exception of Aster ericoides, decreased.

Absolute composition for all species declined insignificantly, while total productivity increased 201 pounds per acre. The largest gain was the 122 pounds per acre of Sorghastrum nutans, approximately 2.7 times the yield of 1964.

After the second burn, A. scoparius increased slightly in relative density (1.7 per cent), relative frequency (5.0 per cent), and absolute composition (14 stems per square meter). Productivity increased about 18 per cent.

Of the minor species, S. nutans showed gains in all categories except productivity. After two burns, it produced about 13 per cent of the absolute composition and about 11.5 per cent of the total vegetative biomass. Two weedy annual grasses, Eragrostis intermedia, and Aristida oligantha also increased significantly until they composed about 9.0 per cent of the total composition.

Relative density of all grasses increased to 82.4 per cent and relative frequency increased to 78 per cent. Both values were slightly less than 1963. Absolute composition increased until it was approximately equal to the 1963 total. Productivity decreased slightly in 1966 and was over 400 pounds less than 1963.

The decrease of A. scoparius in relative density, relative frequency and productivity parallels the results summarized by McMurphy and Anderson (1965) of burning in the Flint Hills of Kansas, a region similar to central Oklahoma in climatic conditions. The increase in S. nutans in relative density and relative frequency was not unexpected (although the magnitude of gain was) as McMurphy and

Anderson report that late spring burning is least detrimental to the species. The decrease in yield of S. nutans was somewhat surprising in view of gains in other categories. The decrease in forbs in the late spring burned plots and the reduction in forage yield is also in keeping with the report of the Kansas researchers.

Soil Temperature

In 1964, soil temperatures on the plot to be burned and the control were virtually the same with an average difference of less than 0.2°F (Figure 9). The control maintained a one degree cooler maximum average and the pre-burning plot held a 1.5°F cooler average minimum. This was expected as the plots were adjacent and both protected.

The first burn warmed the plot only slightly. The average was about one degree warmer than the control. Both maximum and minimum temperatures were one degree warmer.

The second burn increased the average difference to 3.1°F. The burned plot registered a maximum average 3.4°F warmer and a minimum average 2.8°F warmer than the control.

Evaporation

Evaporation prior to burning averaged about one ml less per day than the control (Figure 10). During the year following the first burn, evaporation averaged two ml higher than the control. After the second burn, evaporation averaged only one ml more on the burned plot than the control each day. Differences in evaporation appeared to be insignificant throughout the study.

Soil Moisture

Soil moisture prior to the first burn was almost equal on both the protected and the plot to be burned with the exception of August (Table X). The 6.7 per cent greater moisture on the plot to be burned was probably a sampling error rather than an actual occurrence. With the exception of that month, moisture averaged only 0.25 per cent greater in the pre-burned plot. Moisture was generally greater in the upper foot of soil of the pre-burned plot.

In 1965, after the first burn, average moisture remained about 0.20 per cent higher on the burned plot although it was less in the upper foot of soil May through October by 2.9 per cent.

In 1966, moisture averaged 0.7 per cent less in the burned plot. In the upper foot of soil, moisture averaged 5.6 per cent less in the burned plot although the greatest difference occurred in September and October. Moisture was virtually equal from May through August.

The major cause of the higher soil temperatures, the greater evaporation, and the gradually decreasing soil moisture recorded for the burned plot in comparison to the control was the removal of dead vegetation which exposed the bare soil surface to the direct rays of the sun.

Plowed Once

Before the only plowing of this group of plots, the vegetational analyses indicated the dominance of Andropogon scoparius (Tables XI, XII, XIII). This species accounted for one-half the absolute composition with 50 per cent relative density. Relative frequency was 37.5 per cent. Forty-one per cent of the total phytomass was A. scoparius.

Other species of minor importance were Sorghastrum nutans,

TABLE X

SOIL MOISTURE: PROTECTED VERSUS BURNED

Month	Depth "	Protected	Early Sp. Burn	Late Sp. Burn	Protected	Early Sp. Burn	Late Sp. Burn	Protected	Early Sp. Burn	Late Sp. Burn
A	0-6				16.2	18.9	18.6	21.2	14.7	15.6
p	6-12				18.1	20.7	18.9	21.0	21.8	19.7
r	12-24				16.7	22.1	17.5	14.6	25.7	19.0
	24-36				8.7	22.1	15.1	13.5	14.3	18.0
M	0-6				17.5	16.0	16.1	15.4	11.0	13.7
a	6-12				18.2	17.7	18.7	18.5	15.1	15.3
y	12-24				16.0	19.8	16.3	16.5	17.9	15.1
	24-36				13.6	17.5	15.0	13.1	17.7	15.0
J	0-6	10.5	12.7	11.7	17.3	13.0	14.0	13.6	12.0	13.6
u	6-12	10.4	14.1	12.8	17.0	12.9	17.8	17.2	13.0	15.9
n	12-24	17.0	18.0	14.5	14.7	17.7	16.1	16.1	15.8	14.2
e	24-36	16.1	19.8	15.7	16.3	18.8	15.0	10.8	17.1	13.8
J	0-6	9.3	5.5	9.9	10.5	5.8	10.2	9.2	9.2	13.1
u	6-12	9.4	7.9	10.5	13.8	8.3	12.8	10.8	10.8	14.3
l	12-24	11.8	15.4	11.5	12.3	14.5	12.9	11.4	13.7	15.8
y	24-36	14.3	17.4	12.9	13.2	14.9	13.8	11.2	13.6	12.1
A	0-6	9.6	9.9	13.1	12.1	7.5	11.0	9.7	8.8	10.7
u	6-12	10.9	9.8	19.1	12.5	7.5	11.9	14.7	12.1	14.0
g	12-24	12.3	14.5	19.7	10.6	13.2	11.8	13.0	14.1	11.6
	24-36	12.2	15.2	20.0	12.0	15.0	12.9	9.3	15.4	12.5
S	0-6	11.7	11.7	11.6	16.6	12.3	12.6	15.7	2.6	5.0
e	6-12	11.3	15.0	11.8	15.8	13.1	14.8	16.2	8.2	9.3
p	12-24	12.0	20.3	14.5	13.7	17.7	13.1	13.8	13.8	12.3
t	24-36	14.0	19.7	14.4	10.9	17.8	13.6	10.4	14.7	11.4
O	0-6	11.6	12.1	11.5	17.5	13.1	12.6	12.3	4.3	3.6
c	6-12	11.4	11.8	11.7	18.2	16.9	17.5	13.7	9.6	7.4
t	12-24	12.0	15.9	13.9	14.5	20.3	16.7	12.7	11.8	10.1
	24-36	15.0	15.9	13.6	10.4	19.5	14.7	9.6	12.6	9.9

TABLE XI

RELATIVE DENSITY: PROTECTED VERSUS PLOWED

Species	Protected				Plowed Once				Plowed Each Year			
	1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon scoparius	53.3	51.3	54.2	45.8	50.0	8.3	3.3	8.2	51.3	14.2	9.2	2.5
Andropogon gerardi	11.3	11.7	9.6	11.3	0.8	2.5	-	0.4	-	-	-	0.4
Sorghastrum nutans	4.2	4.6	6.3	10.0	5.4	2.9	2.1	9.2	7.1	0.8	1.7	4.6
Sporobolus asper	2.9	3.2	7.1	7.9	2.5	0.8	0.8	3.3	5.4	-	-	-
Panicum oligosanthes	4.6	4.2	2.5	4.2	6.0	11.3	2.5	1.7	3.8	3.3	1.7	2.1
Andropogon saccharoides	2.5	3.8	0.4	-	7.1	-	-	-	1.2	0.4	-	-
Andropogon ternarius	-	-	-	0.8	-	-	-	0.4	-	-	-	-
Aristida oligantha	-	-	-	0.4	-	7.1	22.5	27.9	-	7.5	22.9	24.2
Eragrostis intermedia	-	-	-	-	-	-	0.4	7.5	-	-	-	5.8
Eragrostis spectabilis	0.4	-	-	-	-	-	-	-	-	0.8	-	-
Leptoloma cognatum	3.3	-	-	0.4	5.0	7.1	-	2.1	5.0	5.8	-	4.6
Other Grasses	6.7	6.6	-	2.5	3.3	2.1	-	2.5	5.4	6.7	-	5.0
Legumes	-	0.4	1.3	2.1	1.7	14.2	-	4.2	2.1	12.1	0.8	5.8
Achillea lanulosa	2.5	0.4	1.7	0.4	4.6	-	-	-	5.0	-	-	-
Ambrosia psilostachya	1.7	6.7	10.8	8.8	5.0	14.6	59.6	24.6	7.1	13.7	54.2	16.7
Aster ericoides	2.1	1.2	1.8	2.9	6.2	6.7	2.5	3.7	2.9	5.4	2.5	4.6
Carex spp.	3.8	3.8	2.5	1.7	2.1	5.8	0.8	-	0.4	12.1	2.8	7.5
Other Forbs	0.8	2.8	2.1	0.8	-	16.7	5.0	4.2	3.3	17.1	5.0	18.2

