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# EVALUATION OF VEGETATION TYPES DIFFERENTIATED BY AERIAL PHOTO INTERPRETATION OF PANCHROMATIC, COLOR, AND INFRA-RED IMAGERY

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## ABSTRACT

A study was conducted on the International Biological Program's Pawnee Site in northeastern Colorado to evaluate vegetation types differentiated by aerial photo inspection. The imagery used was found to be quite adequate for minute delineation work. A total of thirteen vegetation types was recognized through use of photo inspection, Leaf Area Index data, and personal field observations.

ACKNOWLEDGEMENTS

Dr. T. E. Bedell and Dr. D. H. Knight are due a word of thanks for their helpful suggestions as members of the reading committee.

# INTRODUCTION

There are several thousand hectares of rangeland encompassed by the Pawnee Site of the International Biological Program's (IBP) Grassland Biome system. These rangelands, though they are relatively uniform and dominated by a few grass species, exhibit phytosociological variation resulting from soil, moisture, relief, and grazing treatment influences upon the vegetation. The spatial modeling effort of the Grassland Biome program requires a detailed vegetation map with the definitive vegetation types outlined. This study was initiated with this map as a primary objective, but three objectives were established:

1. To make a detailed vegetation map of the Pawnee Site, including the Central Basin Watershed and the Environmental Stress Area on which the IBP headquarters is located.
2. To differentiate and describe the significant vegetation types on the Pawnee Site.
3. To determine and compare weighted average Leaf Area Index values for each separate sampling area.

To enable simplification of the sampling procedure, the Pawnee Site was separated into 12 sampling units based on grazing treatment, fenceline divisions, and cultural developments. Three forms of remote sensing imagery were used -- panchromatic, colored, and infrared aerial photography.

# REVIEW OF LITERATURE

## Interpretation of Aerial Photos

### Historical Aspects

Aerial photography today is an integral component of much range survey work. Legault et al. (1956) pointed out that the uses and applications of "aerial surveys have increased steadily since World War I," and from 1935 to the present this increase has been even more pronounced. According to Legault et al. there are two types of aerial surveys. One covers the area in question with no ground control data while the other has incorporated with it a coordinated ground survey. Almost exclusively, aerial photography as a part of range management is of the second type. This is documented by Driscoll (1971) when he states that "ground sampling is essential in conjunction with photointerpretation."

Driscoll (1969) pointed out that only a very small portion of rangeland has been inventoried using ground sampling techniques. This is due to inherent problems encountered in covering such vast areas as rangelands encompass, using conventional on-the-ground methods alone. Aerial photography, together with these ground techniques, offers an opportunity to alleviate some of these problems and provide detailed information pertinent to management practices of rangeland (Driscoll, 1969). The reasons why this would be possible are, as Driscoll (1969) states, 1) much detailed information about the vegetation is contained in aerial photos, 2) aerial photos can be obtained rather quickly, and 3) the photos allow for a more detailed study than is possible by ground search alone. An appraisal of range survey work by Reid and Pickford (1942) recommended aerial photography as a more accurate method of providing dependable forage estimates and as a basis for more precise vegetation type maps than conventional ground procedures. Driscoll (1969), recognizing that site distinction is a very important contribution to any management program which involves measurement and interpretation of native rangeland vegetation, states that a greater synoptic view of an area can be obtained employing aerial photo inspection than can be realized from ground level viewing.

Black and white panchromatic photographs were first used in aerial survey work to aid in range inventory in 1937 (U. S. Inter-Agency Range Survey Committee, 1937). Since that time aerial photography, or, to use a broader term, remote sensing, has been refined considerably. Remote sensing can now provide much more detailed information about vegetation with the use of color, infrared, near infrared, thermal infrared, multispectral, and radar imagery (Johnson and Atwood, 1970; Peterson et al., 1969; Yost and Wenderoth, 1969).

