EFFECT OF DISTURBANCE ON MICROCLIMATE AND VEGETATION IN TALL GRASS PRAIRIE SITES

By

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VEGETATION IN TALL GRASS PRAIRIE SITES

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J.A.S.

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CHAPTER I

INTRODUCTION

Several workers have reported the effects of cropping on microclimate and the effects of microclimatic factors on crop plants (Flory 1936, Fredricksen 1938, Noll 1939, Broadbent 1950, Champness 1950). In recent years a great interest has been directed toward the role of microclimates in the distribution of natural vegetation (Shanks 1956, Cooper 1961, Rice 1962, Ayyad and Dix 1964). Most of the work has been centered on forested areas, with data on native grassland rather scarce.

In this study the term microclimate is used in a broad sense to refer to the climate within a study site. The atmospheric factors expressing the general microclimate of the site include precipitation, humidity, and temperature. An attempt was made to correlate the microclimatic factors of evaporation, soil temperature, and soil moisture with the different treatments of the sites.

The purpose of this study is to present a comparison of plant composition and the above physical factors in three types of treatments: protected (control); plowed and disked; and mowed, raked and removed.

The effect of various treatments on species composition was determined by the point-centered quarter method of sampling. This method 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 (Dix, 1961).

It was hoped that this study would provide a record of variations in plant composition and certain physical factors between the three types of treatments.

CHAPTER II

SITE DESCRIPTION

The site for this study is located nine miles west and one mile north of Stillwater, in the vicinity of Lake Carl Blackwell, Payne County, Oklahoma. A study of history of the area revealed that it has been protected for twelve years. Throughout the years of protection the accumulation of old foliage has produced a thick mulch cover.

The climate of the region is temperate characterized by dry, hot summers and wet springs and falls. The mean precipitation, based on a seventy-year period (1893-1962), recorded by U.S.D.A. Outdoor Hydraulic Laboratory, Lake Carl Blackwell is 33.07 inches (Table I). The highest monthly precipitation during the seventy-year period occurred during the months of May and June.

Summer temperatures are normally high, often exceeding 100 F. The mean annual temperature is 60.8 F, with the lowest monthly average of 37.9 F occurring in January and the highest, 84.7 F, in July. Weather Bureau data over the past 30 years indicate the average date of the last killing frost is April 4, and the average date of the first killing frost is October 28; thus, there is an average growing season of 207 days.

The general topography is that of a gradual northwestward slope toward the lake with the study site sloping two to four degrees toward the west. The soil of the study is, according to Bruner's (1931)

TABLE I

A COMPARISON OF MEAN RAINFALL FOR 70-YR* PERIOD WITH 1964*

Month	70-Yr. Average Mean Rainfall (inches)	1964 Mean Rainfall (inches)
January	1.11	0.58
February	1.28	1.84
March	2.12	1.12
April	3.44	2.43
May	4.79	4.30
June	4.17	0.95
July	3.09	0.24
August	3.03	8.60
September	3.72	2.32
October	2.91	0.54
November	2.06	5.28
December	1.36	0.64
Avg. Total	33.07	28.74

*Data provided by the USDA Agricultural Research Service, Outdoor Hydraulic Laboratory near Lake Carl Blackwell, Payne County, Oklahoma.

classification, part of the Permian redbed plains. The soil of the region is classified as fine and derived from the clays and shale. The soils of the site consist primarily of Kirkland silt-loam with Renfrow silt-loam on the upper slope and intermittent areas of Kirkland slick-spots on the lower slope. Percentages of each soil type were obtained from the Soil Conservation Service and estimated to be approximately 70% Kirkland silt-loam, 25% Renfrow silt-loam, and 5% Kirkland slick-spots.*

The land adjacent to the lake is a mixture of postoak-blackjack forest and tall grass prairie. Although mapped as postoak-blackjack forest type by Duck and Fletcher (1945), the study area is part of the tall grass prairie (Figure 1). The dominant species in the area include perennial grasses and forbs. One hundred ten species were listed for the study area, with a basal cover of 9.3% (Mueller, 1964). The three most important families represented were Gramineae, Compositae, and Leguminosae.

Figure 1. Site Before Initiation of Study.

*Soil classification is that of James R. Culver, Soil Scientist, Soil Conservation Service, and Jon G. Bockus, 1964.

CHAPTER III

MATERIALS AND METHODS

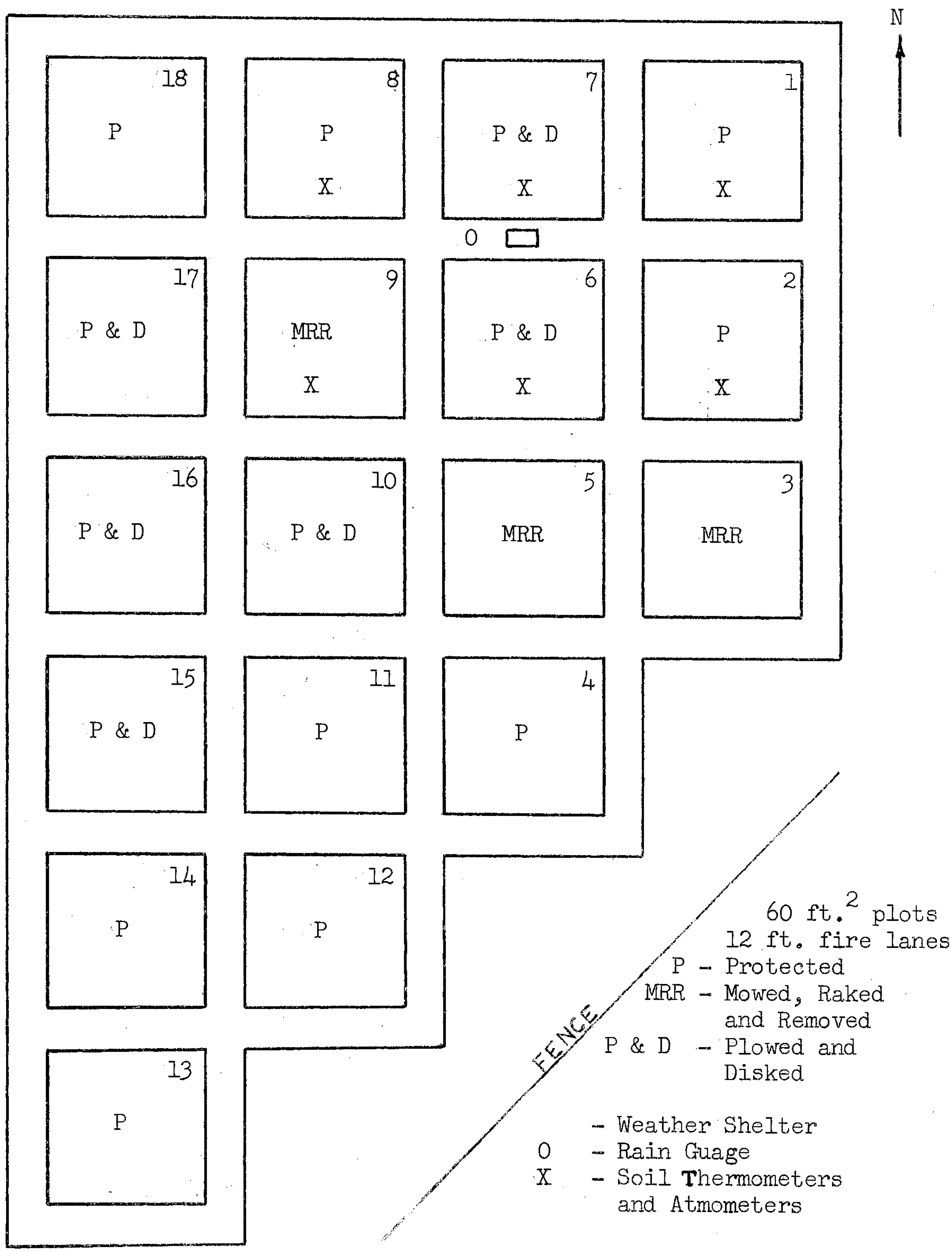
Design of Treatments

The statistical design for the treatments was based on Steel and Torrie (1960), using the completely randomized block design. The original design of the experiment consisted of six treatments and three replications, but due to unfavorable fall and spring weather conditions, burning was omitted. Therefore, the following treatment adjustments were made in the original design: (1) Protected treatments - nine replications, (2) Plowed and disked treatments - six replications, and (3) Mowed, raked and removed treatments - three replications. The plots measure 60 feet by 60 feet with 12 foot fire lanes between (Figure 2). The protected treatments were untreated whereas plowing and disking was completed on March 18, 1964. Mowing was done on March 23, while removal of mulch cover was completed in early June 1964.

Climatological Measurements

A standard weather bureau rain guage and weather bureau shelter with instruments were placed in the center of the six plots representing each treatment (Figure 2). The rain guage was situated 10 feet west of the weather shelter. The shelter contained a hygrothermograph for measuring air temperature and relative humidity, and a set of

Figure 2. Treatment Diagram.



maximum-minimum thermometers for measuring air temperature (Figure 3).

Limited availability of materials and instruments prevented the installation of atmometers and soil thermometers on all eighteen replications; therefore, they were placed near the center of six plots representing each treatment (Figure 2).

Six Livingston (Model-3C) white spherical, porcelain atmometers fitted with non-absrobing devices were put in the field on April 18. The atmometer bulbs were installed nine centimeters above the ground (Figure 4). Readings of total weekly evaporation in milliliters were taken by filling the reservoir bottle to a zero line. The field readings were multiplied by the supplied correction factor to give corrected values.

All measurements and readings were made from April 25 through November 2, 1964.

Soil Measurements

All Palmer dial soil thermometers (Model-35B) were synchronized before they were put in the field. Five thermometers were placed in the field on April 11, and the sixth one was installed on June 8, 1964 (Figure 4). The thermometer stems were placed horizontally six inches below the soil surface with a minimum of disturbance of the plant cover. Maximum and minimum temperature readings in the Fahrenheit scale were taken at weekly intervals throughout the six month period of study. Readings were made from April 25 through November 2, 1964.

Sampling for soil moisture was done at weekly intervals from June 15 to September 8, followed by biweekly sampling through October 23. Soil moisture data were determined at depths of from zero to six inches,

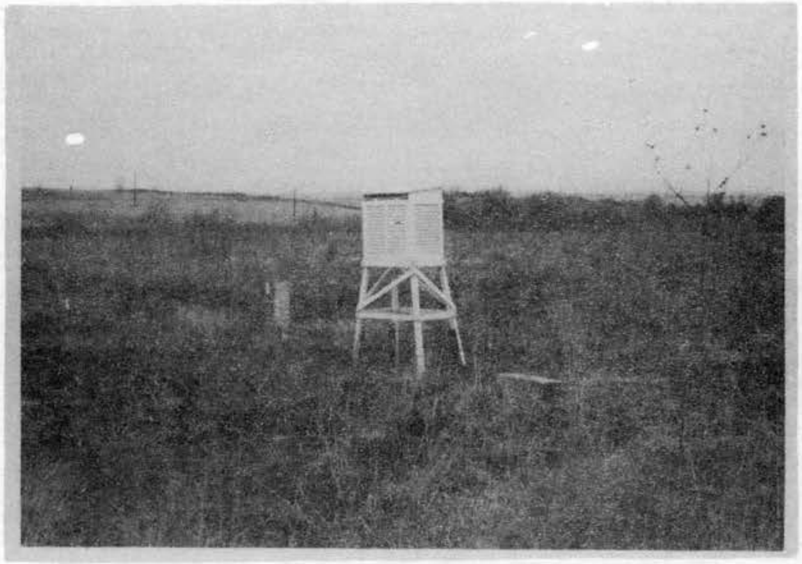


Figure 3. Weather Shelter for Instruments in Center of Six Plots. Rain Guage 10 Feet to the Left. Water Storage Shelter to the Right.

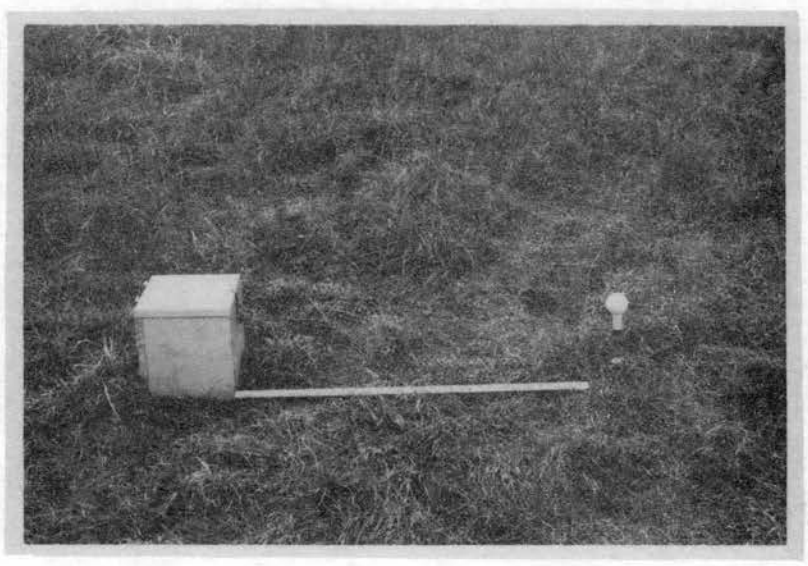


Figure 4. Atmometer Cup Nine Centimeters Above Ground, and Soil Thermometer Shelter 3 Feet to the Left.

six to twelve inches, one to two feet, and from two to three feet, on the six previously selected plots. Samples were taken at these depths using a soil tube or geotome and were transferred to metal cans having tight fitting lids. Wet weights were taken, then the samples were placed in a drying oven at 105 C° and later reweighed to obtain dry weights. Percentage soil moisture was then calculated (Weaver and Clements, 1938).