TABLE XII

RELATIVE FREQUENCY: PROTECTED VERSUS PLOWED

Species	Protected				Plowed Once				Plowed Each Year			
	1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon scoparius	39.7	38.3	43.1	35.0	37.5	9.4	4.0	10.6	37.6	1.8	12.1	2.9
Andropogon gerardi	6.6	10.9	7.8	9.4	0.8	1.7	-	0.7	-	-	-	0.6
Sorghastrum nutans	5.8	5.5	6.0	9.4	5.5	2.2	2.0	7.3	6.8	0.7	2.6	3.5
Sporobolus asper	4.1	3.9	9.5	8.6	2.3	1.1	2.0	2.7	3.8	-	-	-
Panicum oligosanthes	6.6	6.3	3.5	5.1	7.8	12.2	5.0	2.7	6.0	4.4	2.6	-
Andropogon saccharoides	4.1	3.9	0.9	-	6.3	-	-	-	2.3	0.7	-	-
Andropogon ternarius	-	-	-	0.9	-	-	-	0.7	-	-	-	-
Aristida oligantha	-	-	-	0.9	-	7.7	22.0	21.2	-	8.7	24.1	18.2
Eragrostis intermedia	-	-	-	-	-	-	1.0	8.6	-	-	-	6.5
Eragrostis spectabilis	0.8	-	-	-	-	-	-	0	0	1.5	-	-
Leptoloma cognatum	5.0	-	-	0.9	7.0	7.2	-	2.7	6.8	6.5	-	6.5
Other Grasses	7.4	6.3	-	2.6	4.7	1.7	-	3.0	7.5	5.8	-	7.1
Legumes	-	0.8	2.6	4.3	3.1	13.3	-	6.0	3.0	10.2	0.9	7.1
Achillea lanulosa	5.0	0.8	1.7	0.9	2.3	-	-	-	7.5	-	-	-
Ambrosia psilostachya	3.3	8.6	14.7	12.0	9.4	13.7	49.0	24.5	9.0	18.9	43.1	15.3
Aster ericoides	4.1	4.7	2.6	6.0	9.4	6.1	5.0	4.6	3.7	8.0	2.6	5.9
Carex spp	5.8	7.0	3.5	2.6	3.9	3.9	1.0	-	0.8	8.7	2.6	8.8
Other Forbs	1.7	3.1	4.3	1.7	-	20.4	9.0	6.0	5.3	24.7	9.5	17.7

TABLE XIII

ABSOLUTE COMPOSITION: STEMS/METER^2: PROTECTED VERSUS PLOWED

Species	Protected				Plowed Once				Plowed Each Year			
	1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon scoparius	112.4	95.4	123.2	115.1	102.0	1.1	10.0	15.9	108.3	1.9	38.5	1.9
Andropogon gerardi	23.7	21.7	21.8	28.0	1.7	0.3	-	0.8	-	-	-	0.3
Sorghastrum nutans	8.8	8.5	14.0	25.1	11.0	3.4	6.3	17.5	15.0	0.1	7.0	3.5
Sporobolus asper	6.2	6.2	16.1	19.9	5.1	0.1	2.5	6.4	11.5	-	-	-
Panicum oligosanthes	6.2	7.8	5.7	10.5	12.8	1.5	7.5	3.2	7.9	0.5	7.0	-
Andropogon saccharoides	5.3	7.0	1.0	-	14.4	-	-	-	2.6	0.1	-	-
Andropogon ternarius	-	-	-	2.1	-	-	-	0.8	-	-	-	-
Aristida oligantha	-	0.8	-	1.1	-	0.9	67.8	53.4	-	1.0	96.3	18.7
Eragrostis intermedia	-	-	-	-	-	-	1.3	14.4	-	-	-	4.5
Leptoloma cognatum	7.0	-	-	1.1	10.2	0.9	-	4.0	10.6	0.8	-	3.5
Eragrostis spectabilis	0.9	-	-	0.5	-	-	-	-	-	0.1	-	-
Other Grasses	14.0	6.2	-	6.3	6.8	0.6	-	4.8	11.5	0.9	-	5.2
Legumes	-	0.8	2.8	5.2	3.4	1.6	-	7.8	4.4	2.5	3.5	3.5
Achillea lanulosa	5.3	0.8	3.8	1.1	9.4	-	-	-	10.6	-	-	-
Ambrosia psilostachya	3.5	12.4	24.7	22.0	10.2	1.9	179.6	47.0	15.0	1.8	227.5	12.9
Aster ericoides	4.4	7.8	3.8	7.3	12.8	0.9	7.5	7.2	6.2	0.7	10.5	3.5
Carex spp.	7.9	7.0	5.7	4.2	4.2	0.8	2.5	-	0.9	1.6	8.7	5.8
Other Forbs	2.0	3.8	4.8	2.1	-	2.1	16.3	9.6	7.1	2.3	17.5	12.9
Totals	207.6	186.2	227.4	251.6	204.0	16.1	301.3	192.8	201.6	14.3	416.5	76.2

Panicum oligosanthes, Andropogon saccharoides, Leptoloma cognatum, Ambrosia psilostachya, and Aster ericoides.

Grasses, as a group, provided a total relative density of 81.4 per cent and a relative frequency of 71.8 per cent; about 10.0 per cent less than the control in each category. Productivity for 1963 was 1,513.7 pounds per acre, about 9.0 per cent more than the control. Although not appearing to be important in relative density, relative frequency, and absolute composition, Andropogon gerardi accounted for about 13.0 per cent of the phytomass.

After plowing in 1964, the sampling data indicated the decrease of Andropogon scoparius as a major dominant. Of the grass species recorded, Panicum oligosanthes had the highest relative density (11.3 per cent) and relative frequency (12.2 per cent). The forb Ambrosia psilostachya, with a relative density of 14.6 per cent and relative frequency of 13.7 per cent was the most prevalent species on the plowed plots. Absolute composition for the treatment was 12.8 shoots per square meter. Grasses accounted for 43.2 per cent relative density and 42.1 per cent relative frequency.

Nineteen sixty-five found a tremendous increase in absolute composition to 301.4 stems per square meter. Aristida oligantha, a weedy annual, emerged as the dominant grass with a relative density of 22.5 per cent and a relative frequency of 27.0 per cent. Ambrosia psilostachya, probably an invader from the fire lanes, was the major species at 59.9 per cent relative density and 49.0 per cent relative frequency. Grasses declined further as a group to 31.6 per cent relative density and 36.0 per cent relative frequency, most of which was Aristide oligantha.

The third year after plowing saw relative density of grasses increase to 63.3 per cent and relative frequency increase to 60.2 per cent. Ambrosia psilostachya fell to 24.6 per cent relative density and 24.5 per cent relative frequency. Sorghastrum nutans increased to 9.2 per cent relative density and 10.2 relative frequency. A decrease of about 37.0 per cent was recorded in absolute composition for all species.