## Delineation of Vegetation Types

Avery (1968) lists criteria of importance in inspection of aerial photographs as follows: 1) topographic location, 2) texture, 3) pattern, 4) shape, 5) size, 6) tone, and 7) shadow. Lord and McLean (1969) reported distinguishing six land units paying particular attention to combinations of tone, pattern, and texture. These were subsequently determined by vegetation differences, drainage, topography, nature of bedrock or superficial deposits, and patterns of microfeatures. These land units were found to be related to land use. Using accepted interpretation techniques, significant relationships were found to exist between photo patterns and soil-vegetation-physiographic units (Lord and McLean, 1969). Larson et al. (1971) found a similar correlation between photo interpretation results and ground control work. This correlation was found between aerial photo and ground estimates of "Ponderosa Pine (Pinus ponderosa Laws.) cubic-foot volume and basal area per acre, aspect, and slope steepness" working with three sizes of panchromatic contact prints having scales of 1:3,000, 1:6,000, and 1:15,840. It was found that a scale of 1:15,840 was generally adequate for this work with perhaps the 1:6,000 prints being somewhat more desireable in certain small areas.

Vegetation type mapping is essentially a subjective process; therefore the quality and accuracy of the final map depends largely on the experience and judgement of the worker who is making delineations (USDA Region 6, Forest Service, 1962). While boundaries are rather specific on a map, many of the boundaries are in actuality ecotones where types blend together. This, combined with the common quality of stand heterogeneity, makes for rather difficult classification at times, even with intensive ground inspection (USDA Region 6, Forest Service, 1962).

Broad vegetation types, i. e. grassland, open forest, dense forest, etc., can be delineated on standard black and white aerial prints (Harris, 1951). More precise delineations can be realized through the use of more sophisticated photography such as near infrared, thermal infrared, and radar imagery (Peterson et al., 1969). This type of imagery, combined with techniques such as differentiation, level selection, combination, and texture discrimination, allows the interpretor to make decisions based on species and density differences both within and between plant communities. Yost and Wenderoth (1969) reported that the "near infrared spectrum apparently offers significant possibilities for detection of differences among vegetative species".

## Color vs. Black and White

In each study where some type of comparison between black and white imagery and some type of color, either true color or infrared, was made, the black and white was found to be inferior for delineation work (Driscoll, 1969; Johnson and Atwood, 1970; Wimbush et al., 1967). However, even with the use of sophisticated color photography, problems may be encountered in interpretation and delineation work. Driscoll (1971) reports that phenology of the vegetation is important when trying to identify individual species on photographs. Color differences were found to be so subtle on photos taken in mid-July that they could not be distinguished. Due to phenological changes however, by mid-August, individual species could be differentiated on the basis of color. Because of the complexity of the range environment, there is no one optimum time to procure photographs for use in interpretation (Driscoll, 1971). Harris (1951) reported having to make corrections in type boundaries in the field. Incomplete interpretation or error due to changes in the vegetation which had occurred after the area had been photographed were the reasons for these corrections.

## Leaf Area Index and the Point Quadrat Method of Sampling Vegetation

An important aspect of vegetation structure is leaf area per unit ground area (Knight, 1969). This is commonly termed Leaf Area Index or LAI. The LAI concept as developed by Warren-Wilson (1963) requires data collection using a point frame and recording point contacts for each species (Shaver and Fisser, 1971). According to Warren-Wilson (1960), data recorded using point quadrats does not measure actual foliage area. Measured instead is the foliage area "projected in the direction in which the quadrat lies" (Warren-Wilson, 1960). Foliage area measurements then vary with the slope of the foliage and, when using inclined quadrats, with the degree of inclination of the quadrat (Warren-Wilson, 1960). The author further points out that errors are greatly reduced when quadrats are inclined at 32.5° and are of a magnitude acceptable in general survey work. Dr. Dennis Knight, in his work done on the Pawnee Grassland, was able to determine LAI values from the data which was obtained through the use of the single quadrat inclination of 32.5° (Knight, 1971). Warren-Wilson (1963) utilized three quadrat angles: 8°, 32.5°, and 65°, along with modifying constants' for each of these. The LAI values were then calculated by entering the average number of hits per pin (f) for each of these three angles in the formula:

$$\mathrm{LAI} = .089f_{8^\circ} + .462f_{32.5^\circ} + .453f_{65^\circ}$$

Knight (1971) in his work, arrived at a constant of 0.87 on the Pawnee Grassland for the single inclination of 32.5 and thus the following formula:

$$LAI = 0.87f_{32.5}$$

There are problems associated with the use of a point frame in vegetation such as that characteristic of the Pawnee Site. Knight (1969) points out that leaf area is difficult to measure in native grasslands under windy conditions. It is difficult to determine when an actual point contact has been made on the herbaceous material if the wind is constantly blowing the vegetation.