Vegetation Measurement

Point-Centered Quarter Method

The method was developed in 1956 by Curtis and Cottam for use in forest sampling and modified by Dix (1961) for use in grassland sampling. The sampling instrument consists of a small slender rod that is placed vertically into the ground. Four horizonal strips of thin metal are attached above the point of the rod dividing the area around the rod into four quarters. Each time the instrument is placed in the ground, the distance from the central point to the nearest species in each quarter is measured and recorded to the nearest centimeter. Thus, each sampling unit consists of four shoots and four measured distances. Measurements were taken at ground level where the shoot of the species emerges from the ground. When a shoot touched the rod or pin, a distance of zero was recorded.

During August 1963, this method was used for a vegetational analysis on the study area. Twenty quadrats, or twenty points, were taken in each of the eighteen replications (Figure 2). The point was placed in the soil at five intervals, each along four sampling lines running north and south with ten foot spacing. The distance between the four sampling lines was twelve feet running east to west. Sampling was done in a north-south direction. The relative density, total density, absolute density, frequency, and relative frequency of species encountered were calculated from these data.

In 1964, sampling was started on August 11 and completed during the first week of September. The same sampling method and calculations used in the previous year were applied to treatments.

CHAPTER IV

RESULTS AND DISCUSSION

Climatological Factors

Precipitation

Precipitation in the area was from 0.9 to 3.4 inches below normal in June, July, September, and October. Total precipitation during August was 5.6 inches above normal, however. The total precipitation in May was slightly below the average normal. The normal precipitation is based on a seventy-year period, recorded by U.S.D.A. Outdoor Hydraulic Laboratory near Lake Carl Blackwell, Payne County, Oklahoma.

Observations showed that from May to October there were two periods, each of two or more weeks duration, in which no moisture fell and only seven times did rainfall exceed one-half inch. Total precipitation for the six month study was 18.2 inches. A comparison of the precipitation each week in the study area with that at the U.S.D.A. Outdoor Hydraulic Laboratory, Lake Carl Blackwell, about two miles to the northeast, illustrates the variation which often occurs over short distances (Table II). There were large differences in the amounts of precipitation in the two areas during some weeks, and the total precipitation during the study was almost 1 inch greater at the study site.

TABLE II

COMPARISON OF WEEKLY PRECIPITATION AT THE STUDY AREA AND AT THE U.S.D.A. OUTDOOR HYDRAULIC LABORATORY AT LAKE CARL BLACKWELL DURING THE 1964 STUDY PERIOD

WEEK ENDING	PRECIPITATION IN INCHES	
	STUDY SITE	HYDRAULIC LABORATORY
April 25.	0.02	0.07
May 2	0.90	0.96
May 9	0.25	0.23
May 16	2.42	2.35
May 23	0.00	0.00
May 30	1.04	0.97
June 8	0.34	0.20
June 15	0.34	0.29
June 22	0.00	0.00
June 29	0.40	0.46
July 6	0.03	0.08
July 13	0.35	0.15
July 20	0.00	0.00
July 27	0.00	0.00
Aug. 3	0.00	0.01
Aug. 10	0.47	0.58
Aug. 17	2.56	3.04
Aug. 24	1.17	1.24
Aug. 31	4.10	3.74
Sept. 7	0.00	0.00
Sept. 14	2.02	1.61
Sept. 21	0.47	0.39
Sept. 28	0.35	0.32
Oct. 5	0.00	0.00
Oct. 19	0.50	0.10
Oct. 26	0.41	0.48
Nov. 2	0.00	0.00
Total	18.15	17.17

Air Temperature

Air temperatures were measured by both a hygrothermograph and maximum-minimum thermometers. Due to the similarly in data from the two devices, only data from the hygrothermograph will be discussed. Average weekly maximum and minimum temperatures were determined from the hygrothermograph and are shown in Figure 5. Absolute weekly maximum and minimum temperatures were recorded by the thermometers and their averages can be seen in Appendix A. These temperatures readily show the range of temperature fluctuation. They are important since plant distribution may be controlled by temperature extremes.

Maximum and minimum air temperatures show an over all increase throughout May, June, and July due to the lack of precipitation, especially in June and July. A peak in air temperature was reached in the month of July. The greatest differences between maximum and minimum temperatures occurred during this period. Maximum air temperatures ranged between 75 F and 90 F the majority of the study period. Maximum temperatures averaged over 100 F for two different weekly periods during the study, and the highest temperature recorded was 108 F for the week ending August 10. A major drop in temperature was recorded the week ending August 17 when there was 2.56 inches of rainfall (Figure 5). This was followed by a brief rise in temperature in early September when precipitation was sparse. The last of September and October were characterized by increased precipitation and lower temperatures.

Minimum temperatures ranged between 55 F and 75 F during the majority of the study period. A peak in minimum temperature of 75 F was recorded the week ending August 3, while a low of 46 F was recorded

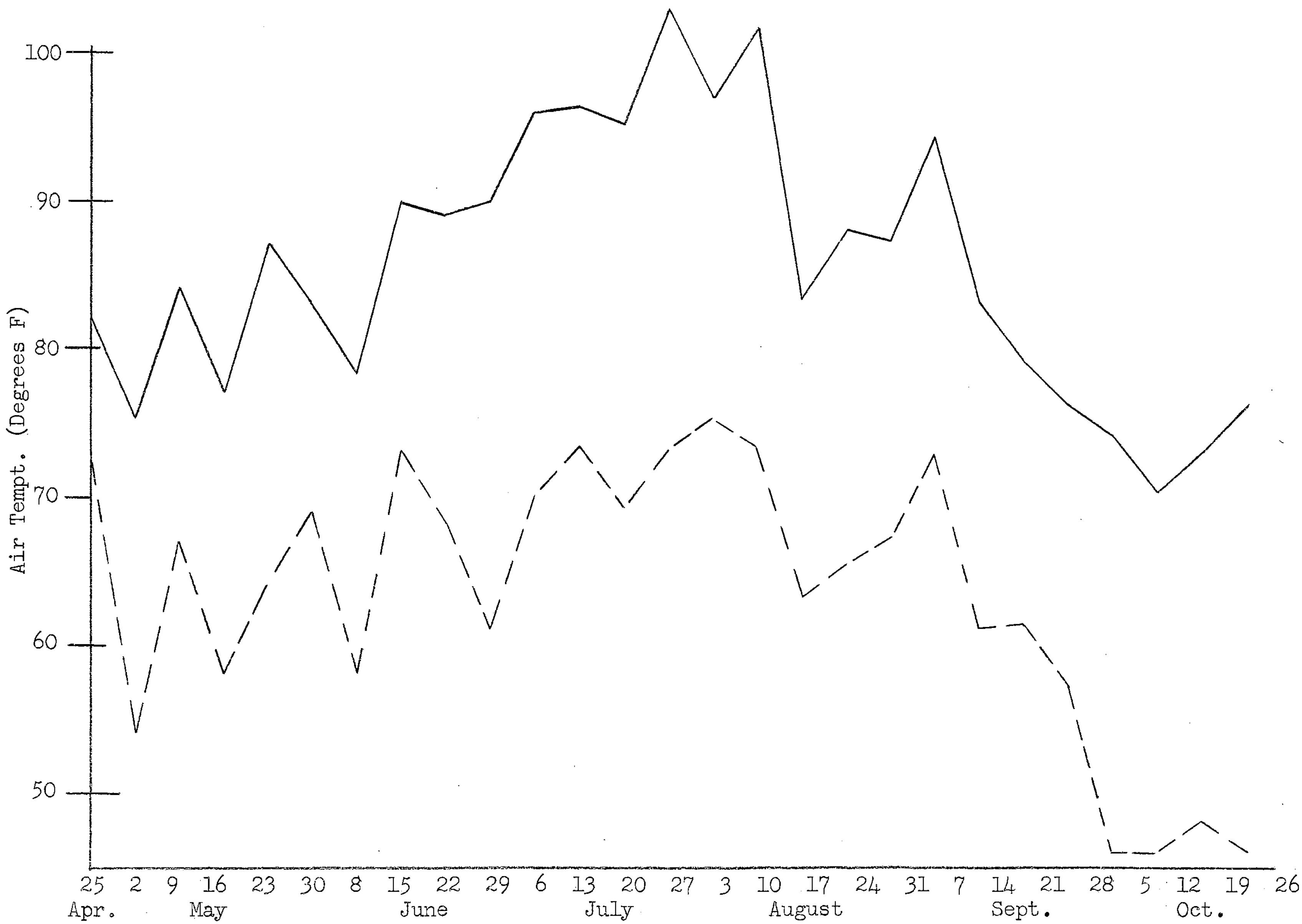


Figure 5. Average Maximum and Minimum Weekly Air Temperature from the Hygrothermograph.

twice in early October. The average maximum, average minimum, and average temperatures can be seen in Appendix A.

Relative Humidity

Following the practice of the U.S. Weather Bureau, relative humidity values were based on averages of measurements recorded continuously by a hygrothermograph. The humidity values were found to vary directly with precipitation during the study period. A high in humidity was recorded the first month of the study. This is understandable because rainfall amounted to 4.6 inches during May. Relative humidity declined slowly during months of June and July when temperatures increased and rainfall decreased. During this hot dry period the low in relative humidity was recorded in July (Figure 6). Mid-August brought increased precipitation. This cool rainy weather increased humidity values throughout the remainder of August and September. The last month of the study showed a pronounced drop in humidity very similar to the month of July.

During the study, maximum relative humidity values averaged 100% over six different weekly periods, and never fell below 80% throughout the study period. Minimum humidity values stayed between 30 and 50 per cent the majority of the study period. A peak in minimum humidity of 61% was recorded the week ending September 21, while a low of 24% was recorded the week ending October 26. The average humidity values for the six month study period can be seen in Appendix B.

Evaporation

Protected Sites

In general, evaporation varied inversely with precipitation during the six-month study period. Evaporation fluctuations in protected

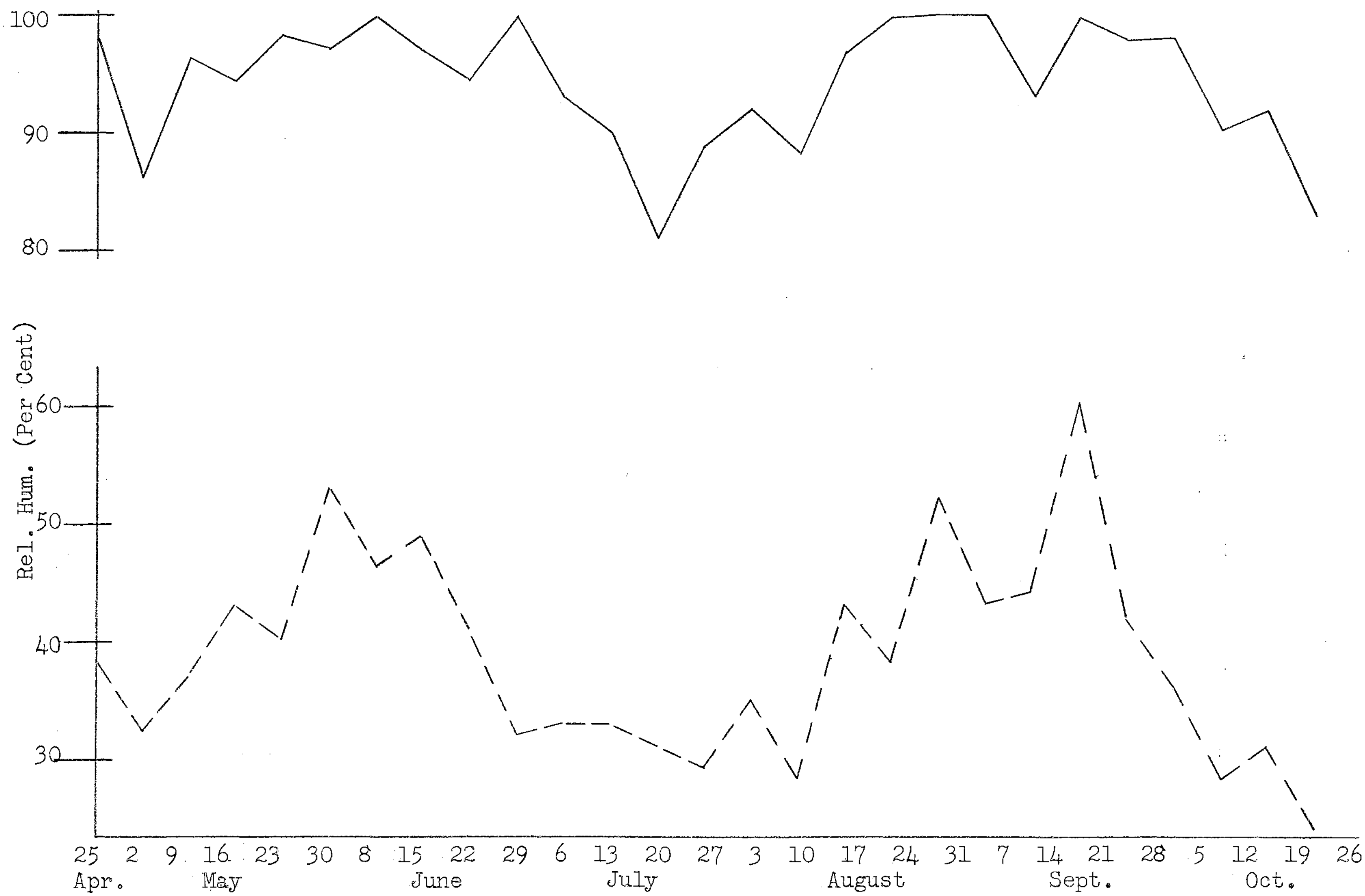


Figure 6. Average Maximum and Minimum Weekly Relative Humidities from the Hygrothermograph.

treatments were not as irregular as those of disturbed treatments (Figure 7). The tall dense vegetation in the protected areas hampered air movements, radiation, etc. thus, reducing evaporation. This was substantiated in an early study by Flory (1936). The general pattern of water loss in late spring and early summer was considerably below those of the disturbed treatments, but with the advance of the growing season and increased vegetation, variations between all treatments became less pronounced.