Total productivity after the first plowing was 1,014.5 pounds per acre, about 33.0 per cent less than under protected conditions during the previous year (Figure 11, Table XIV). Most of the forb yield was Helianthus annuus. In 1965, phytomass increased by 31.0 per cent to 1,333.2 pounds per acre. Most of the forb yield that year was A. psilostachya. A slight increase of 8.0 per cent was recorded in 1966 to 1,440.0 pounds per acre. Over the two year period, there was a 42.0 per cent increase in phytomass, although this was still less than under protected conditions in 1963.

From 1964 to 1966, Sorghastrum nutans increased from 5.5 per cent to 17.4 per cent of the total phytomass. Other grasses increased from 18.7 per cent to 33.1 per cent and forbs decreased from 62.6 per cent to 43.1 per cent. Andropogon gerardi, A. scoparius and legumes were relatively insignificant.

The initial effect of the plowing was caused by the burial of plant propagules (Rice and Penfound, 1957a) which drastically reduced absolute composition during the first growing season. Two years after plowing the plots were dominated by the forb A. psilostachya. After the third season, A. psilostachya was still prevalent but the annual grass Aristida oligantha was the dominant species. Booth (1941)

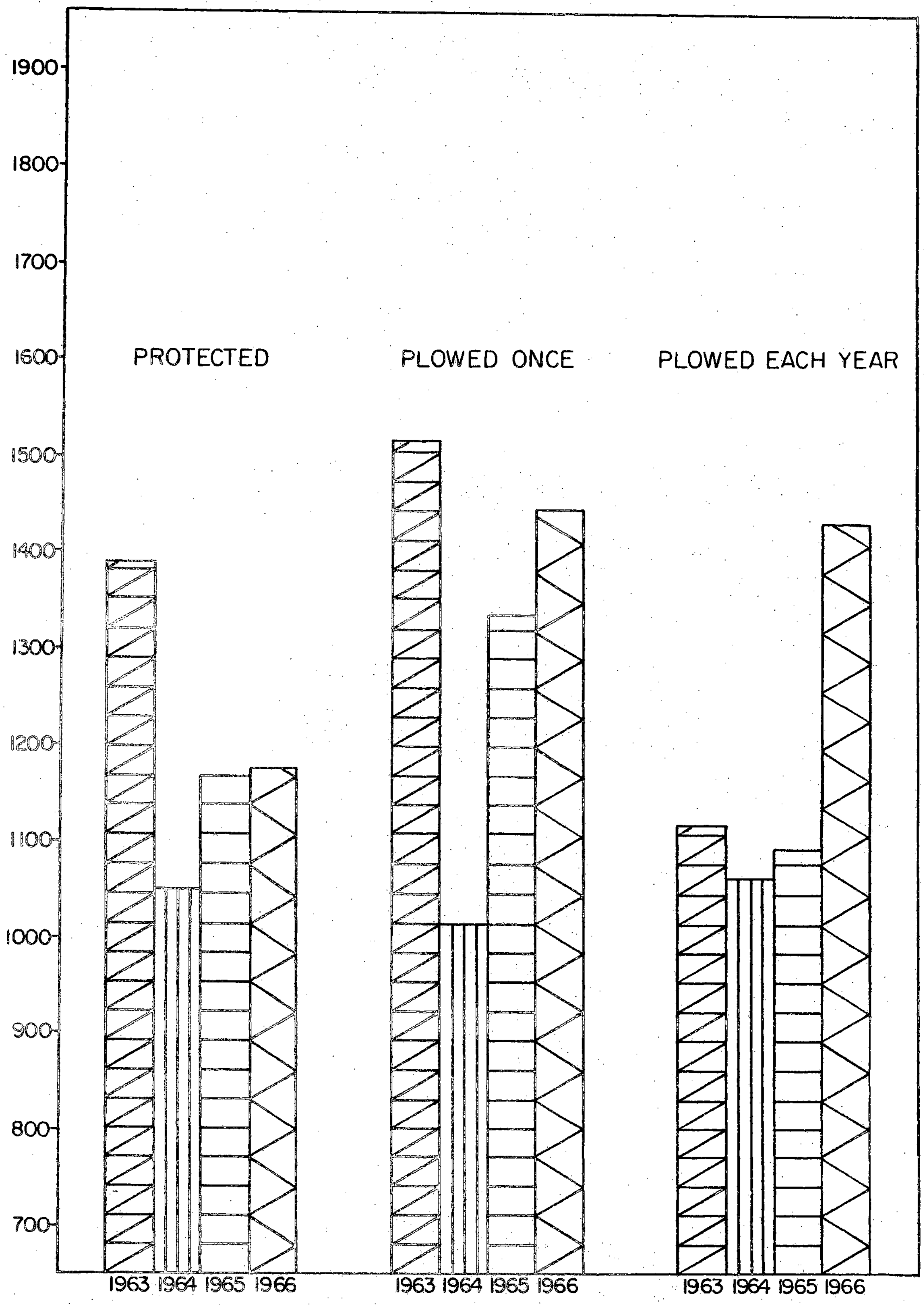

Figure 11. Total Productivity: Lbs./Acre: Protected Versus Plowed

TABLE XIV

PRODUCTIVITY: LBS./ACRE: PROTECTED VERSUS PLOWED

Species	Protected				Plowed Once				Plowed Each Year			
	1963	1964	1965	1966	1963	1964	1965	1966	1963	1964	1965	1966
Andropogon gerardi	201.0	190.8	213.3	192.2	196.7	14.7	48.3	8.8	-	-	0.7	1.2
Andropogon scoparius	646.5	329.3	318.3	295.2	723.3	24.8	103.5	51.2	648.5	19.5	55.8	152.2
Sorghastrum nutans	77.5	121.5	145.0	150.7	126.0	56.2	203.0	250.0	10.8	45.8	8.8	38.7
Other Grasses	309.5	208.0	165.5	253.3	296.0	189.8	113.5	476.0	205.2	271.8	93.2	436.0
Legumes	3.7	16.2	23.2	-	19.2	93.8	16.7	33.2	28.2	53.5	17.0	55.5
Forbs	59.0	182.3	304.7	288.5	144.5	635.2	848.2	620.8	257.8	673.0	912.0	743.5
Total	1297.2	1048.1	1170.0	1179.9	1505.7	1014.5	1333.2	1440.0	1150.5	1063.6	1087.5	1427.1

described succession on abandoned fields in central Oklahoma in a similar manner. He found an initial weed state lasting two or three years, followed by an annual grass stage lasting nine to 13 years.

Propagules of Sorghastrum nutans apparently were not buried deeply enough to destroy them as this species increased rapidly. Conditions of abundant nutrients and moisture, and little competition allowed its rhizomes to spread rather quickly. Sorghastrum nutans probably will be the major dominant on the once-plowed plot within very few years.

The greater phytomass of this plot than the control is thought to be due to greater availability of nutrients caused by the decomposition of organic matter plowed under initially (Rice and Penfound, 1954).

Soil Temperature

Soil temperature (Figure 12) on the plowed once plots was an average of 1.5°F warmer per sampling date in 1964. The maximum average was 2.5°F greater while the minimum average was only 0.5°F warmer. In 1965 the average difference was only 0.4°F warmer. Maximum temperature averaged 1.2°F warmer and the minimum was 0.2°F cooler. The average temperature in 1966 was about 0.8°F greater while the average maximum was 0.9°F greater and the average minimum was 0.7°F greater. Removal of mulch was responsible for the warmer temperature on the plowed plot. This factor also allowed more rapid cooling at night which accounts for the insignificant difference in the average minimum.