Heady et al. (1959) encountered another problem when making a comparison between the charting, line intercept, and line point methods of sampling in shrub communities. They found that species having a ground cover of less than three percent required extremely large numbers of samples when using the point method. The line intercept method sampled these species much better. Another problem, not especially specific for point sampling, is pointed out by Knight (1969). This is that "a characteristic of grassland vegetation is its patchy, heterogeneous nature". The problem then is to locate each of these "patches" allowing the structural parameters of each to be estimated separately (Knight, 1969). He further states that once this has been accomplished the data from these patches could be synthesized to determine the characteristics of the ecosystem.

The point frame has, in general, been found to be a faster method of sampling than other methods with which it has been compared. Whitman and Siggeirsson (1954) found the point contact method to be slightly faster when recording all contacts as opposed to only basal contacts or the line intercept method. It was also noted that, of a total of 57 recorded species, the all contacts method encountered 49 of them while with the basal contact and line intercept methods 22 and 51 species, respectively, were recorded. In an arid grassland community the point method and an ocular estimate method using a small circular quadrat were found to be more rapid than ocular estimates in larger quadrats or the use of line interception (Winkworth et al., 1962). Brun and Box (1963) worked with a point frame in desert shrub vegetation. Using a frame 5 feet long with ten pins per frame and randomly locating 15 frames throughout each study area, the point contact data were found to be obtained more rapidly than with the line intercept method for estimating percent cover of major species in either sagebrush-grass or sagebrush-shadscale vegetation.

## Association Analysis

Association analysis in ecological research is more likely to be used in connection with the primary survey of an area than in a later, more detailed investigation as it serves more to expose problems than to solve them (Williams and Lambert, 1959). Kershaw (1961), in an evaluative look at association analysis, points out that it is a useful primary survey technique, much more so than co-variance analysis. He also says that association analysis is definitely of value in defining the real problems in the field.

Association analysis provides the basis for a hierarchical classification (Greig-Smith, 1964). This allows for a more ready interpretation in relation to the habitat. According to Kershaw (1964), a hierarchical classification positions a number of species characterizing species groupings in descending order of importance with the degree of association being used to determine the relative position of each species. The hierarchical groupings result in homogenous units which are defined as units in which all species associations are either indeterminate or non-significant (Greig-Smith, 1964; Williams and Lambert, 1959). The problem therefore, is to find the attribute which, with each subdivision, is most likely to reduce the residual associations to the lowest level possible (Williams and Lance, 1958). Greig-Smith (1964) puts forth the same idea, stating subdivision is made on that species which produces the smallest number of significant associations in the two subclasses. There will generally be a number of alternative subdivisions which will accomplish this. Kershaw (1961), in a paper on association and co-variance analysis, has summarized the work by Williams and Lambert on hierarchical division of quadrat data.

In a comparison of pooling versus hierarchical division, Williams and Lambert (1960) stated that either method was liable to result in essentially the same final groupings. A longer route is involved with pooling, however, which makes it a somewhat less desireable method.

Association analysis is sensitive to differences in floristic richness and it is relevant to determine the extent to which this richness may have dominated the classification (Webb et al., 1967a). This sensitivity allows for the use of association analysis in the grouping or clustering of separate sampling units. Webb et al. (1967b), in another paper, go on to point out that an ecologically meaningful group of species is liable to consist of species having a rather appreciable range of predictive efficiency. They further state that a random sample from a group such as this may fail to exhibit the properties of the group. Presence and absence data for heterogeneous sites can be expected to carry a larger part of the needed information and sampling can be confined to the larger species, essentially ignoring species which contribute little or nothing to the regional configuration which is being sought (Webb et al., 1967b).