The first month of the study was characterized by pronounced precipitation. Evaporation averaged only 274.6 ml per week on protected treatments. The following months of June and July showed several weekly periods of high evaporation because of prevailing periods of hot weather. The most marked period of evaporation was during mid-July and early August when little rain fell and there were a high percentage of cloudless, sunny days. Water loss during this peak ranged from 469.3 to 510.3 ml per week (Figure 7). From this mid-summer peak, evaporation dropped drastically to 147.3 ml the week ending August 17 probably due to increased precipitation and cooler weather. Continued cool rainy weather slowed evaporation throughout the months of September and October. Evaporation during September and October averaged 184.5 and 180.5 ml per week in protected areas respectively. Weekly evaporation ranged from a high of 507 ml the week ending July 20 to a low of 102 ml the week ending September 21. The weekly evaporation for the six month study period can be seen in Appendix C.

Observations between protected treatments showed that the vegetation and mulch cover in treatment number eight was considerably higher and more dense than treatments one and two at the beginning of the

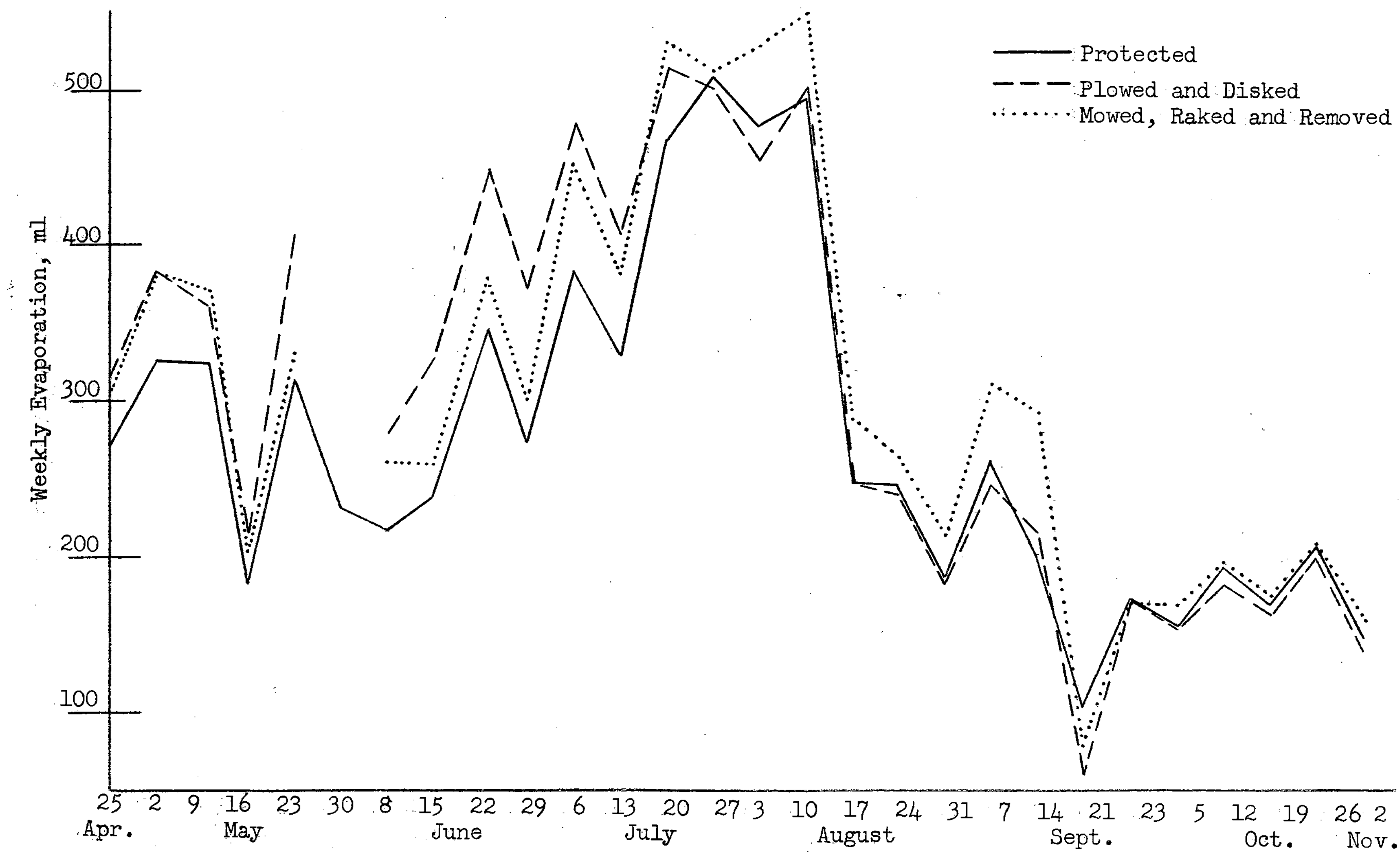


Figure 7. A Comparison of Evaporation from White Spherical Livingston Atmometer Cups Between Treatments. (Missing data on May 30th)

study (Figure 2). Evaporation on this site was consistently lower than the other two replications. Sites one and two were adjacent to each other, and more or less similar in vegetation and water loss.

Plowed and Disked Treatments

The rate of evaporation in the plowed and disked treatments was relatively high from April 25 to July 20 (Figure 7). This pronounced water loss was apparently due to the exposure of the moist bare soil to wind movements, radiation and other physical factors. Evaporation during the rainy month of May averaged only 323.4 ml per week in the plowed and disked treatments. The advent of June and July brought weekly periods of hot dry weather and high evaporation. A peak in evaporation was noted from July 20 to August 10, when water loss ranged from 455 to 514 ml per week. From this seasonal high, evaporation dropped 252.5 ml the week ending August 17 because of increased cool rainy weather. As observations continued, a prominent soil crust and increased vegetative growth throughout August, September, and October caused a reduction in evaporation. Continued cool weather and scattered precipitation were also major factors in reducing evaporation. Water loss during August, September, and October averaged 325, 167, and 173 ml per week respectively. Weekly evaporation ranged from a high of 514 ml the week ending July 20 to a low of 60.5 ml the week ending September 21.

As a result of plowing and disking, Helianthus annuus* became abundant and the shade produced by its vegetative growth slowed evaporation in plowed and disked treatments six and seven (Figure 2). Furthermore,

*Scientific nomenclature will follow that of U. T. Waterfall (1962).

the variation in abundance of this species in the two replications resulted in different water loss values in late summer and early fall (Noll, 1939).

Mowed, Raked and Removed Treatment

The general trend of evaporation in the mowed, raked and removed treatment was high throughout the six month study period due to the removal of vegetative growth and mulch cover (Figure 7). Others agree that mulch removal definitely increases water loss throughout the growing season (Russell 1939, Weaver and Rowland 1952, Geiger 1957).

In May, precipitation amounted to 4.6 inches, thereby holding evaporation to 305.4 ml per week on the mowed, raked and removed treatment. The succeeding months of June and July showed weekly periods of increased evaporation. Both months were related to periods of hot dry sunny weather. A seasonal high in evaporation occurred between July 20 and August 10. Evaporation ranged from 512 to 530 ml per week during this high (Figure 7). Increased precipitation and humidity during the middle of August reduced evaporation to 260 ml during the week ending August 17. Continued cool weather and increased vegetative growth on this type treatment held evaporation down throughout the remaining months of September and October, except for a brief rise in early September. Water loss during September and October averaged 213 ml and 186 ml per week respectively. Weekly evaporation on the mowed, raked and removed treatment ranged from a high of 550 ml the week ending August 10 to a low of 78 ml the week ending September 21 (Figure 7).

Comparison of Evaporation

Plowed and Disked vs. Protected

The rate of evaporation in the plowed and disked treatments was considerably higher than those of protected areas from April 25 to July 20. Water loss during this period in plowed and disked treatments ranged from 9 to 102.7 ml per week higher than the protected sites (Figure 7). During the peak in the months of June and July, plowed and disked treatments exceeded protected by 88.8 and 52.7 ml per week respectively. From this peak, evaporation sharply during the week ending August 17 because of increased cool rainy weather. A difference of only 5.2 ml was noted between the two treatments during this period of drastically decreased evaporation. A prominent soil crust and increased vegetative cover on plowed and disked treatments presumably reduced evaporation below that of protected areas. Evaporation from plowed and disked treatments exceeded protected only twice during the remainder of the study period; once during the week ending August 10 by 5.2 ml and again the week ending September 14 by 14 ml. Evaporation from protected plots ranged from 0.1 to 42.2 ml higher per week the remainder of the study period. Thus, protected treatments were apparently more effective in retarding loss of water because of more dense vegetation and increased mulch cover.

Mowed, Raked and Removed vs. Protected

The general pattern of evaporation in the mowed, raked and removed treatment was somewhat greater than those of protected treatments throughout the six month study period (Figure 7). Evaporation from the mowed, raked and removed treatment exceeded protected treatments from 1.3 to 90 ml per week throughout the study except for a two week interval. During this two week period, from September 21 to October 5 water loss ranged from 2.7 to 27.2 ml per week lowered than the protected treatments. During the peak of evaporation in the months of June and July the mowed, raked and removed treatment exceeded protected treatments by 33.2 and 47.7 ml per week respectively. From this seasonal high, evaporation dropped suddenly on both treatments the week ending August 17 because of increased precipitation. Continued cool rainy weather plus increased vegetative cover on the mowed, raked and removed treatment gradually reduced evaporation from mid-August to November 2. A brief rise in evaporation occured in early September on the mowed, raked treatment. Water loss ranged from 44.3 to 91 ml per week higher than those of protected treatments. Differences between the two treatments were slight during the remainder of the study. In the months of September and October evaporation on the mowed, raked and removed treatment exceeded protected treatments 28.5 and 5.5 ml per week respectively. Thus, protected treatments were apparently more effective in retarding loss of water because of the height of vegetation and heavier mulch cover.

Soil Factors

Soil Temperature

Protected Sites

Soil temperature fluctuations at the six inch depth closely followed the weekly fluctuations in air temperatures on all treatments.

The general trend of soil temperatures in protected treatments was lower than those of disturbed treatments throughout the six month study period (Figures 8 and 9). The effect of vegetation height and organic debris covering the plots were the determining factors in retarding soil radiation and reducing the loss of heat. Thus soil temperatures in protected treatments were lower and not subject to extreme fluctuations as in the more open disturbed treatments (Geiger, 1957).

The first month of the study was characterized by pronounced precipitation. Maximum and minimum soil temperatures averaged only 76.2 F and 63.5 F respectively. The following months of June and July showed weekly periods of little rainfall and pronounced warm sunny days. Soil temperatures reached their seasonal peak during July. During this time, maximum and minimum temperatures averaged 89.9 F and 76.9 F respectively. This high was followed by a pronounced drop of 13 F in maximum temperature over a two week period due to cool rainy weather. Maximum temperature is stressed because it showed greater and more consistent differences during the study. As precipitation continued throughout September another drop of 11 F was recorded from September 14 to 21. The lowest values in soil temperatures were recorded in the month of October with maximum and minimum averages of 69.3 F and 59.2 F respectively.

The maximum soil temperature six inches below the soil surface was 95.5 F during the week ending August 10. The minimum soil temperature recorded between April 25 and November 2 was 56.6 F the week ending October 26. The weekly maximum and minimum soil temperatures can be seen in Appendix D.