Evaporation

Evaporation (Figure 13) averaged six ml greater per day on the plowed plot than the control through the middle of July. Thereafter,

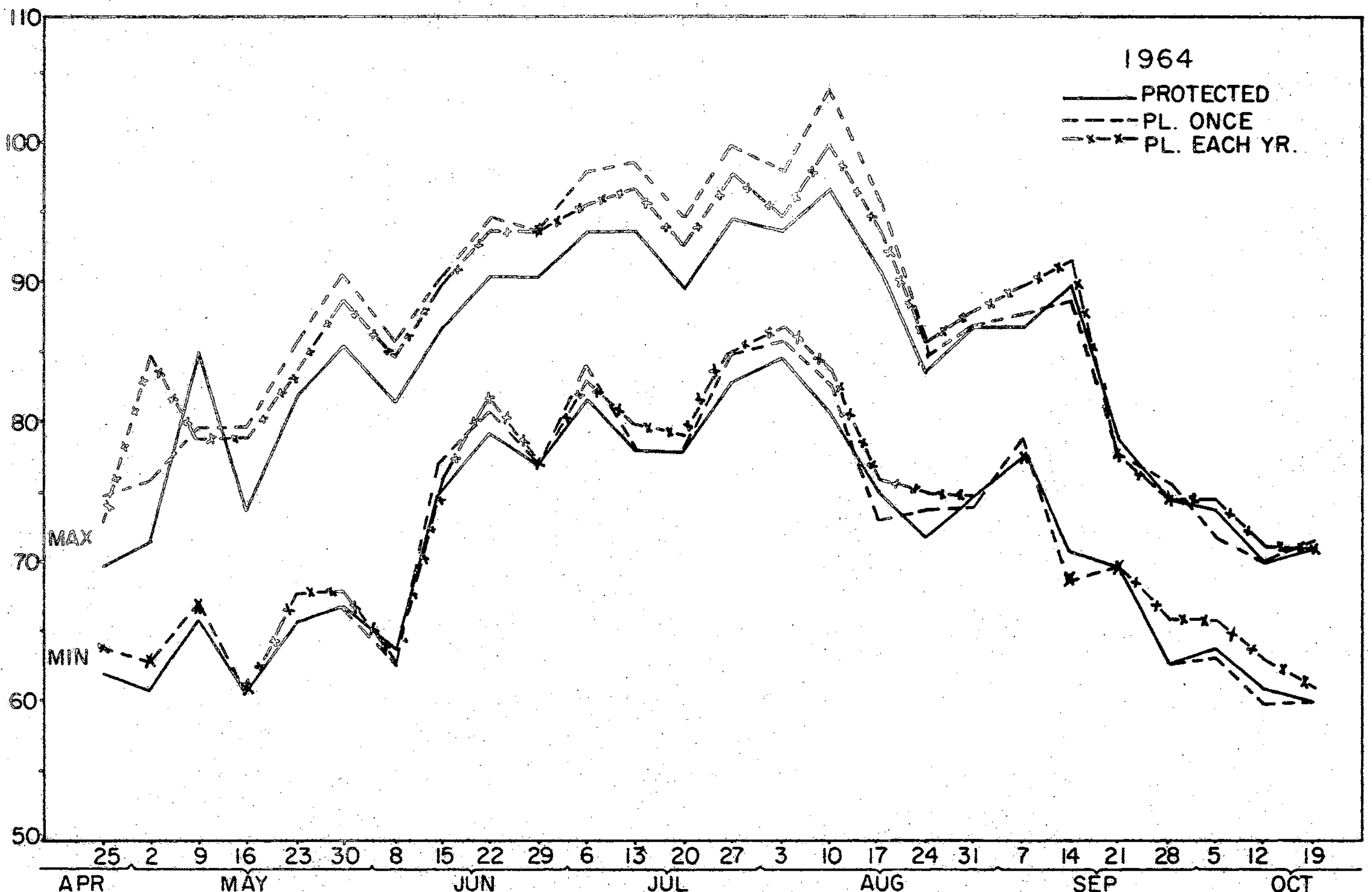

Figure 12. Soil Temperature: Protected Versus Plowed

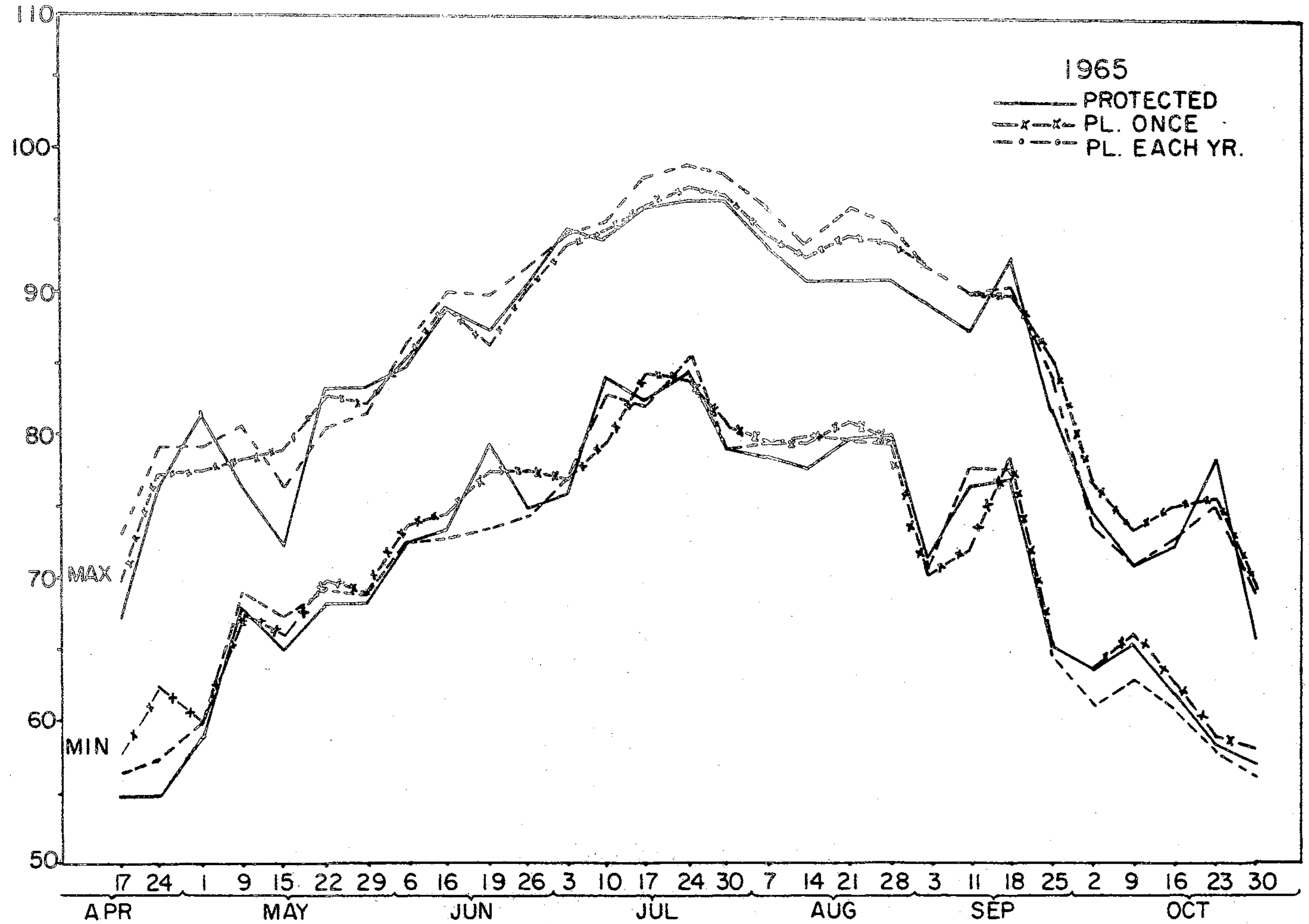

Figure 12. (Continued)