Govoni et al. (1970) have compiled an analysis of computer programs which are useful in dealing with vegetation association analysis. They point out that the computer is able to handle voluminous amounts of data rather easily, amounts which would require months for an individual to handle by hand. Lambert and Williams (1962) also point out that the use of computers in analysis of ecological data has certain advantages. One of these is that the computer has not gained any experience from other ecological situations and in the analysis does not become entangled in any preconceived ideas which may be inappropriate to the situation under consideration. Using a given set of data, it is quite possible to extract meaningful vegetation entities entirely by mathematical processes without any previous ecological experience being involved (Lambert and Williams, 1962). The idea is brought out also by these authors that it is not the erection of these units but their interpretation which requires the services of a trained ecologist.

Govoni et al. (1970) discuss six computer programs useful in analysis of botanical data. The program H GROUP is one of these which is designed to "cluster profiles (in this case all of the character values of every plant) such that there is a minimum variation within the groups and a maximum variation between groups" (Govoni et al., 1970). The grouping method used is sensitive to absolute distances among the plants, and the result is a grouping of the closest pair (Veldman, 1967). A potential error is computed for putting the components into each group as each new grouping is made with the optimum grouping being that grouping prior to the greatest error increase (Govoni et al., 1970). For example, assume one has five sample units and wishes to determine the optimum grouping of these five units. Assuming that units 1 and 4 are most alike, the computer will group these, leaving only four groups. A potential error is then computed and the process is repeated this time leaving only 3 groups and so on. This grouping will continue until only two groups remain. The H GROUP program is useful in determination of discernible groups although care should be taken against drawing erroneous conclusions (Govoni et al., 1970). A statistical significance may be indicated by the program when there may not be any real biological significance.

Erroneous conclusions are also cautioned against by Lambert and Williams (1962) as they point out that vegetation units which are extracted from a given population should not be taken as "necessarily equivalent to 'fundamental units' (if any such exist) in a general phytosociological system". They point out that these units may be more comparable to the vegetational 'noda' simply providing "'abstract points of reference...which coincide with frequently recurring and easily recognizable plant communities'" (Lambert and Williams, 1962).

## DESCRIPTION OF THE STUDY AREA

### Location

This study was a part of the International Biological Program's Grassland Biome research. It was conducted on the Pawnee Site (Figure 1) in northeastern Colorado, approximately 25 miles south of Cheyenne, Wyoming and 12 miles northeast of Nunn, Colorado. The Pawnee National Grassland and the Central Plains Experimental Range make up the Pawnee Site. Extensive studies requiring large areas of land are conducted on the Pawnee National Grassland which encompasses approximately 42,500 hectares. The Central Plains Experimental Range, a much smaller area consisting of about 6,000 hectares, is available to the International Biological Program for studies requiring smaller land areas. The Central Basin Watershed lies within the Central Plains Experimental Range (Figure 2; Appendix G). This study was conducted over the entirety of the watershed.

### Vegetation

Blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) and buffalo grass (*Buchloe dactyloides* (Nutt.) Engelm.) are the two dominant grass species in this region (Klipple and Costello, 1960). In addition to these dominant species, numerous midgrasses can be found growing in association with them. These minor species are quite common and comprise a conspicuous element of the vegetation, especially during wet years or

Figure 1. A general view of the vegetation on the Pawnee Site.