Observations between protected treatments showed that the vegetation and mulch cover on treatment number eight was considerably taller

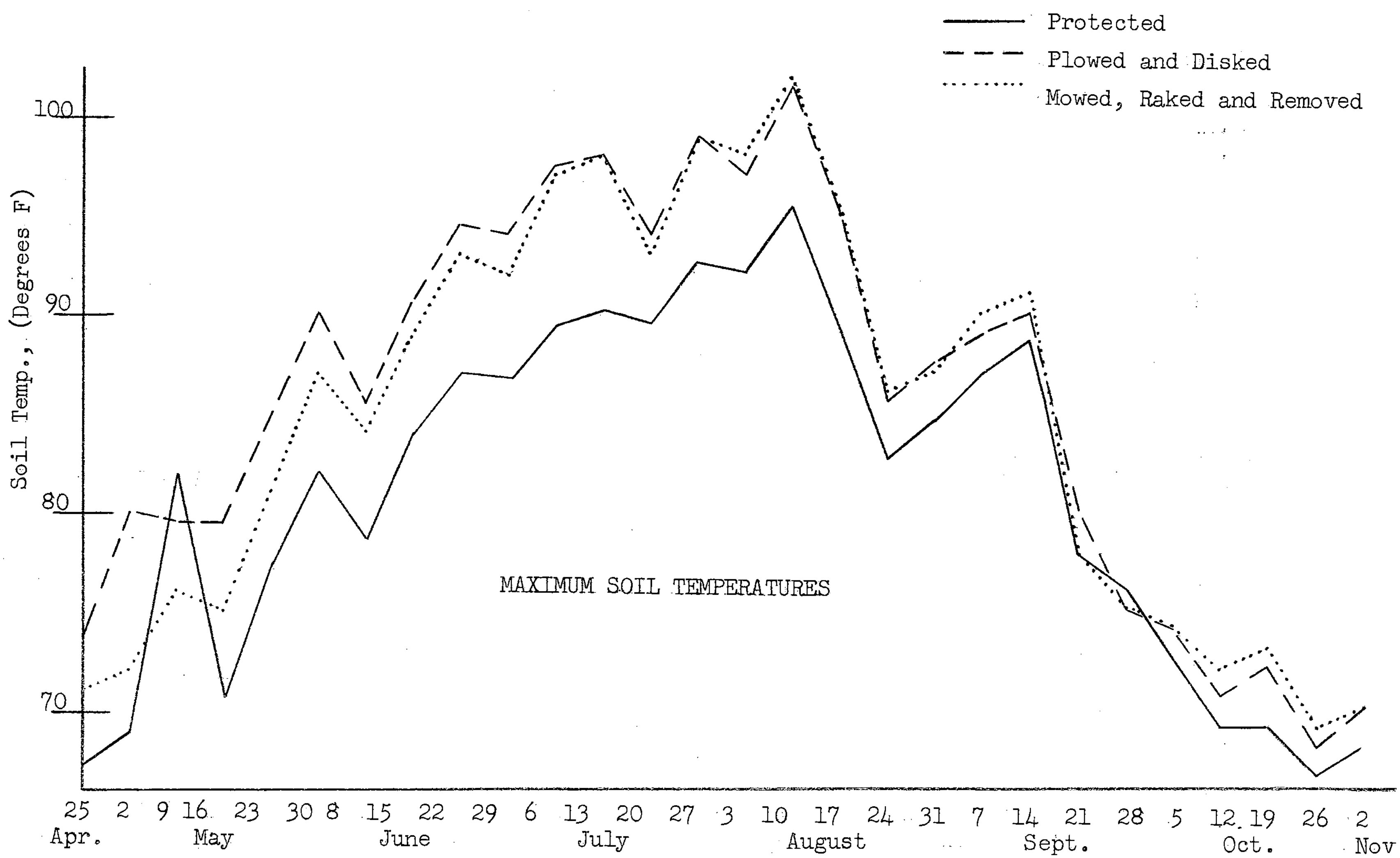


Figure 8. A Comparison of Maximum Soil Temperatures at the 6-inch Depth Between Treatments.

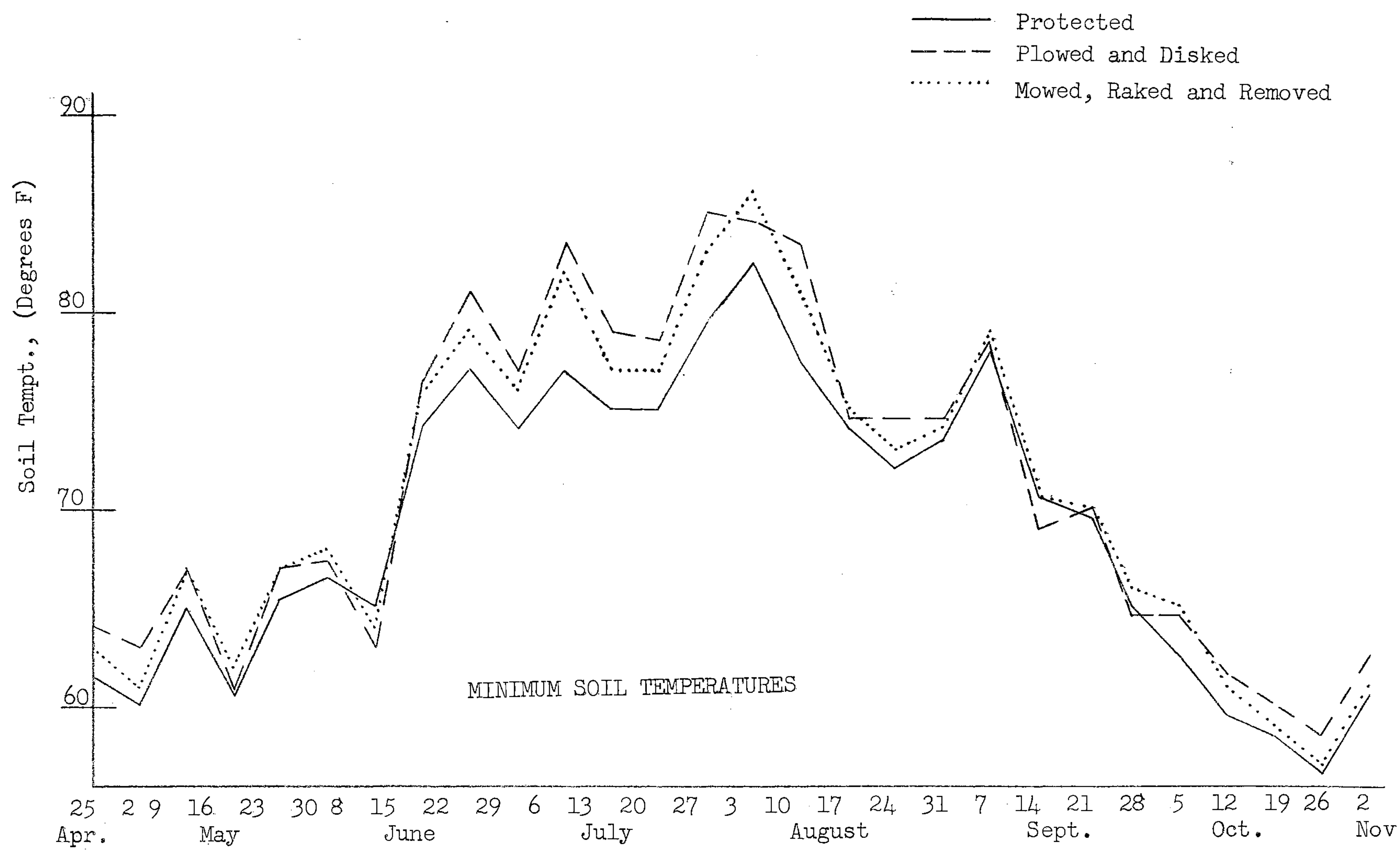


Figure 9. A Comparison of Minimum Soil Temperatures at the 6-inch Depth between Treatments.

and more dense than treatments one and two at the beginning of the study (Figure 2). Soil temperature response to this vegetation and cover was somewhat lower than the other two protected plots. Replications one and two were adjacent to each other, and more or less similar in vegetation development and soil temperatures.

Plowed and Disked Treatments

Following plowing and disking the affect of direct radiation on the exposed dark soil increased soil temperatures throughout the study period on the plowed and disked treatments. This was supported by a study by Ehrenreich and Aikman (1963).

In a study by Bouyoucos (1916), who worked with prairie and bare soil in Michigan, it was reported that the maximum difference in soil temperature was reached in June and July at a depth of seven inches. He also reported prairie temperatures were about 6 F cooler than bare soil. By September, however, the difference disappeared, and in October the bare soil was colder and the prairie warmer.

In the rainy month of May, maximum and minimum soil temperatures averaged only 82.8 F and 65.1 F respectively. The following mid-summer months were characterized by hot dry weather. A peak in temperature was reached in the month of July. During this peak, maximum and minimum temperatures averaged 97.1 F and 81.5 F respectively. This seasonal high was followed by two major drops in temperature in mid-August and September because of increased cool rainy weather. The first drop of 16 F was recorded between August 10 to 24, while a more pronounced drop of 12 F occurred over a one week period (Figure 8). Both of the above figures were maximum temperatures.

The gradual development of a prominent soil crust throughout mid-summer plus increased vegetative cover on the plowed and disked treatments apparently reduced soil temperatures during late summer and early fall. Continued precipitation and cool weather were also contributing factors in lowering the soil temperature. A low in temperatures at the six inch depth was recorded in October. During this monthly low maximum and minimum temperatures averaged 71.1 F and 61.1 F respectively.

Soil temperatures on plowed and disked treatments ranged from a maximum of 101.5 F the week ending August 10 to a minimum of 58.5 F the week ending October 26 (Figures 8 and 9).

Mowed, Raked and Removed Treatment

Soil temperatures in the mowed, raked and removed treatment were relatively high throughout the six month study period due to the removal of vegetative growth and mulch cover (Figures 8 and 9). Similar results were obtained by Weaver and Rowland (1952) on a prairie undisturbed for 15 years and where mulch was allowed to accumulate, the soil temperatures were 22-28 F lower than on a mowed prairie. It was also noted by Hopkins (1955) that the temperature on a grazed short grass prairie was about 9 F higher than an ungrazed short grass prairie.

In May, the first full month of study, precipitation amounted to 4.6 inches, and maximum and minimum soil temperatures averaged only 78.2 F and 65 F respectively. The advent of June and July brought weekly periods of hot dry weather. A peak in soil temperature was reached in July, with average maximum and minimum temperatures of 96.7 F and 79.7 F respectively. Following this monthly peak, there was a major drop of 16 F in maximum temperature in mid-August because of increased precipitation. As cool rainy weather continued throughout September another drop of 13 F was noted from September 14 to 21. Increased vegetative cover and cool weather held soil temperatures down for the remainder of the study. In October temperatures were at a low. During this low, maximum and minimum temperatures averaged 72.0 F and 60.5 F respectively.

Soil temperatures on the mowed, raked and removed treatment ranged from a maximum of 102 F the week ending August 10 to a minimum of 57 F the week ending October 26.

Comparison of Soil Temperature

Plowed and Disked vs. Protected

Soil temperatures in plowed and disked treatments were considerably higher than those of protected plots most of the study period (Figures 8 and 9). The maximum temperature attained each week in plowed and disked treatments ranged from 2.5 F below to 11 F above the protected sites with a mean 2 F higher over the six month study period. The greatest differences occurred during hot dry periods. For example, during the month of June the average weekly maximum and minimum temperatures on plowed and disked treatments were 91.1 F and 74.4 F respectively. The corresponding temperatures on the protected plots were only 84 F and 72.5 F. Minimum weekly temperatures in plowed and disked treatments ranged from 2 F below to 6 F above those of protected plots. The mean was 0.7 F above. The smallest differences occurred during the cool rainy month of September. During September maximum and minimum temperatures on plowed and disked treatments were 83.1 F and 70.5 F respectively.

The corresponding temperatures on the protected plots were a close 82.3 F and 70.7 F. Average weekly variations between maximum and minimum temperatures were 11.4 F on protected plots and 13.8 F on plowed and disked treatments, showing that the protected areas have a more uniform environment.

Mowed, Raked and Removed vs. Protected

The general trend of soil temperatures in the mowed, raked and removed treatment was relatively higher than the protected areas throughout most of the study period (Figures 8 and 9). The maximum temperature attained each week in the mowed, raked and removed treatment ranged from 6 F below to 7.5 F above those of protected plots with a mean 1 F higher over the six month study period. The greatest differences occurred during the hot dry months of June and July. For instance, during the month of June the average weekly maximum and minimum temperatures on the mowed, raked and removed treatment were 89.5 F and 73.7 F respectively. The corresponding temperatures on the protected sites were only 84 F and 72.5 F. Minimum weekly temperatures in the mowed, raked and removed treatment ranged from 0.5 F below to 5 F above those of the protected areas. The mean was 0.1 F above. The smallest differences occurred during the cool rainy periods. For example, during the month of September the average weekly maximum and minimum temperatures on the mowed, raked and removed treatment exceeded protected an average of 1 F and 0.3 F per week respectively. Average weekly variations between maximum and minimum temperatures were 1.9 F higher on the mowed, raked and removed treatment compared to those of protected areas during the six month study. Thus, the protected plots had lower temperatures with less fluctuations and a more stable environment.

Correlation Between Evaporation and Soil Temperature

The rate of evaporation integrates in a general way the factors of humidity, wind movement, temperature, transpiration, and other physical factors. Among the factors that directly affect soil temperature are color, texture, structure, water content, amount of humus, and slope exposure, as well as the presence or absence of vegetative cover. Of all these factors, water content is probably the most important because water has a specific heat about five times greater than that of the solid constituents of the soil. This explains why wet soils are colder in spring than drier ones and why a heavy rain in summer lowers the temperature of the soil (Weaver and Clements 1938).

Correlation coefficients between evaporation and soil temperature in protected, plowed and disked, and mowed, raked and removed treatments are shown in Table III.