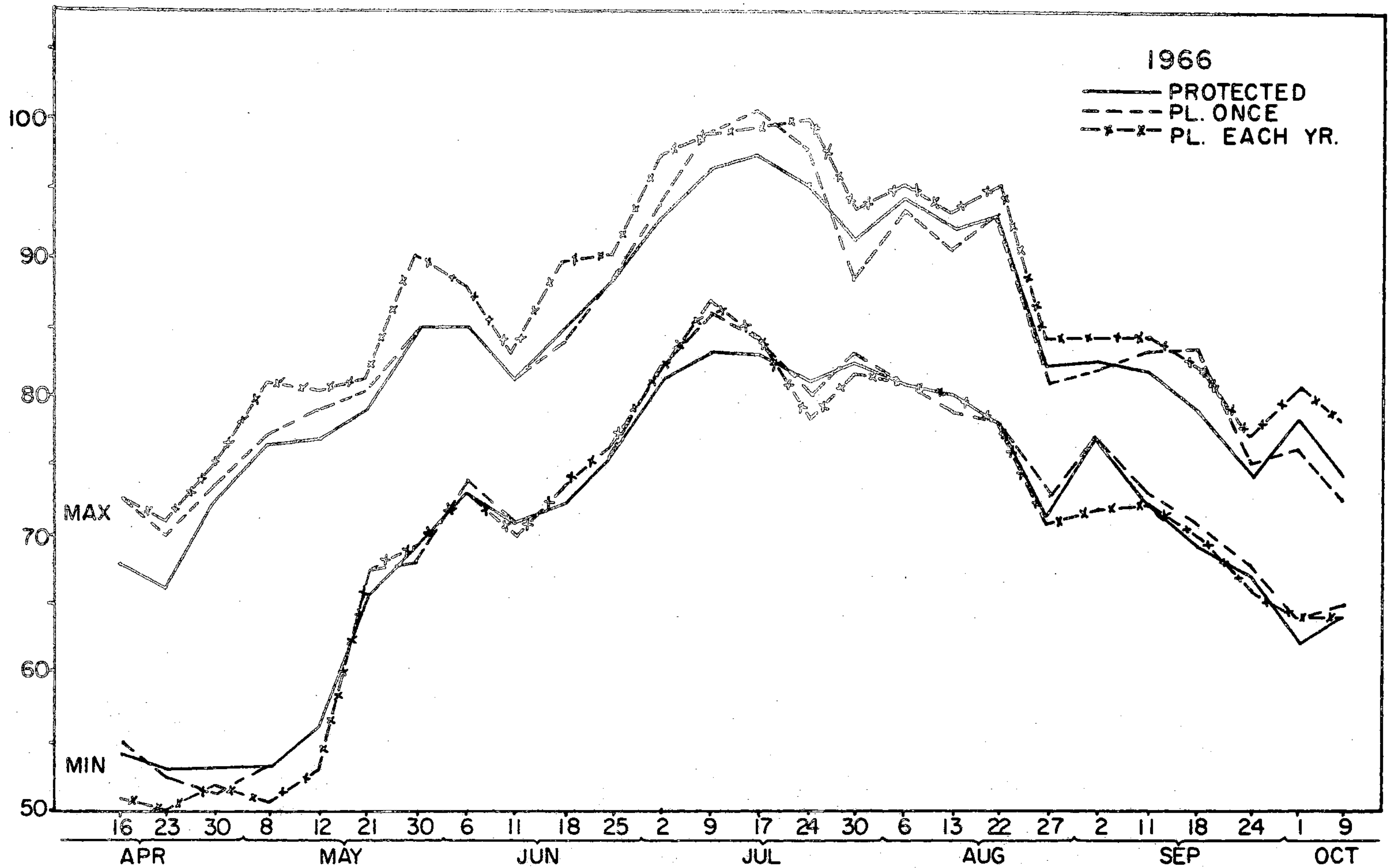

Figure 12. (Continued)

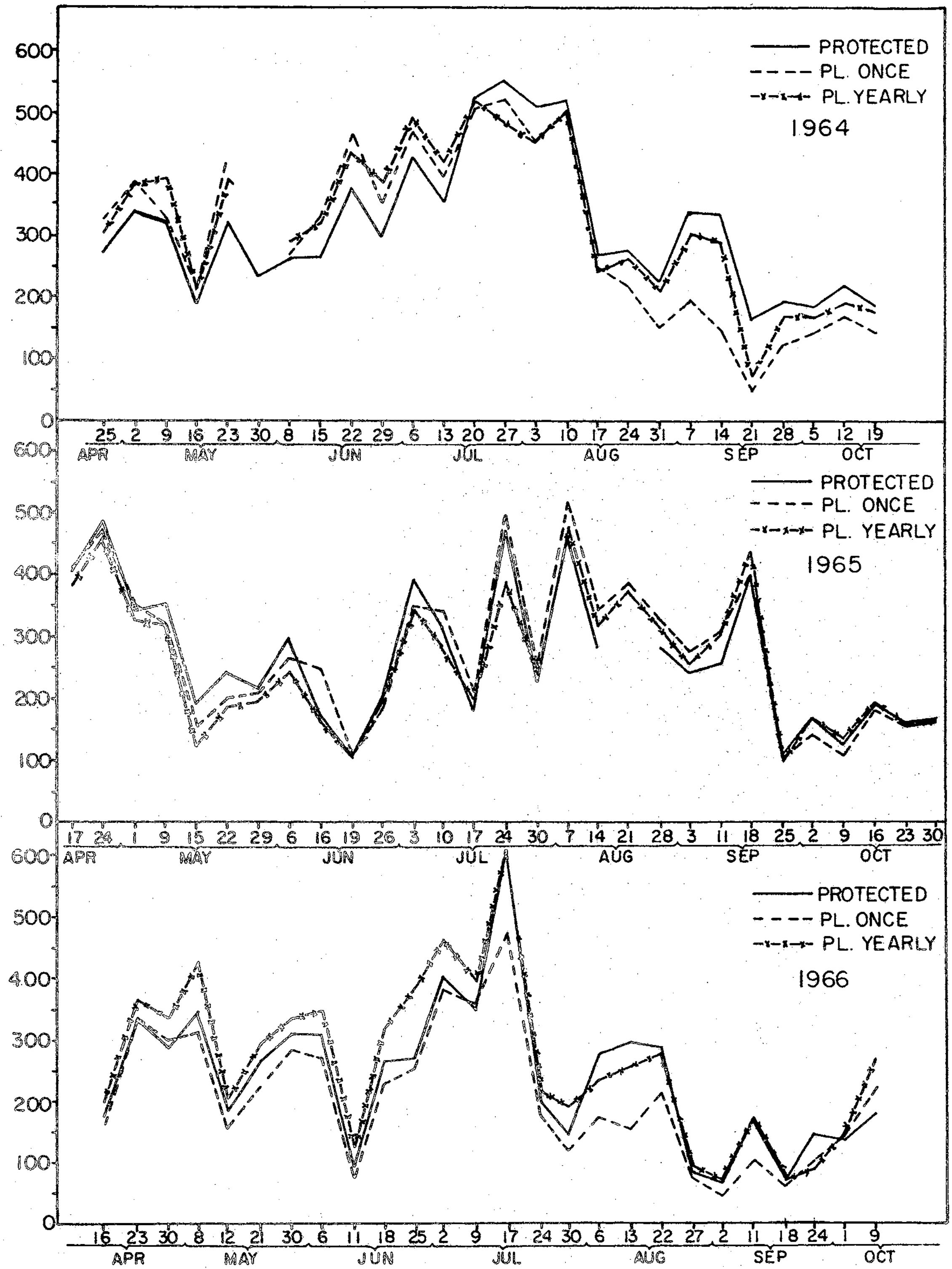

Figure 13. Evaporation: Protected Versus Plowed

the average was about nine ml less. Exposure of the plot to the direct rays of the sun, and the lack of vegetation to reduce wind velocity attributed to the greater evaporation through July. During 1964, the annual sunflower (Helianthus annuus) was prevalent on the plowed plots and created an effective wind break as well as affording some shading from the sun. These factors partially explain the reduction in evaporation after mid-July.