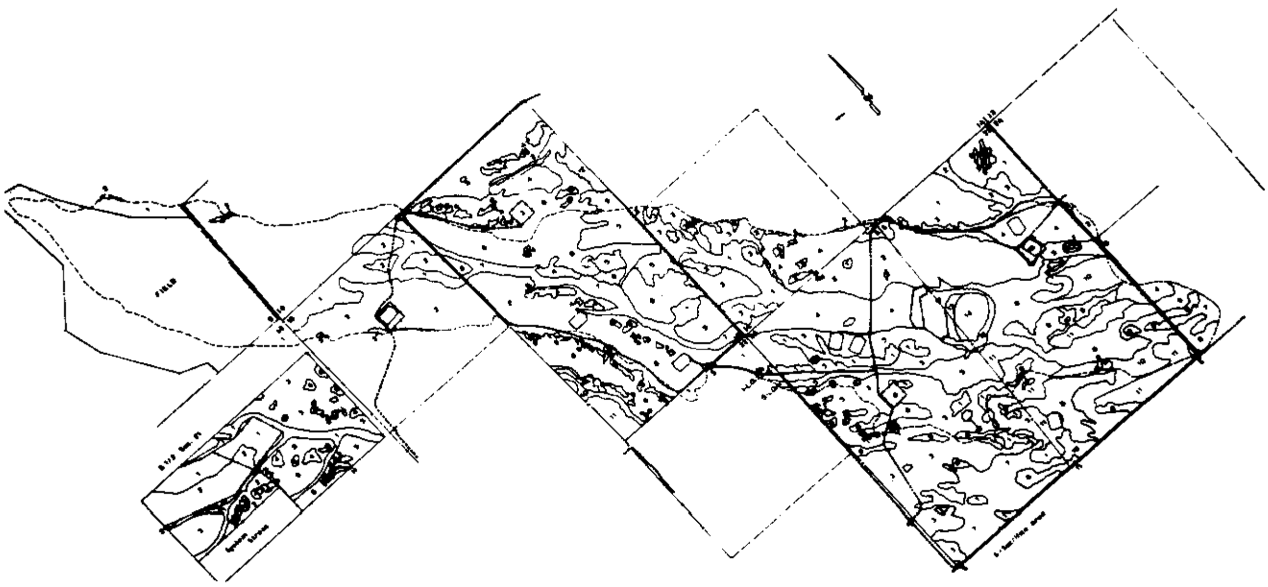

Figure 2. S½ Sec. 21 and the Central Basin Watershed with vegetation sub-type delineation lines.

on lightly grazed areas (Mitchell, 1971). Western wheatgrass (*Agropyron smithii* Rydb.), red three-awn (*Aristida longiseta* Steud.), bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) J. C. Smith), needleandthread (*Stipa comata* Trin. and Rupr.), and sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray) are some of the more common of these minor species. Although not very conspicuous, needleleaf sedge (*Carex eleocharis* Bailey) is quite common over the entire area.

Several perennial forbs are found distributed throughout the entire area. Some of the more common of these are plains bahia (*Bahia oppositifolia* (Nutt.), slimflower scurfpea (*Psoralea tenuiflora* Pursh.), spreading wildbuckwheat (*Eriogonum effusum* Nutt.), scarlet gaura (*Gaura coccinea* Nutt. ex Pursh.), and scarlet globemallow (*Sphaeralcea coccinea* (Pursh.) Rydb.). Present over the entire area also are annual forbs such as lambsquarter (*Chenopodium* species), Russian thistle (*Salsola kali tenuiflora* Tausch.), bluebur stickseed (*Lappula redowskii* (Nornem.) Greene), and Rocky Mountain beeplant (*Cleome serrulata* Pursh.). Abundance of these forbs varies yearly with amount of precipitation.

## Grazing

The three main pastures in the watershed have been subjected to summer grazing since 1939 (Klipple and Costello, 1960). The heavy use pasture, E½ Sec. 23, (for a close-up of this, see Figure 3) has been grazed so that 60 percent of the current year's herbage growth of the dominant grasses (blue grama and buffalo grass) has been utilized by summer's end. Use has been regulated to 40 percent and 20 percent