Spring

In this study the term spring is used in a broad sense to refer to the nine week period from April 25 to June 22. Correlation coefficients between evaporation and soil temperatures during this period were not significant on any of the three treatments. This is possibly explained in the above paragraph, in that during the early weeks of the study due to large amounts of moisture in the soil the heat capacity of the soil becomes so great that variations in temperature may not be significant.

TABLE III

COMPARISON OF CORRELATION COEFFICIENTS BETWEEN WEEKLY EVAPORATION (ml.) AND SOIL TEMPERATURES (F). THE SOIL TEMPERATURE FIGURES ARE BASED ON ABSOLUTE WEEKLY RECORDS.

EVAPORATION AND SOIL TEMPERATURES	PROTECTED (CONTROL) 3 Reps	PLOWED AND DISKED 2 Reps	MOWED, RAKED AND REMOVED 1 Rep
MAXIMUM			
Spring	0.122	0.269	0.096 -
Summer	0.676*	0.778*	0.767**
Fall	0.306	0.325	0.675*
AVERAGE			
Spring	0.153	0.423	0.019
Summer	0.762**	0.829**	0.842**
Fall	0.288	0.285	0.583
MINIMUM			
Spring	0.225	0.557	0.183
Summer	0.770**	0.811**	0.817**
Fall	0.215	0.193	0.406

*Significant at 0.05 level.
**Significant at 0.01 level.

Summer

The term summer represents the ten week period from July 6 to August 31. Correlation coefficients between evaporation and soil temperatures were highly significant on all treatments except at the maximum soil temperature range on the protected plots which was significant at the .05 level. This over all significance during the summer period presumably was attributed to the high temperatures and consequent increased evaporation.

Fall

The term fall represents the nine week period between September 7 and November 2. In this period the correlation between evaporation and maximum soil temperature was significant only in the mowed, raked and removed treatment. This lone value does not necessarily emphsize the general trend of this treatment because the value represents only one replication.

Soil Moisture

Protected Sites

In general, variations in soil moisture content compared favorably with the amount and duration of periods of precipitation, and varied inversely with evaporation. Fluctuations in moisture content on protected areas were not as irregular as on disturbed sites. The dense cover of mulch and the height of the vegetation were apparently the major factors in holding soil moisture fluctuations down and retarding evaporation. Similar results were obtained by (Weaver and

Clements 1938, Weaver and Rowland 1952, and Hopkins 1955) in that a heavy mulch helps intercept more moisture and retard evaporation.

The month of May was characterized by pronounced precipitation and the per cent soil moisture was presumably high. Sampling for soil moisture was not started however, until mid-June. The advent of June and July brought prevailing periods of hot dry weather and high evaporation. The soil moisture in the upper one foot of soil declined from a maximum of 13.4% in June, to a minimum of 8.3% in July (Figure 10). Then, it steadily increased during the month of September, because of increased precipitation. A brief drop was noted the remainder of study period at the one foot level.

The pattern for moisture content was consistently higher at the lower depths throughout the sampling period. Soil moisture was generally greatest in the third foot of soil. Percentages of soil moisture at the lower depths ranged from a high of 16.9% in June to a low of 12.8% in August, both the above figures were at the 12-24 inch depth. At these lower depths recordings of soil moisture content did not show as great a fluctuation as occurred at the surface, but rather a gradual change in moisture content. Soil moisture values at different depths can be seen in Appendix E.

Plowed and Disked Treatments

The soil moisture content in the upper layers of soil in the plowed and disked treatments was rather high during the first month of the study apparently because of the exposure of the moist bare soil following the plowing operation, thus providing excess moisture in the upper layers of soil (Figure 10). Observations by Rice and Penfound, (1954)

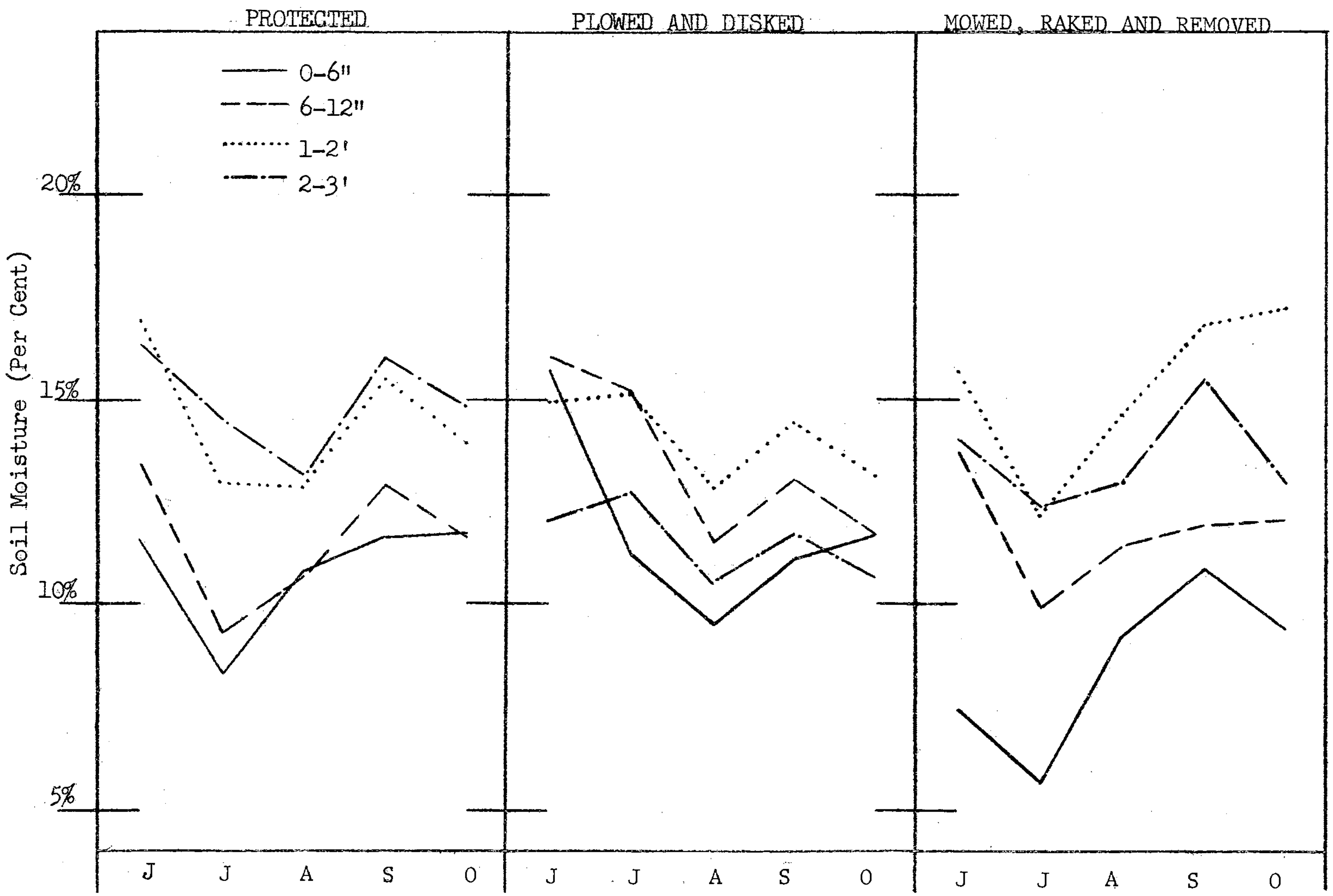


Figure 10. A Comparison of Soil Moisture at Different Depths Between Treatments.

showed that plowed plots contained more moisture in the spring than protected plots, but during mid-summer the reverse was observed.

The weather during June and July was hot and dry, and there was a steady decline in per cent moisture at the 0-6 inch depth. The soil moisture in the upper six inches of soil declined from a maximum of 15.7% in June, to a minimum of 9.5% in August. It was noted that soil moisture at all depths attained a low in the month of August. Then it increased steadily during the month of September. A brief drop at all depths was observed in October. The moisture content at the 6-12 inch depth fluctuated between 10 and 13 per cent throughout the study period.

Soil moisture was generally greatest in the second foot of soil. The moisture content in the second foot was generally between 13 and 15 per cent, while in the third foot it tended to stay between 10 and 12 per cent.

Mowed, Raked and Removed Treatment

Soil moisture in the upper six inches of soil on the mowed, raked and removed treatments was the lowest as compared to the other levels throughout the five months of sampling (Figure 10). This pronounced difference was probably due to the removal of vegetative growth and mulch cover. Water content at this level ranged below 11% throughout the study period. Results by Steiger (1930) showed that mowing promoted water loss from the upper layers of soil. Kelting (1954) noted that a grazed prairie had lower percentages of soil moisture in the upper layers of soil than did an undisturbed area.

Percentage of soil moisture dropped sharply at all levels from June to July apparently because of increased hot dry weather. A low in moisture content was recorded at all levels in the month of July. Then it steadily increased and peaked at all levels during the month of September. Soil moisture at the 6-12 inch depth tended to fluctuate between 10 and 14 per cent.

Soil moisture was relatively high at the lower depths throughout the sampling period. Moisture content was generally greatest in the second foot of soil ranging from 0.9 to 8.3 per cent higher than the upper one foot of soil. Soil moisture at the three foot depth was generally between 12 and 16 per cent.

Comparison of Soil Moisture

Plowed and Disked vs. Protected

The pattern for soil moisture in the plowed and disked treatments as compared to that of the protected plots was generally higher in the upper foot of soil and lower at the two and three foot levels (Figure 10). Soil moisture from mid-June through July in the upper foot of soil ranged from 0.2 to 7.3 per cent higher than the protected sites. Near mid-summer high temperatures prevailed and a lack of rainfall lowered soil moisture content on both treatments. Following this hot dry weather, moisture content at the 0-6 inch level in the plowed and disked treatments dropped below that of the protected sites. Soil moisture at the 6-12 inch depth stayed consistently higher on plowed and disked treatments than on protected plots.

Moisture content at the lower depths was generally greatest in the protected areas throughout the five months of sampling. Soil moisture in the protected areas at the lower depths ranged from 2.7% below to 5.4% above the plowed and disked treatments. The mean was 1.8% above. Thus, protected areas were apparently more effective in retarding loss of moisture during dry weather and increasing infiltration during rainy weather.

Mowed, Raked and Removed vs. Protected

Soil moisture in the mowed, raked and removed treatment was significantly below the protected sites at the 0-6 inch depth. At this level moisture content on the protected areas ranged from 0.6 to 3.2 per cent higher through the study period (Figure 10). Soil moisture at the 6-12 inch depth on the mowed, raked and removed treatment ranged from 2.4% below to 6.5% above the protected areas throughout the sampling period. The greatest differences in moisture content between the treatments were in the hot dry periods.

Moisture content at the two foot depth in the mowed, raked and removed treatment was relatively greater than at the same depth on protected sites. Percentages of moisture at the three foot depth were generally higher in the protected plots, ranging from 2.8% below to 5% above with a mean of 1.4% above the mowed, raked and removed treatment. Thus, mowing increased water loss in the upper six inches of soil. Also, new vegetative growth after mowing apparently decreased the soil moisture content at the three foot level.

Vegetational Analyses

Protected Sites

Eleven grass species were recorded in sampling the protected treatments (Table IV). The most prominent species on the treatments was *Andropogon*

TABLE IV

SPECIES DENSITIES, RELATIVE COMPOSITION, AND FREQUENCY VALUES IN PROTECTED TREATMENTS. (Based on 180 quadrats)

Species	Number Quadrats Species Occurred	Number Species Occurred	Relative Composition	Frequency	Relative Frequency	Sum of Distances (cm)	Absolute Density (Shoots per sq. meter)
Andropogon scoparius	156	411	57.50	86.66	41.48	2878	109.08
Andropogon Gerardi	37	54	7.50	20.56	9.84	433	14.22
Aster ericoides	33	53	7.36	18.33	8.78	332	13.95
Ambrosia psilostachya	34	44	6.11	18.88	9.04	386	11.58
Panicum oligosanthes	23	33	4.17	12.78	6.12	215	7.91
Sorghastrum nutans	13	21	2.92	7.22	3.46	122	5.53
Andropogon saccharoides	12	20	2.78	6.66	3.19	151	5.26
Carex spp.	17	19	2.64	9.44	4.52	186	5.01
Sporobolus asper	11	15	2.08	6.11	2.92	127	3.95
Achillea lanulosa	10	12	1.67	5.56	2.66	79	3.16
Panicum virgatum	7	9	1.25	3.89	1.86	94	2.37
Helianthus annuus	4	8	1.11	2.22	1.06	34	2.11
Bromus japonicus	4	5	0.69	2.22	1.06	41	1.31
Erigeron strigosus	3	3	0.42	1.67	0.80	18	0.80
Solanum eleagnifolium	3	3	0.42	1.67	0.80	29	0.80
Acalypha gracilens	2	2	0.28	1.11	0.53	38	0.53
Euphorbia marginata	1	2	0.28	0.56	0.27	28	0.53
Aristida oligantha	1	1	0.14	0.56	0.27	12	0.27
Diodia teres	1	1	0.14	0.56	0.27	8	0.27
Eragrostis spectabilis	1	1	0.14	0.56	0.27	5	0.27
Gnaphalium obtusifolium	1	1	0.14	0.56	0.27	2	0.27
Liatris punctata	1	1	0.14	0.56	0.27	5	0.27
Strophostyles leiosperma	1	1	0.14	0.56	0.27	1	0.27
Total	376	720	100.02	208.90	100.01	5,224	189.72

Mean distance $= \frac{5,224}{720} = 7.26$ cm.