During 1965, evaporation averaged only one ml more on the plowed plot per day. In general, evaporation was higher during June, July, August, and September, but lower in May and October and approximately the same in April. In 1965 absolute composition was highest at 301.4 stems per square meter. This factor contributed to reducing evaporation on the plowed plot although during the hottest months the lack of mulch allowed significantly greater evaporation than the control. Helianthus annuus was not abundant on the plot in 1965.

In 1966 evaporation averaged about six ml less per day. The decreased evaporation reflects the amount of dead and decomposing vegetation which accumulated in the two years following plowing.

Soil Moisture

In 1964 soil moisture in the plowed plot averaged slightly higher than the control plot (Table XV). Moisture was greater in the upper foot of soil each month; greater in the one to two feet level on all but the first month, but was always less in the two to three feet level. The reason for the higher soil moisture in the upper two feet of soil was probably due to the moisture holding organic matter plowed under at the beginning of the season. The barren soil surface did allow

TABLE XV

SOIL MOISTURE: PROTECTED VERSUS PLOWED

Month	Depth "	1964 Protected	1964 Plowed Once	1964 Plowed Ea. Yr.	1965 Protected	1965 Plowed Once	1965 Plowed Ea. Yr.	1966 Protected	1966 Plowed Once	1966 Plowed Ea. Yr
Apr	0-6				16.2	15.3	18.0	21.2	12.5	13.8
	6-12				18.1	19.2	19.5	21.0	19.7	21.7
	12-24				16.7	18.7	16.7	14.6	20.5	13.8
	24-36				8.7	14.7	13.0	13.5	12.2	9.1
May	0-6				17.5	15.5	13.8	15.4	15.4	15.6
	6-12				18.2	17.7	17.1	18.5	18.5	19.1
	12-24				16.0	16.7	15.5	16.5	16.5	15.7
	24-36				13.6	12.4	12.6	13.1	13.1	10.1
June	0-6	10.5	15.6	12.4	17.3	12.0	12.8	13.6	15.4	15.6
	6-12	10.4	17.3	14.7	17.0	14.5	15.8	17.2	18.5	19.1
	12-24	17.0	14.9	11.5	14.7	15.7	13.6	16.1	16.5	15.7
	24-36	16.1	14.7	9.3	16.3	12.9	11.3	10.8	10.8	10.1
July	0-6	9.3	7.3	15.1	10.5	7.5	9.4	9.2	14.4	9.8
	6-12	9.4	13.3	17.0	13.8	9.7	10.9	10.8	10.5	15.0
	12-24	11.8	16.3	14.0	12.3	12.8	13.2	11.4	11.2	12.8
	24-36	14.3	13.8	11.6	13.2	11.2	9.1	11.2	10.2	10.0
Aug	0-6	9.6	10.0	10.4	12.1	7.2	8.2	9.7	6.5	7.6
	6-12	10.9	10.3	12.8	12.5	10.3	13.4	14.7	12.2	13.8
	12-24	12.3	12.3	13.5	10.6	11.8	11.4	13.0	13.8	12.4
	24-36	12.2	14.1	9.3	12.0	12.8	9.4	9.3	10.9	14.9
Sept	0-6	11.7	10.8	11.5	16.6	11.2	12.8	15.7	5.0	7.5
	6-12	11.3	11.7	15.0	15.8	13.7	16.3	16.2	9.3	16.9
	12-24	12.0	16.4	12.5	13.7	15.0	13.0	13.8	12.3	12.7
	24-36	14.0	13.4	10.0	10.9	12.1	9.2	10.4	11.4	9.7
Oct	0-6	11.6	11.2	12.3	12.5	11.0	10.5	12.3	4.1	6.7
	6-12	11.4	11.9	11.7	18.2	16.2	17.3	13.7	9.2	13.3
	12-24	12.0	12.9	13.4	14.5	16.2	13.2	12.7	11.7	10.6
	24-36	15.0	11.3	10.0	10.4	13.1	8.6	9.6	9.6	8.5

somewhat more evaporation but there were very few plants per square meter to use moisture. Soil moisture was less at the two to three feet level probably due to decreased infiltration caused by interception by surface ground cover.

Moisture was generally less in 1965 and 1966 in most months and soil depths, the exceptions usually being in the early part of the year. These results concur with Rice and Penfound (1954).

Plowed Each Year

In 1963 the plots that were to be plowed each year were dominated by *Andropogon scoparius* with a relative density of 51.3 per cent (Table XI) and a relative frequency of 37.6 per cent (Table XII). Productivity of the species was 649.0 pounds per acre, or about 58 per cent of the total yield of 1,117.2 pounds per acre (Table XIV).

Other relatively minor dominants were *Sorghastrum nutans*, *Panicum oligosanthes*, *Leptoloma cognatum*, *Achillea lanulosa*, *Ambrosia psilostachya*, and *Aster ericoides*.

Grasses accounted for 79.2 per cent of the relative density and 70.8 per cent of the relative frequency, about 10.0 per cent less in each category than the control. Absolute composition in 1963 was 211.3 stems per square meter (Table XIII), about the same as the control.

After the first plowing, the total density fell to 13.4 stems per square meter. *Andropogon scoparius* had the highest relative density of 14.2 per cent although this was about 37 per cent less than 1963. *Ambrosia psilostachya* increased in relative density to 13.8 per cent and *Carex spp.* increased to 12.1 per cent from an insignificant 0.4 per cent in 1963. The most frequently encountered species were *A.*

psilostachya, Carex spp., Aster ericoides, Aristida oligantha, and Leptoloma cognatum. In 1964, grasses accounted for 32.6 per cent of the relative density and 30.2 per cent relative frequency, less than one-half the values of the previous year.

After plowing again in 1965, the plowed plots showed considerably different results from 1964. Total density increased tremendously from 13.4 to 420.0 stems per square meter. Aristida oligantha became the dominant grass and Ambrosia psilostachya was the most prevalent of all species increasing to 54.2 per cent relative density and 43.1 per cent relative frequency. Andropogon scoparius decreased about five per cent in relative density but increased 10.3 per cent in relative frequency. Carex spp. decreased about nine per cent. Grasses decreased 4.0 per cent to 35.5 per cent relative density but increased 11.3 per cent in relative frequency to 41.4 per cent.

After the third consecutive year of plowing, sampling data again changed radically. Absolute composition decreased from 420.0 to 129.3 stems per square meter. Aristida oligantha increased about 1.5 per cent in relative density but decreased in relative frequency about six per cent. Ambrosia psilostachya decreased in relative density from 54.2 per cent to 16.7 per cent and in relative frequency from 43.1 per cent to 15.3 per cent. Andropogon scoparius decreased further, but Carex spp. increased again, although only slightly. Grasses increased in relative density to a value of 49.2 per cent and in relative frequency to 45.3 per cent.

Phytomass, after the first plowing in 1964, was 1,063.6 pounds per acre, most of which was accounted for by Helianthus annuus. Yield increased only 2.2 per cent to 1,087.5 pounds per acre in 1965, and most of this was Ambrosia psilostachya. A 31.0 per cent increase in 1966 boosted the yield to 1,427 pounds per acre. The increase was about 22.0 per cent more than in 1963. After three consecutive plowings, yield increased 34.0 per cent.

Andropogon scoparius increased in yield each year after the first plowing until in 1966 it comprised 10.7 per cent of the total. Other grasses were quite variable, being 25.6 per cent in 1964, 8.5 per cent in 1965, and 30.5 per cent in 1966. Forbs were variable also, but were always 50.0 per cent or more of the total phytomass. Andropogon gerardi, Sorghastrum nutans, and legumes were relatively unimportant.

Penfound and Rice (1957a) noted that after three consecutive plowings, weedy annuals comprised the dominant vegetation. This was not the case in this study as remnants of the original dominant vegetation remained after three years, although an annual grass, Aristida oligantha, was the dominant species of vegetation.

The increase in phytomass of plowed plots over the control has been attributed to increased nutrients available as a result of the decomposition of organic matter buried by plowing (Rice and Penfound, 1954).