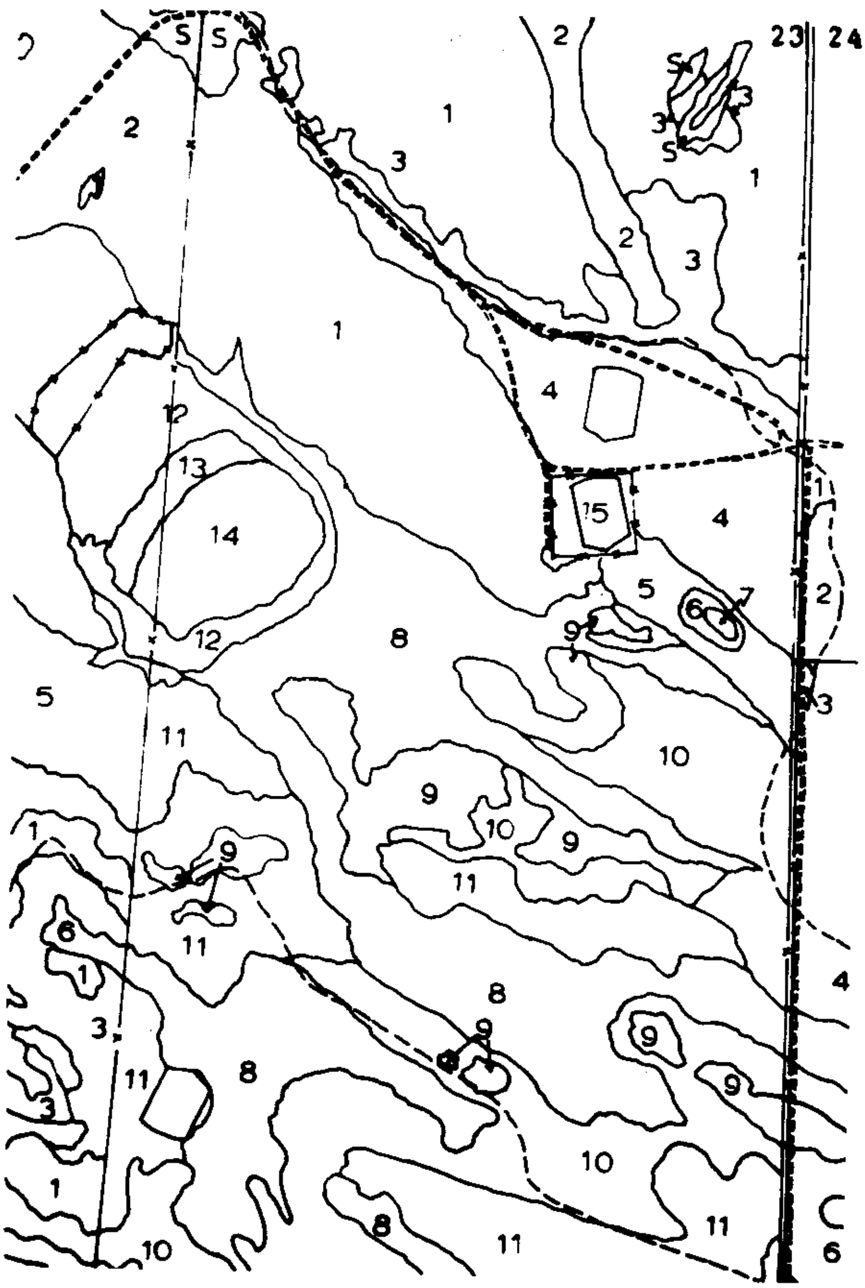


Figure 3. A detailed view of sub-type delineations in the heavy use pasture.

on the medium use pasture, E½ Sec. 15 (Figure 4), and the light use pasture, W½ Sec. 23 (Figure 5), respectively. Forage production increases during years of above average rainfall and 60 percent utilization is often difficult to obtain. During the 13 years following the initiation of the grazing treatments, heavy use was obtained during only 8 years on some pastures. The light and moderate use treatments were easier to regulate, even during dry years, since cattle could be removed when the planned amount of use had been obtained (Klipple and Costello, 1960).

## Climate

The area in which the Pawnee Site lies receives 10 to 15 inches of precipitation per year. A 15 year average of 11.96 inches was recorded at the Central Plains Experimental Range headquarters for the years 1939 to 1953 (Klipple and Costello, 1960). Approximately 70 percent of the total precipitation was recorded during the growing season from May 1 to September 30 during this same 15 year period. The amount of precipitation received annually and during the growing season varies considerably (Mitchell, 1971). Large variations were also noted from pasture to pasture within comparatively short distances. This variation is attributed to local severe summer storms which affect only small areas.