Mean area $= (7.26)^2 = 52.71$ cm.^{2} per shoot

Total density $= \frac{10,000}{52.71} = 189.72$ shoots per sq. meter scoparius, which contributed 57.5% of the relative composition. Andropogon Gerardi and Panicum oligosanthes were of secondary importance with a relative abundance of 7.5 and 4.2 per cent respectively. Other perennial grasses contributing to the composition were Sorghastrum nutans, Andropogon saccharoides, Sporobolus asper, Panicum virgatum, Eragrostis spectabilis, and Carex spp. Of annual species Aristida oligantha and Bromus japonicus comprised 0.7 and 0.1 per cent respectively of the vegetation.

Observations showed that twelve forb species made up a total of 18.2% of the composition. Aster ericoides was the most abundant comprising 7.4%. Ambrosia psilostachya was second in abundance with 6.1%. Achillea lanulosa and Helianthus annuus were of little abundance representing 1.7 and 1.1 per cent respectively. Other perennial forbs, of little abundance were Strophostyles leiosperma, Solanum eleagnifolium, and Liatris punctata. The only biennial species recorded during the sampling was Gnaphalium obtusifolium, which made up 0.1% of the vegetation. Some annuals of secondary importance that contributed to the composition were Erigeron strigosus, Euphorbia marginata, Diodia teres, and Acalypha gracilens.

The results of 180 quadrats with a point centered quarter showed that the vegetation provided a total density of 189.92 shoots per square meter (Table IV).

1963 Data

The 1963 data were recorded on eighteen protected sites in late August, for reason of comparison these data are embodied in a later Table (VII). The number of species encountered were thirty-two compared to the twenty-three species on nine protected treatments in 1964. Andropogon scoparius was the most prevalent grass species representing 60.7% of the vegetation. Sorghastrum nutans and Panicum oligosanthes were of secondary importance, representing 5 and 4 per cent respectively. Twelve other grass species contributed 16.9% to the relative composition. Practically all the forbs observed in the treatments were perennials; the annuals constituted only a very small percentage. The most prominent forb species was Achillea lanulosa, which made up 4% of the vegetative composition. Similar stands of Ambrosia psilostachya and Aster ericoides each occupied about 3% of the vegetation.

The results of 360 quadrats with a point centered quarter showed that the vegetation provided a total density of 202.92 shoots per square meter (Table VII). The decrease in recorded species from 32 to 23 is apparently because half as many treatments were sampled in 1964 thereby, decreasing the chances of recording certain species on different protected treatments in the study area.

Plowed and Disked Treatments

Of the thirteen species on plowed and disked treatments, Andropogon scoparius was the most important comprising 11.4% of the relative composition (Table V). Carex spp. were the second most important making up 9.1% of the composition. All the dominant prairie grasses decreased, apparently because their propagules were buried so deeply by the plowing operation (Penfound and Rice, 1957). Of the secondary species, Panicum oligosanthes and Leptoloma cognatum comprised 7.2 and 6.6 per cent respectively. The only annual species recorded was Aristida oligantha which made up 7.4% of the vegetation. Other perennial grasses contributing

TABLE V

SPECIES DENSITIES, RELATIVE COMPOSITION, AND FREQUENCY VALUES IN PLOWED AND DISKED TREATMENTS. (Based on 120 quadrats)

Species	Number Quadrats Species Occurred	Number Species Occurred	Relative Composition	Frequency	Relative Frequency	Sum of Distances (cm)	Absolute Density (Shoots per sq. meter)
Ambrosia psilostachya	51	75	14.38	42.48	15.31	2,137	1.85
Andropogon scoparius	42	54	11.42	35.00	12.63	1,668	1.45
Carex spp.	19	43	9.10	15.83	5.65	682	1.15
Aristida oligantha	26	35	7.40	21.66	7.69	840	0.93
Panicum oligosanthes	27	34	7.19	22.48	8.12	1,045	0.91
Leptoloma cognatum	22	31	6.56	18.33	6.51	1,057	0.84
Aster ericoides	22	29	6.14	18.33	6.60	707	0.78
Strophostyles leiosperma	16	22	4.66	13.33	4.78	705	0.59
Sorghum halepense	11	20	4.23	9.15	3.30	724	0.58
Acacia angustissima	7	20	4.23	5.83	2.17	311	0.54
Helianthus annuus	18	19	4.02	15.00	5.59	524	0.50
Solanum eleagnifolium	13	15	3.18	10.83	3.91	356	0.41
Psoralea tenuiflora	8	10	2.12	6.67	2.41	225	0.26
Sorghastrum nutans	5	9	1.91	4.16	1.51	227	0.25
Asclepis viridis	5	7	1.49	4.16	1.51	148	0.19
Andropogon Gerardi	3	6	1.27	2.50	0.96	111	0.16
Lespedeza virginica	5	6	1.27	4.16	1.51	213	0.16
Chloris verticillata	3	5	1.06	2.50	0.96	140	0.14
Convolvulus sepium	5	5	1.06	4.16	1.51	216	0.14
Antennaria compestris	4	4	0.85	3.33	1.18	86	0.11
Solanum rostratum	3	4	0.85	2.50	0.96	183	0.11
Liatris punctata	2	3	0.64	1.67	0.40	134	0.08
Plantago virginica	2	3	0.64	1.67	0.40	84	0.08
Capsella bursa-pastoris	2	2	0.43	1.67	0.40	51	0.06
Croton lindeimerianus	2	2	0.43	1.67	0.40	91	0.06
Diodia teres	1	2	0.43	0.83	0.29	90	0.06
Euphorbia marginata	2	2	0.43	1.67	0.40	79	0.06
Eragrostis spectabilis	2	2	0.43	1.67	0.40	111	0.06
Panicum virgatum	2	2	0.43	1.67	0.40	61	0.06
Sporobolus asper	2	2	0.43	1.67	0.40	48	0.06
Solidago missouriensis	1	2	0.22	0.83	0.29	72	0.03
Andropogon saccharoides	1	1	0.22	0.83	0.29	7	0.03
Baptisia australis	1	1	0.22	0.83	0.29	8	0.03
Cassia fasiciulata	1	1	0.22	0.83	0.29	38	0.03
Desmodium sessilifolium	1	1	0.22	0.83	0.29	15	0.03
Oxalis stricta	1	1	0.22	0.83	0.29	20	0.03
Total	338	480	100.00	281.56	100.00	13,214	12.81

Mean distance $= \frac{13,244}{480} = 28.00$ cm.   Mean area $= (28.00)^2 = 784.00$ cm^2 per shoot

Total density $= \frac{10,000}{784.00} = 12.81$ shoots per sq. meter.

to the composition were Andropogon Gerardi, Sorghastrum nutans, Andropogon saccharoides, Sporobolus asper, Chloris verticillata, Sorghum halepense, Panicum virgatum, and Eragrostis spectabilis.

The quality vegetation decreased materially on the plowed and disked treatments. Weedy forbs comprised 48.1% of the vegetative composition. Observations by Bard (1952) in a New Jersey field showed that one year after plowing the forb Ambrosia psilostachya appeared to be the dominant species. In a study by Rice and Penfound (1954) of plant succession on a plowed prarie, western ragweed was the most important species in the growing season after plowing.

In this study the dominant forb species, of some twenty-two sampled, was also Ambrosia psilostachya which furnished 14.4% of the total composition. Important secondary species and their relative compositions were Aster ericoides 6.1%, Helianthus annuus 4%, Strophostyples leiosperma 4.7%, Solanum eleagnifolium 3.2%, Psoralea tenuiflora 2.1% (Table IV). The five listed above represented 48% of the relative frequency of forbs. Other perennial forbs of relatively little abundance were Lespedeza virginica, Antennaria compestris, Asclepis viridis, Liatris punctata, Solidago missouriensis, Desmodium sessilifolium, and Baptisia australis. Annual forbs of little abundance were Convolvulus sepium, Solanum rostratum, Capsella bursa-pastoris, Croton lindheimerianus, Plantago viridis, Cassia fasciculata, Oxalis stricta, Euphorbia marginata, and Diodia teres.

The results of 120 quadrats showed that the vegetation provided a total density of 12.8 shoots per square meter (Table V).

Mowed, Raked and Removed Treatments

The grass species Andropogon scoparius represented 67.1% of the relative composition on the mowed, raked and removed treatments (Table VI). Other sub-dominant species, of the seven which occurred, were Sorghastrum nutans, Andropogon saccharoides, and Andropogon Gerardi which comprised 5.8, 4.6, and 4.2 per cent respectively of the vegetation. The increaser species, Carex spp., made up 2.6% of the total; while an invader species Chloris verticillata represented 2.5% of the composition. Two grasses of little abundance were Panicum oligosanthes and Sporobolus asper. All grasses recorded on these treatments were perennials.

The quality of the species of vegetation seemed to improve materially on the mowed, raked and removed treatments because there only four forbs recorded during the sampling. The most prevalent species was Ambrosia psilostachya comprising 7.5% of the relative composition. Other species of secondary importance were the annual Helianthus annuus and the two perennials, Aster ericoides and Strophostyples leiosperma. Forbs species represented only 8.8% of the relative composition and 14.7% of the relative frequency.

The results of 60 quadrats showed that the vegetation provided a total density of 201.74 shoots per square meter (Table VI).

Comparison of Species

Plowed and Disked vs. Protected

In general, the plowed and disked treatments exhibited strikingly lower density values than the protected sites because of the drastic

TABLE VI

SPECIES DENSITIES, RELATIVE COMPOSITION, AND FREQUENCY VALUES IN MOWED, RAKED AND REMOVED TREATMENTS. (Based on 60 quadrats)

Species	Number Quadrats Species Occurred	Number Species Occurred	Relative Composition	Frequency	Relative Frequency	Sum of Distances (cm)	Absolute Density (Shoots per sq. meter)
Andropogon scoparius	54	161	67.08	90.00	49.56	1,064	135.33
Ambrosia psilostachya	13	18	7.50	21.66	11.93	144	15.12
Sorghastrum nutans	8	14	5.83	13.33	7.34	84	11.76
Andropogon saccharoides	8	11	4.58	13.33	7.34	94	9.23
Andropogon Gerardi	9	10	4.16	15.00	8.26	85	8.41
Panicum oligosanthes	6	9	3.75	10.00	5.50	76	7.55
Chloris verticillata	4	6	2.53	6.66	3.66	54	5.10
Carex spp.	2	4	1.66	3.33	1.84	39	3.36
Sporobolus asper	2	4	1.66	3.33	1.84	36	3.36
Aster ericoides	1	1	0.42	1.66	0.91	12	0.84
Helianthus annuus	1	1	0.42	1.66	0.91	17	0.84
Strophostyles leiosperma	1	1	0.42	1.66	0.91	5	0.84
Total	109	240	100.01	181.62	100.00	1,710	201.74

Mean distance $= \frac{1710}{240} = 7.04$ cm.

Mean area $= (7.04)^2 = 49.56$ cm. per shoot.

Total density $= \frac{10,000}{49.56} = 201.74$ shoots per sq. meter.

change brought about by the plowing operation (Table VII). Andropogon scoparius a major dominant species on plowed and disked treatments had an absolute density of 1.45 shoots per square meter, while on the protected plots, the corresponding species had a much greater density of 109.08 shoots per square meter.

The number of species encountered in this study on the plowed and disked treatments was 36 with 23 on the protected treatments. Measurements made on the plowed and disked treatments showed a relative composition of 51.9% for grasses and 48.1% for forbs, while on the protected plots there was a relative composition of 81.7% for grasses and 18.3% for forbs (Figure 11). Andropogon scoparius was the dominant grass species on both treatments. It made up 57.5% of the vegetation on the protected plots and 11.4% on the plowed and disked treatments. The most important species on the plowed and disked treatments was the forb Ambrosia psilostachya comprising 14.4% of the vegetation. The same species was the third most abundant on the protected areas furnishing 6.1% of the relative composition. In the protected plots the most prevalent forb species was Aster ericoides which contributed 7.4% of the vegetation.

Observations showed that on the plowed and disked treatments, perennials made up 84.9% of the vegetation and annuals 16.1%, while on the protected plots, perennials comprised 96.9% of the vegetation and annuals only 3.1% (Figure 12). Of perennial species on the plowed and disked treatments, grasses comprised 49.5% of the vegetation and forbs the remaining 35.4%, while on the protected sites, grasses made up 81.1% of the perennials and forbs 15.8%.