Soil Temperature

Soil temperatures were warmer on the plowed plot by 2.0°F in 1964, 2.1°F in 1965, and 1.3°F in 1966 (Figure 12). During 1965 and 1966, the plot also showed the greatest fluctuation between maximum and minimum temperatures. Only during 1966, however, was the minimum of the plowed tratement less than the minimum of the control and then only by 0.3°F.

Evaporation

The pattern of evaporation on the plot plowed each year was much the same as the plot plowed only once (Figure 13). Evaporation was greater until the last week in July and thereafter was generally less. The development of Helianthus annuus was undoubtedly responsible for part of the reduction.

Nineteen sixty-five brought less evaporation on the plowed plot through most of July. Evaporation then was greater through most of the rest of the year. The large population of plants (420.0 stems per square meter) helped protect the plot early in the year. With the arrival of the hottest part of the growing season, however, the absence of protective mulch apparently stimulated the increased evaporation.

After the third plowing, evaporation was greater than on the control. This occurrence was mostly due to lack of mulch, but the absolute density was low in 1966 which also contributed to the greater evaporation than the control.

Soil Moisture

In 1964 soil moisture was somewhat greater from zero to 24 inches in the plowed plot than in the control. It was, however, less at the two to three feet level (Table XV). Moisture was greater in the upper two feet because of the moisture holding capacity of organic material which had been plowed under. Clark (1940) found that vegetation could intercept up to 50.0 per cent of a 0.5 inch rain in 30 minutes. The plowed plot was probably able to better utilize small amounts of precipitation that fell during the abnormally dry year of 1964. Infiltration to greater depth was less because of the increased runoff on the practically barren plots (Hanks and Anderson, 1957).

In 1965 moisture was generally less at all levels in the plowed plot than the control. Since evaporation was also less through most of July on the plowed treatment, the early moisture deficit was probably due to the plant population of 420 stems per square meter which undoubtedly created a considerable drain on available moisture, especially in the upper foot of soil.

In 1966 soil moisture was generally greater in the upper foot of soil through July. At the one to three feet level, however, moisture was usually less throughout the year.

Comparison of All Treatments

Although this was not the object of the study, comparison of all treatments points out that no treatment improved the relative density, relative frequency, or productivity of the major dominant Andropogon scoparius. All plots showed a decline in relative density and relative frequency of this species and only on the early spring burn did productivity equal the 1963 yield.

Andropogon gerardi was important only in the control and the early spring burn plots. This species was least affected by the abnormally dry year of 1964 on the protected plot although it did decline somewhat on the early spring burn plots before burning was carried out. Burning apparently had no adverse effect on its relative density and relative frequency, and it too equalled the 1963 yield on the early spring burn plots.

Sorghastrum nutans improved in relative density and relative frequency on the control, late spring burn, mowed and the plot plowed once. Although late spring burning has been reported as least detrimental to S. nutans by McMurphy and Anderson (1965), they did not report gains for the species. Crockett (1966) reported the gain of S. nutans due to mowing near Stillwater. The rapid gains of S. nutans on the plowed plot were attributed to the spread of its rhizomes under ideal conditions of available nutrients, soil moisture and little competition because of the burial and destruction of propagating structures of other plants (Penfound and Rice, 1957).

The single stemmed grass, Panicum oligosanthes was present in small quantities on all plots in 1963. None of the treatments greatly improved its position, although it did increase more in relative density and relative frequency in the late spring burn plots than on the plots of the other treatments.

The annual grass, Aristida oligantha, appeared to any great extent only on the plowed treatments, and increased each year in relative density. Rice and Penfound (1954) did not report the presence of A. oligantha in plots plowed once nor did Penfound and Rice (1957a) find the species in plots plowed annually for five years. The rise of A. oligantha to dominance during the fourth year after plowing is in keeping with Booth (1941) who found the same species to be the dominant of the annual grass stage of succession which appeared about four years after abandonment of crop land. Aristida oligantha began appearing on the mowed plots after three mowings; on the early spring burn plots after two burns; and on the late spring burned plots after the first burn.

Ambrosia psilostachya was the principal forb on all plots except the late spring burn. This species proved to be the most vigorous invader, particularly during the third year of the study. Rice and Penfound (1954) noted *A. psilostachya* as the dominant species one year after plowing, but during the second year it was insignificant.

The findings of this study, however, are similar to those of Booth (1941) who noted a weed stage of two or three years duration initiating succession in abandoned fields. The presence of *A. psilostachya* was least significant on the late spring burned plot. Other investigations, according to McMurphy and Anderson (1965), have found late spring burning detrimental to forbs in general.

The forb *Aster ericoides* was most abundant in the early spring burned plots. Fire apparently had little affect on this species. Owensby and Anderson (1967) found that weed yields on early spring burned plots and controls to be approximately equal. *Aster ericoides* was little affected by plowing each year, but did decrease in the plot plowed once. Mowing caused the forb to increase only insignificantly.

Productivity

From a low of four per cent in 1963, forbs increased until they comprised 24.5 per cent of the total phytomass of the control plot in 1966. This occurrence was due to disturbance connected with experimental procedures. Total phytomass of the control remained relatively stable.

Forbs comprised about 23.0 per cent of the phytomass on early spring burned plots, approximately the same as the control, whereas they comprised 10.0 per cent of the yield on the late spring burned plots. These findings are similar to those reported by Owensby and Anderson (1967) for the Flint Hill region of Kansas. Total phytomass of late spring burns and controls were approximately equal, again in accord with Owensby and Anderson. Early spring burns increased yields, probably due to the removal of mulch which had reduced plant population on these plots. Increased yields on sites burned early in the spring are not the rule (Owensby and Anderson, 1967). Phytomass on the mowed plots increased slightly over 1963. Forb yield was about 13.0 per cent of the total, an increase over the five per cent before mowing was started. The plot plowed once did not show an increase in phytomass over the original 1,513.7 pounds per acre occurring under protected conditions in any of the three years following plowing as Rice and Penfound recorded (1954). The plot plowed each year did show an increase in phytomass due largely to a 300 per cent increase in forb yield. Rice and Penfound attributed the increase in phytomass of the plowed plot to greater availability of nutrients due to the decomposition of organic matter turned under by the plow.

Soil Temperature

Soil temperature remained the coolest on the early spring burned plot throughout the study period, although there was a definite warming trend evident during the last year. In 1964 there was an average 3.4°F difference between the early spring burn and the next coolest plot. In 1965 the average difference was 2.4°F, and in 1966 the average difference was 1.0°F. Most burning studies have indicated that soil temperatures are higher on burned sites in comparison to controls. This probably will be the case on the plots of this study in the near future. The site condition before burning, heavy mulch cover, low absolute composition, and high productivity due to the lush vegetation, indicate that fire would be detrimental only after three or four consecutive burns.

The late spring burn became the warmest plot after two burns. The many barren areas on the plot due to the removal of mulch cover caused this plot to become the warmest.

Higher temperatures were recorded on the mowed plot than on the control and this treatment became the second warmest of all experimental plots. The annual removal of vegetation allowed more soil surface to be exposed to the sun's rays thereby causing increased soil temperature.

The plowed treatments were warmer than the control plot, as expected, due to the removal of mulch. However, they were slightly cooler than the mowed and late spring burned treatments. The plot plowed once was slightly cooler than the one plowed each year, due to the accumulation of dead vegetation over the three year period. The once plowed plot had more mulch cover than did either the late spring burn plot or the mowed site, which explains why it was cooler than these plots. The site plowed each year was relatively barren on the surface and the probable reason for it being cooler than the late spring burn or mowed sites is greater radiation.

Evaporation

Evaporation was less from the early spring burn plot than any of the others throughout the study although the difference decreased each year. The advanced state of vegetational development initially existing on this plot undoubtedly caused the lower evaporation.

The late spring burn treatment proved to have the highest evaporation rate. After the first burn, there was little mulch cover left and consequently there was more evaporation from the rather bare soil surface. Soil temperature was also warmest on this plot which contributed to the higher evaporation rate.