TABLE VII
SPECIES DENSITIES, RELATIVE COMPOSITION, AND FREQUENCY VALUES IN THE DIFFERENT TREATMENTS
(August 1964)

Species	Mowed, Raked and Removed (60 quadrats)				Plowed and Disked (120 quadrats)				Protected (180 quadrats)				Protected* (360 quadrats)			
	Relative Composition	Frequency	Relative Frequency	Absolute Density (Shoots per sq. meter)	Relative Composition	Frequency	Relative Frequency	Absolute Density (Shoots per sq. meter)	Relative Composition	Frequency	Relative Frequency	Absolute Density (Shoots per sq. meter)	Relative Composition	Frequency	Relative Frequency	Absolute Density (Shoots per sq. meter)
Andropogon scoparius	67.08	90.00	49.56	135.33	11.42	35.00	12.63	1.45	57.50	86.66	41.48	109.08	60.69	86.94	44.21	123.15
Ambrosia psilostachya	7.50	21.66	11.93	15.12	14.38	42.48	15.31	1.85	6.11	18.88	9.04	11.58	3.12	11.11	5.65	6.33
Panicum oligosanthes	3.75	10.00	5.50	7.55	7.19	22.48	8.12	0.91	4.17	12.78	6.12	7.91	4.03	10.83	5.51	8.18
Andropogon Gerardi	4.16	15.00	8.26	8.41	1.27	2.50	0.96	0.16	7.50	20.56	9.84	14.22	3.96	5.28	2.68	8.04
Aster ericoides	0.42	1.66	0.91	0.84	6.14	18.33	6.60	0.78	7.36	18.33	8.78	13.95	3.06	10.28	5.23	6.21
Sorghastrum nutans	5.83	13.33	7.34	11.76	1.91	4.16	1.51	0.25	2.92	7.22	3.46	5.53	5.00	10.28	5.23	10.15
Carex spp.	1.66	3.33	1.84	3.36	9.10	15.83	5.65	1.15	2.64	9.44	4.52	5.01	2.22	7.78	3.96	4.50
Andropogon saccharoides	4.58	13.33	7.34	9.23	0.22	0.83	0.29	0.03	2.78	6.66	3.19	5.26	2.57	7.50	3.81	5.22
Leptoloma cognatum					6.56	18.33	6.51	0.84					3.82	11.67	5.93	7.75
Achillea lanulosa									1.67	5.56	2.66	3.16	3.96	12.22	6.21	8.04
Helianthus annuus	0.42	1.66	0.91	0.84	4.02	15.00	5.59	0.50	1.11	2.22	1.06	2.11				
Sporobolus asper	1.66	3.33	1.84	3.36	0.43	1.67	0.40	0.06	2.08	6.11	2.92	3.95	2.99	6.67	3.39	6.07
Aristida oligantha					7.40	21.66	7.69	0.93	0.14	0.56	0.27	0.27				
Chloris verticillata	2.53	6.66	3.66	5.10	1.06	2.50	0.96	0.14					1.32	4.17	2.12	2.67
Strophostyles leiosperma	0.42	1.66	0.91	0.84	4.66	13.33	4.78	0.59	0.14	0.56	0.27	0.27				
Solanum eleagnifolium					3.18	10.83	3.91	0.41	0.42	1.67	0.80	0.80	0.07	0.28	0.14	0.14
Sorghum halepense					4.23	9.15	3.30	0.53					0.07	0.28	0.14	0.14
Acacia angustissima					4.23	5.83	2.17	0.54					0.42	1.39	0.71	0.85
Psoralea tenuiflora					2.12	6.67	2.41	0.26					0.21	0.83	0.42	0.43
Panicum virgatum					0.43	1.67	0.40	0.06	1.25	3.89	1.86	2.37	0.21	0.55	0.28	0.43
Lespedeza virginica					1.27	4.16	1.51	0.16					0.14	0.55	0.28	0.28
Convolvulus sepium					1.06	4.16	1.51	0.14								
Eragrostis spectabilis					0.43	1.67	0.40	0.06	0.14	0.56	0.27	0.27	0.21	1.11	0.56	0.43
Antennaria compestris					0.85	3.33	1.18	0.11								
Asclepis viridis					1.49	4.16	1.51	0.19								
Bromus japonicus									0.69	2.22	1.06	1.31				
Solanum rostratum					0.85	3.50	0.96	0.11								
Erigeron strigosus									0.42	1.67	0.80	0.80	0.07	0.28	0.14	0.14
Liatris punctata					0.64	1.67	0.40	0.08	0.14	0.56	0.27	0.27	0.07	0.28	0.14	0.14
Bouteloua curtipendula													0.28	1.39	0.71	0.57
Euphorbia marginata					0.43	1.67	0.40	0.06	0.28	0.56	0.27	0.53				
Diodia teres					0.43	0.83	0.29	0.06	0.14	0.56	0.27	0.27				
Elymus canadensis													0.42	1.11	0.56	0.85
Acalypha gracilens									0.28	1.11	0.53	0.53				
Solidago missouriensis					0.22	0.83	0.29	0.03					0.07	0.28	0.14	0.14
Bouteloua hirsuta													0.21	0.83	0.42	0.43
Capsella bursa-pastoris					0.43	1.67	0.40	0.06								
Croton lindheimerianus					0.43	1.67	0.40	0.06								
Plantago virginica					0.64	1.67	0.40	0.08								
Desmodium sessilifolium					0.22	0.83	0.29	0.03								
Cassia fasiculata					0.22	0.83	0.29	0.03								
Oxalis stricta					0.22	0.83	0.29	0.03								
Baptisia australis					0.22	0.83	0.29	0.03								
Rudbeckia hirta													0.21	0.55	0.28	0.43
Artemisia ludoviciana													0.14	0.55	0.28	0.28
Elymus virginicus													0.21	0.55	0.28	0.43
Gnaphalium obtusifolium									0.14	0.56	0.27	0.27				
Solanum Torreyi													0.07	0.28	0.14	0.14
Apocynum cannabinum													0.07	0.28	0.14	0.14
Ulmus americana													0.07	0.28	0.14	0.14
Prunus angustifolia													0.07	0.28	0.14	0.14
TOTALS	100.01	181.62	100.00	201.74	100.00	281.56	100.00	12.81	100.02	208.90	100.01	189.72	100.03	196.66	99.97	202.98

Mowed, Raked and Removed:
Mean distance = $\frac{1710}{240}$ = 7.04 cm
Mean area = $(7.04)^2$ = 49.56 sq.cm.per shoot
Total density = $\frac{10,000}{49.56}$ = 201.74 shoot/m^2

Plowed and Disked:
Mean distance = $\frac{13,244}{480}$ = 28.00 cm.
Mean area = $(28.0)^2$ = 784.0 sq.cm.per shoot
Total density = $\frac{10,000}{784.0}$ = 12.76 shoot/m^2

Protected (180 quadrats):
Mean distance = $\frac{5,224}{720}$ = 7.26 cm.
Mean area = $(7.26)^2$ = 52.71 sq.cm.per shoot
Total density = $\frac{10,000}{52.31}$ = 189.72 shoot/m^2

Protected* (360 quadrats):
Mean distance = $\frac{10,112}{1440}$ = 7.02 cm.
Mean area = $(7.02)^2$ = 49.28 sq.cm.per shoot
Total density = $\frac{10,000}{49.28}$ = 202.92 shoot/m^2

*1963 Data Based on Research by J. J. Crockett.

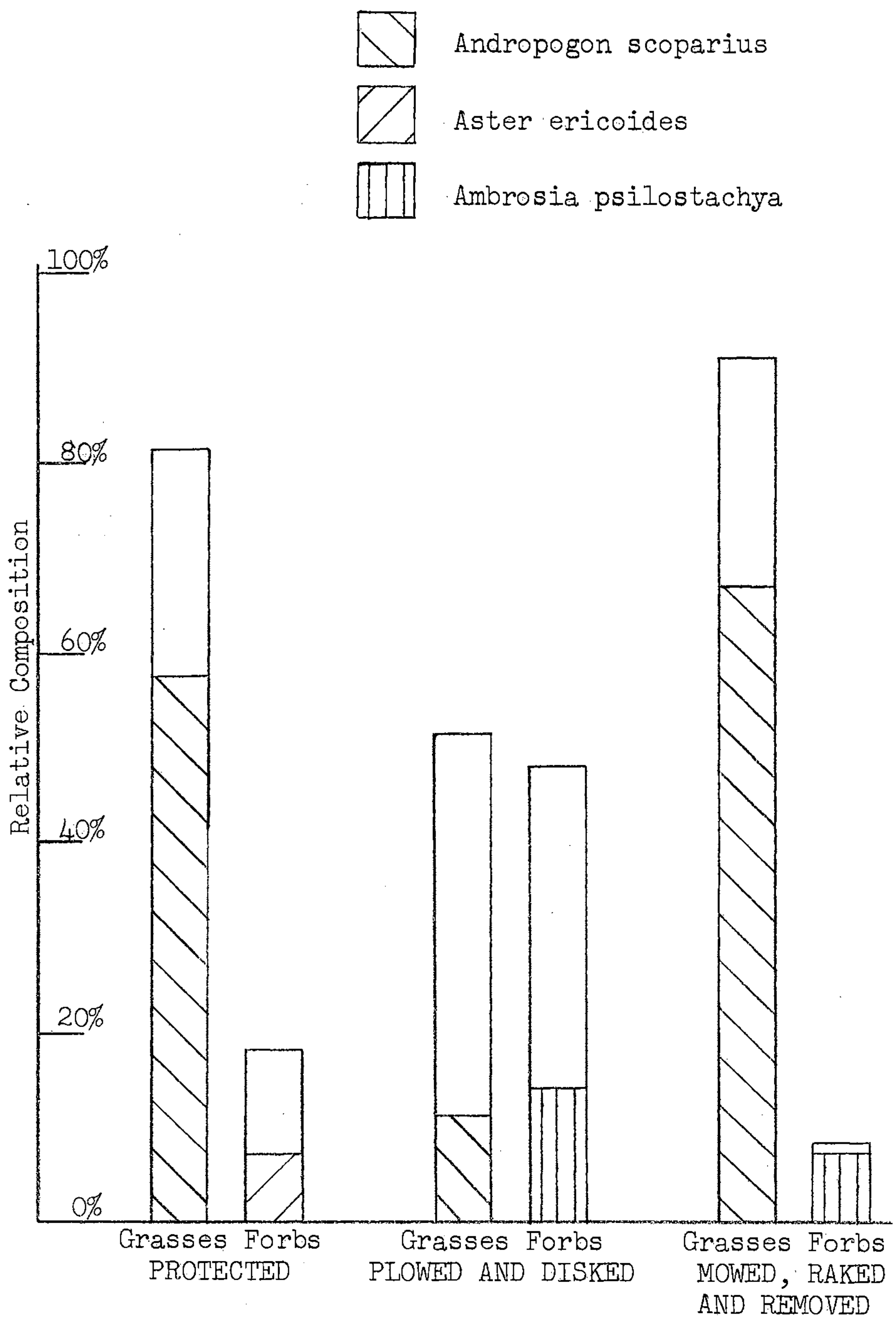


Figure 11. Relative Composition by Treatments Comparing Grasses with Forbs and Showing Dominant Species of Each.

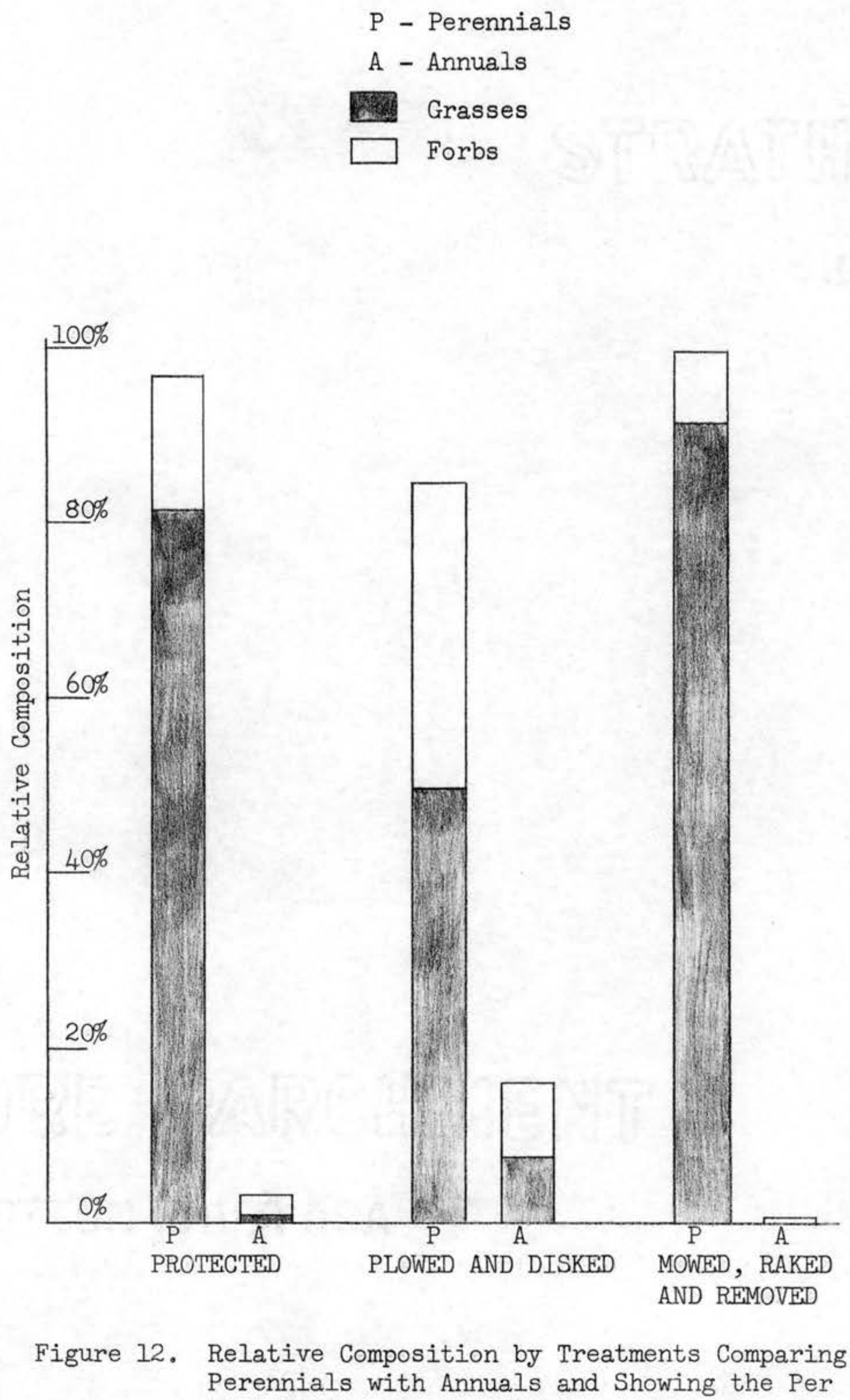


Figure 12. Relative Composition by Treatments Comparing Perennials with Annuals and Showing the Per Cent of Grasses and Forbs.

Mowed, Raked and Removed vs. Protected

The total density of vegetation on the mowed, raked and removed treatments was slightly higher than the protected plots (Table VII). Andropogon scoparius the major dominant species on the mowed, raked and removed treatments had a absolute density of 135.33 shoot per square meter, while on the protected plots the same species had a density of 109.08 shoots per square meter.

The number of species recorded on the mowed, raked and removed treatments was 12 with 23 on the protected sites. The mowed, raked and removed treatments showed a relative composition of 91.3% for grasses and 8.8% for forbs, while on the protected areas the corresponding values were 81.7 and 18.3 per cent respectively (Figure 11). The most prevalent species on the mowed, raked and removed treatments was Andropogon scoparius. It made up 67.1% of the vegetation about 10% higher than on the protected areas. The most important forb species on the mowed, raked and removed treatment was Ambrosia psilostachya which comprised 7.5% of the relative composition. The same species was the second most abundant forb on the protected sites furnishing 6.1% of the vegetation.

Measurements made on the mowed, raked and removed treatment showed that perennials made up 99.6% of the vegetation and annuals only 0.4%, while on the protected plots, perennials comprised 96.9% of the vegetation and annuals 3.1% (Figure 12). Perennial species on the mowed, raked and removed treatments were predominantly grasses (91.3%), while forbs (8.3%) were rather scarce. The only annual species recorded on the mowed, raked and removed treatments was Helianthus annuus, which represented 0.4% of the relative composition, while on the protected sites grasses made up 0.8% and forbs 2.7% of the annuals.

CHAPTER V

SUMMARY

Variations in microclimate and plant composition were studied for a six month period on a native tallgrass prairie under conditions of protection, plowing, and mowing. An attempt was made to correlate microclimatic factors with evaporation, soil temperature and soil moisture in the different treatments. An analysis of the vegetation was made on each treatment by the point centered quarter method.

The important findings were:

(1) Evaporation in protected sites was lower than in the disturbed treatments. Protected sites were more effective in retarding evaporation because of denser vegetation and mulch cover.

(2) The general pattern for soil temperatures in protected plots was lower than in disturbed treatments. Protected plots showed less fluctuation in soil temperatures thus, providing a more uniform environment.

(3) Correlation between evaporation and soil temperatures was generally highly significant on the three treatments during the summer period (July 6 to August 31). This significance was attributed to the high temperatures and consequent high evaporation.

(4) The amount of soil moisture was found to be generally greater throughout the period of investigation on the protected sites except in a few instances, such as the 6 to 12 inch depth

on the plowed and disked treatments.

(5) All three treatments were predominantly occupied by perennial species. In the protected plots the most important species were *Andropogon scoparius*, *Andropogon Gerardi*, *Panicum oligosanthes*, *Aster ericoides*, and *Ambrosia psilostachya*.

(6) The dominant prairie species present before plowing and disking on the plowed and disked treatments decreased drastically, possibly because their propagules were buried so deeply by the two operations. Weedy forbs comprised almost half of the vegetative composition on the plowed and disked treatments. The dominant species present near the end of the growing season were *Ambrosia psilostachya*, *Andropogon scoparius*, and *Carex* spp.

(7) The quality of vegetational composition improved materially in one growing season after mowing because forb species decreased greatly. The most prevalent species present near the end of the growing season were *Andropogon scoparius*, *Ambrosia psilostachya*, and *Sorghastrum nutans*.

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APPENDIX

APPENDIX A

WEEKLY AIR TEMPERATURES FOR THE SIX MONTH STUDY PERIOD

Week Ending on:	HYGROTHERMOGRAPH			(degrees F)	THERMOMETERS		
	MAX	MIN	AVG		MAX	MIN	AVG
April 25	82.0	72.3	77.0		90.0	47.5	69.0
May 2	75.3	54.0	65.0		90.0	52.0	71.0
May 9	84.2	67.1	76.0		91.0	49.0	70.0
May 16	77.1	58.1	68.0		83.0	43.0	63.0
May 23	87.1	64.1	76.0		89.0	64.0	77.0
May 30	83.0	69.0	76.0		95.0	54.0	75.0
June 8	78.4	58.0	68.0		93.1	56.1	75.1
June 15	90.0	73.0	81.4		97.0	67.2	82.0
June 22	89.1	68.1	78.5		97.1	67.0	82.0
June 29	90.0	61.0	76.0		91.3	61.1	76.1
July 6	96.0	70.0	83.0		102.0	68.4	85.2
July 13	96.4	72.4	84.0		106.0	58.1	79.0
July 20	95.1	69.2	82.0		98.3	70.3	84.3
July 27	103.1	73.2	88.1		100.0	69.5	85.1
Aug. 3	97.0	75.1	86.3		98.0	71.2	85.0
Aug. 10	102.1	73.3	88.2		108.0	59.3	84.2
Aug. 17	83.4	63.3	73.3		107.0	57.1	82.0
Aug. 24	88.1	65.4	77.2		96.1	55.3	76.0
Aug. 31	87.4	67.2	77.3		96.0	72.1	84.0
Sept. 7	94.6	73.4	84.5		96.1	67.0	82.0
Sept. 14	83.1	61.0	72.0		98.0	54.1	76.0
Sept. 21	79.0	61.3	70.1		89.3	55.2	72.1
Sept. 28	76.2	57.1	67.0		82.1	42.2	62.0
Oct. 5	74.1	45.0	59.0		82.0	38.2	60.0
Oct. 12	70.3	45.0	57.1		78.1	34.0	56.0
Oct. 19	73.0	48.0	61.0		88.2	32.1	60.0
Oct. 26	76.1	46.0	61.1		86.1	49.3	68.0

Two methods of calculation followed: Hygrothermograph (Figures based on averaged daily records), Thermometers (Figures based on weekly records).

APPENDIX B

WEEKLY HUMIDITIES FOR THE SIX MONTH STUDY PERIOD

(FIGURES BASED ON AVERAGE DAILY RECORDS)

Week Ending on:	HYGROTHERMOGRAPH (per cent)		
	MAXIMUM	MINIMUM	AVERAGE
April 25	98.0	38.1	68.0
May 2	86.0	32.6	59.0
May 9	96.4	37.1	67.0
May 16	94.3	43.0	69.0
May 23	98.4	40.1	69.3
May 30	97.4	53.3	75.4
June 8	100.0	46.4	73.2
June 15	97.0	49.0	73.0
June 22	94.4	41.2	68.0
June 29	100.0	32.1	66.2
July 6	93.0	33.1	63.0
July 13	90.1	33.0	62.3
July 20	81.0	31.0	56.1
July 27	89.1	29.4	59.3
Aug. 3	92.0	35.1	64.0
Aug. 10	88.3	28.2	58.2
Aug. 17	97.1	43.1	70.0
Aug. 24	100.0	38.1	69.1
Aug. 31	100.0	52.2	76.0
Sept. 7	100.0	43.3	72.2
Sept. 14	93.4	44.3	61.2
Sept. 21	100.0	61.3	81.4
Sept. 28	98.1	42.0	70.1
Oct. 5	98.3	36.3	67.3
Oct. 12	90.4	28.2	59.3
Oct. 19	92.1	31.1	61.1
Oct. 26	83.0	24.0	53.0

APPENDIX C

WEEKLY EVAPORATION FROM WHITE SPHERICAL LIVINGSTON ATMOMETER CUPS ON THE THREE TREATMENTS

(Evaporation in ml.)

Week Ending on:	PROTECTED (CONTROL)	PLOWED AND DISKED	MOWED, RAKED AND REMOVED
April 25	272.5	314.5	307.0
May 2	325.5	383.5	383.0
May 9	323.0	365.5	370.0
May 16	182.0	214.0	203.0
May 23	313.0	404.0	331.0
May 30	230.5	-	-
June 8	217.5	279.5	265.0
June 15	239.3	327.5	264.0
June 22	346.3	449.0	378.0
June 29	272.7	371.5	300.0
July 6	383.3	479.0	453.0
July 13	328.3	407.0	383.0
July 20	469.3	514.0	533.0
July 27	510.3	501.0	512.0
Aug. 3	477.7	455.0	528.0
Aug. 10	495.3	500.0	550.0
Aug. 17	247.0	248.0	289.0
Aug. 24	245.0	241.0	268.0
Aug. 31	185.7	181.5	213.0
Sept. 7	262.7	246.5	311.0
Sept. 14	202.0	216.0	293.0
Sept. 21	102.7	60.5	78.0
Sept. 28	172.7	146.0	170.0
Oct. 5	155.3	154.5	167.0
Oct. 12	193.3	180.5	195.0
Oct. 19	168.0	161.5	175.0
Oct. 26	206.7	198.5	208.0
Nov. 2	147.0	137.0	160.0

APPENDIX D

WEEKLY SOIL TEMPERATURES AT THE SIX INCH DEPTH ON THE THREE TREATMENTS. (Figures Based on Weekly Records).

(Soil Temperatures in F)

Week Ending on:	PROTECTED (CONTROL)		PLOWED AND DISKED		MOWED, RAKED AND REMOVED	
	MAX	MIN	MAX	MIN	MAX	MIN
April 25	67.5	61.5	74.0	64.0	71.0	63.0
May 2	69.0	60.0	80.0	63.0	72.0	61.0
May 9	82.0	65.0	79.5	67.0	76.2	67.0
May 16	70.5	60.5	79.5	61.0	75.0	62.0
May 23	77.5	65.5	85.0	67.0	81.0	67.2
May 30	82.0	66.5	90.0	67.5	87.0	68.0
June 8	78.5	65.0	85.5	63.0	84.2	64.0
June 15	84.0	74.2	90.5	76.5	89.0	76.0
June 22	87.0	77.0	94.5	81.0	93.0	79.0
June 29	86.6	74.0	94.0	77.0	92.1	76.0
July 6	89.5	77.0	97.5	83.5	97.0	82.3
July 13	90.2	75.0	98.0	79.0	98.5	77.0
July 20	87.5	75.0	94.0	78.5	93.3	77.2
July 27	92.5	79.5	99.0	85.0	99.0	83.5
Aug. 3	92.0	82.5	97.0	86.5	98.2	86.5
Aug. 10	95.0	77.5	101.5	83.5	102.0	81.3
Aug. 17	89.0	74.0	95.0	74.5	95.5	75.5
Aug. 24	82.5	72.0	85.5	74.5	86.5	73.2
Aug. 31	84.5	73.5	87.5	74.5	87.5	74.0
Sept. 7	87.0	78.0	89.0	78.5	90.2	79.0
Sept. 14	88.3	70.5	90.0	69.0	91.0	69.0
Sept. 21	77.0	69.5	78.0	70.0	78.0	70.0
Sept. 28	76.0	65.0	75.5	64.5	75.0	66.0
Oct. 5	72.5	62.5	74.0	64.5	74.0	65.0
Oct. 12	69.0	59.5	70.5	61.5	72.0	61.0
Oct. 19	69.2	58.5	72.0	60.0	73.5	59.0
Oct. 26	66.5	56.5	68.0	58.5	69.5	57.5
Nov. 2	68.0	60.0	70.0	62.5	70.0	61.5

APPENDIX E

SOIL MOISTURE AT DIFFERENT DEPTHS FOR THE FIVE MONTHS OF SAMPLING.

FIGURES REPRESENT AVERAGE PER CENT

MONTH	0-6" P	0-6" P&D	0-6" MRR	6-12" P	6-12" P&D	6-12" MRR	12-24" P	12-24" P&D	12-24" MRR	24-36" P	24-36" P&D	24-36" MRR
JUNE	11.6	15.7	7.4	13.4	16.0	13.7	16.9	14.9	15.7	16.3	12.0	14.0
JULY	8.3	11.2	5.6	9.3	15.2	9.9	12.9	15.1	12.1	14.5	12.7	12.3
AUGUST	10.8	9.5	9.2	10.7	11.5	11.4	12.8	12.8	14.6	13.1	10.5	12.9
SEPTEMBER	11.6	11.1	10.8	12.9	13.0	11.9	15.5	14.4	15.5	16.0	11.7	15.5
OCTOBER	11.7	11.7	9.3	11.6	11.7	12.0	13.9	13.1	17.2	14.8	10.6	12.9

P - Protected Sites
P&D - Plowed and Disked Treatments
MRR - Mowed, Raked and Removed Treatment

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