The mowed plot had a relatively low evaporation rate, being second or third lowest the three years. It was noted that as absolute composition increased, the rate of evaporation decreased on this treatment. The large populations found on the plots in 1965 and 1966 had some retarding effect on evaporation, largely the slowing of air movement across the plot.

The low evaporation from the plot plowed once can be attributed to the amount of dead vegetation than accumulated after the second and third growing seasons. During 1964 a dense stand of Helianthus annuus developed, providing some shade, and forming a wind break which also slowed evaporation.

Evaporation from the plot plowed each year was generally high. In 1964 evaporation averaged the highest of all plots although it was slowed toward the last of the year by a stand of Helianthus annuus, equal in density to the one of the plot plowed once. The rather low evaporation of 1965 can be attributed to the large population of plants, some 400 stems per square meter, most of which was Ambrosia psilostachya. In 1966 evaporation was virtually equal to the highest of all treatments, being only four ml less. During that year, the absolute composition was low and more bare soil surface was exposed to sunlight and wind.

Soil Moisture

After two early spring burns, it became apparent that the early spring burn treatment was becoming drier in relation to the control. Soil moisture averaged less for the season in 1966 on the burned plot, yet four of seven months found soil moisture greater on the burned plot. Moisture in the upper foot of soil was always less, however. This was due to increasing evaporation coupled with high absolute density on the burned plot. Beiber and Anderson (1961) found that plants utilize moisture in the upper levels of soil first.

Soil moisture on the late spring burned plot, after two burns, averaged less than the control in 1966, but was higher during three of seven months. In two of the seven months, soil moisture was slightly higher in the upper foot of soil. Since, after two burns, absolute composition was about the same as the control, the lower soil moisture was due to more evaporation caused by the exposure of the soil surface of the burned plot.

Moisture in the mowed plot averaged higher than the control throughout the study, although it was generally less in the upper foot of soil. Since absolute density was more than twice the control, lower moisture in the upper foot of soil was expected. The higher soil moisture in the lower soil levels was due to more precipitation reaching the soil surface and infiltrating. Weaver and Rowland (1952) reported that mulch "intercepted much precipitation". However, they did note that more rapid infliltration was promoted by the mulch. Nevertheless, since soil moisture was higher five of seven months and higher in the six inch to 36 inch level a sixth month, it appears that high density of plants is also effective in promoting infiltration.

The plowed plots, as expected, averaged less soil moisture than the control or any other treatment on most sampling dates. This is virtually the same as Rice and Penfound (1954) discovered. Moisture was less due to less interception and infiltration and greater runoff. Evaporation probably had little effect on the soil moisture as it was not greatly different during any year.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The data accumulated during the three years of sampling indicated certain general trends associated with type of treatment and micro-environmental effects, and specific tendencies of individual species or species groups. The most important of these are discussed below. It should be noted, however, that all treatments were applied to prairie which had been protected for several years.

Mowing

Although there were considerable changes in relative density and relative frequency of individual vegetative species, there was also an increase in absolute composition and phytomass as a result of mowing. The latter two phenomena occurred provided environmental conditions were fairly normal during the growing season. Mowing followed by deficient precipitation early in the growing season reduced phytomass and absolute composition.

Early Spring Burn

The effect of early spring burning was much like that of mowing in regard to general vegetation reaction. The relative density and relative frequency of vegetative species changed, but there was a trend toward greater absolute composition and phytomass.

Late Spring Burn

Late spring burning had little affect on absolute composition although there was a slight reduction in phytomass. Again, there was a change in relative density and relative frequency of vegetative species.

Plowed Once

The initial reaction of vegetation to one plowing was a large decrease in both absolute composition and phytomass. This was followed by a large increase in both categories, principally of species which become established the year after plowing. The third trend was toward absolute composition and phytomass levels similar to those of pre-disturbance times.

Plowing Each Year

Yearly plowing had unpredictable results. The yearly turning under of organic matter increased phytomass somewhat. Those species whose propagules were not buried too deeply probably were favored.

Soil Temperature

Disturbances such as mowing, burning, and plowing, which removed vegetation both living and non-living, caused average maximum soil temperatures to be greater in comparison to controls. This was due mainly to the exposure of barren soil to the direct rays of the sun. Average minima showed little difference or were cooler due to radiation from denuded areas.

Evaporation

Differences in evaporation among the plots were more closely correlated with amount and type of vegetation cover than other factors. Retardation of air flow across plots greatly reduced evaporation.

Soil Moisture

Soil moisture was dependent on interception, infiltration, and absolute composition. Plots with high absolute composition, but little mulch, had high moisture in the lower soil levels because of effective interception and infiltration. These plots had relatively little moisture in upper soil levels as plants utilize moisture in the upper soil levels first.

Plots with little mulch and low absolute composition were drier at all levels than protected plots, whose mulched surface was effective in intercepting precipitation and retarding evaporation. Relatively barren plots also were drier as a result of little infiltration and increased evaporation.

Reaction of Sampling Groups

Andropogon gerardi

Andropogon gerardi was present to any extent only in the control and early spring burned plots. In the controls, this species maintained virtually equal values of relative density, relative frequency, absolute composition, and phytomass from year-to-year. On the burned plots, relative density and relative frequency were lowered slightly. However, absolute composition of the species increased due to the threefold increase of stem density on the plots. In 1966, phytomass of A. gerardi on the burned plots was practically equal to the 1963 pre-burning yield. These data indicate A. gerardi was stimulated to produce a greater number of shoots by an early spring burn, although actual yield was little affected.

Andropogon scoparius

Andropogon scoparius occurred on all plots and was clearly the dominant species. On the protected plots, values for relative density, relative frequency, and absolute composition were relatively stable throughout the four year period. Productivity was halved from 1963 to 1964, indicating intolerance of arid conditions during the 1964 growing season. Relative density and relative frequency were diminished for this species by all treatments. Burning, both early and late, reduced values approximately equally. The effect of mowing was slightly greater. Both plowing methods had deleterious affects on A. scoparius. Absolute composition increased on the early spring burned plots and the mowed plots, while it decreased slightly as a result of late spring burning. Plowing drastically reduced the absolute composition of A. scoparius.

Productivity increased (over 1964 levels although not 1963) about the same on mowed and early spring burned plots. Yield increased only slightly on late spring burned plots. Yield was decreased severely on plowed plots, although the degree was unpredictable from year-to-year.

Sorghastrum nutans

This species increased on the protected plots even during the relatively dry 1964 growing season indicating the efficiency of its deep, rhizomatous root system. Mowing most stimulated the growth and spread of this species as indicated by increases in relative density, relative frequency, absolute composition, and yield. Early spring burning had no apparent affect on S. nutans, but late spring burning improved its relative composition. Sorghastrum nutans spread rather rapidly on the once plowed plot, taking advantage of the good growing conditions. All sampling categories showed progressive yearly increases. Plowing each year had not eliminated the species, although the data was variable from year-to-year.

Other Grasses

This group of species, although showing some variation among its members, decreased on the protected and the early spring burned plots and increased on the others; moderately in the mowed and late spring burned plots, considerably in the plowed plots. On the plowed plots, the annual Aristida oligantha was the dominant grass of the group. This species also had begun to appear on the burned plots and mowed plots. Panicum oligosanthes was stimulated slightly by late spring burning and mowing.

Legumes

Legumes were never present on any plots in appreciable quantities, although the data indicate that they were most stimulated as a result of plowing.

Forbs

An increase of forbs occurred on all plots including the control due mainly to the increase of *Ambrosia psilostachya*. This occurrence probably reflected the disturbance caused by plowing fire lanes between plots.

Plowing most stimulated the growth of forbs while mowing and early spring burning increased them to a lesser extent. Burning late effectively controlled their growth. Burning, in general, stimulated the growth of *Aster ericoides*. *Helianthus annuus*, the annual sunflower, appeared the year following disturbance, but seldom occurred two years afterwards.

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