The Pawnee Site has an average growing season of about 135 days, although frost has been recorded in all months except July and August. Daytime temperatures average 80 degrees F during the summer period, but

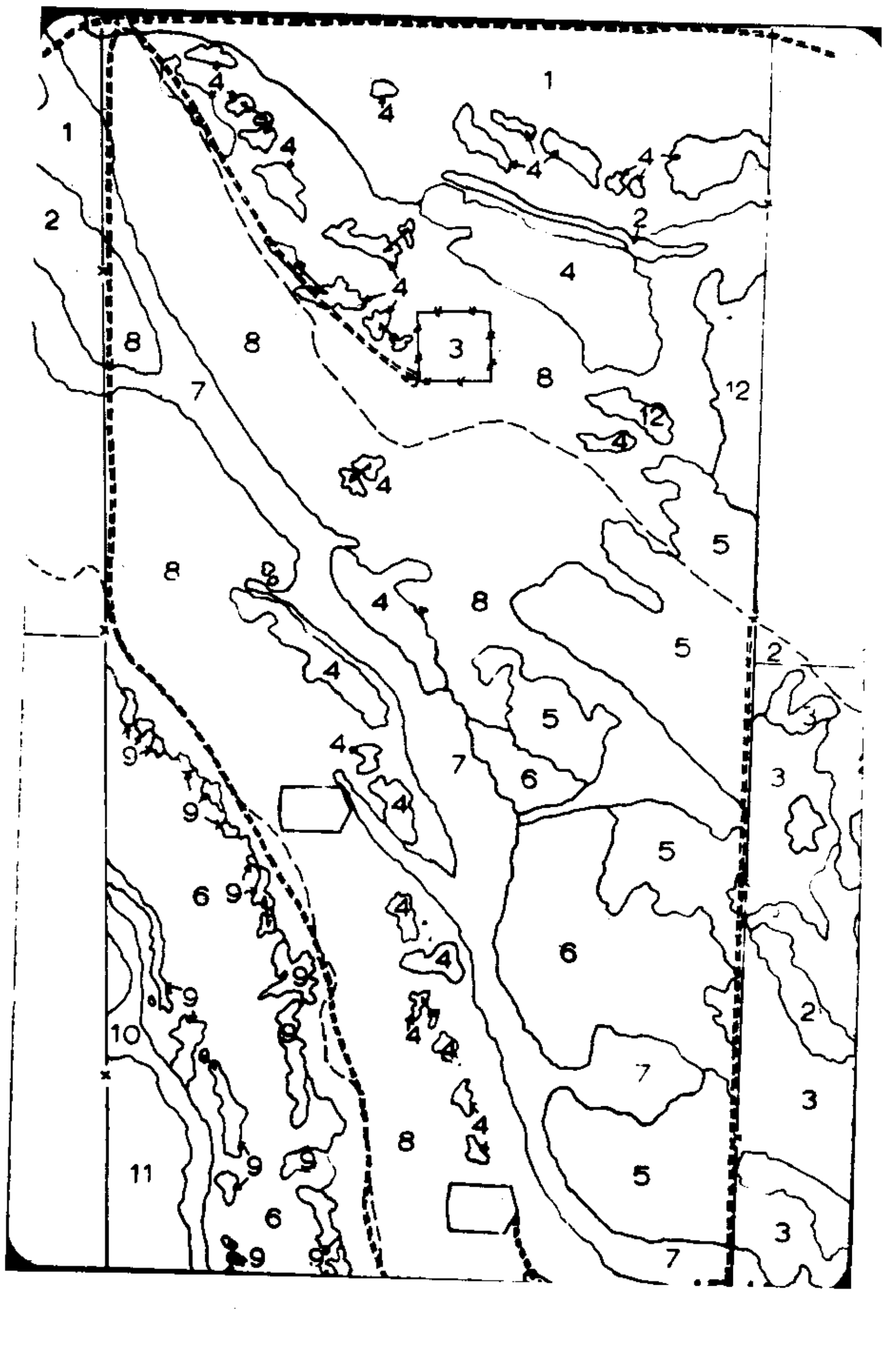


Figure 4. A detailed view of sub-type delineations in the medium use pasture.

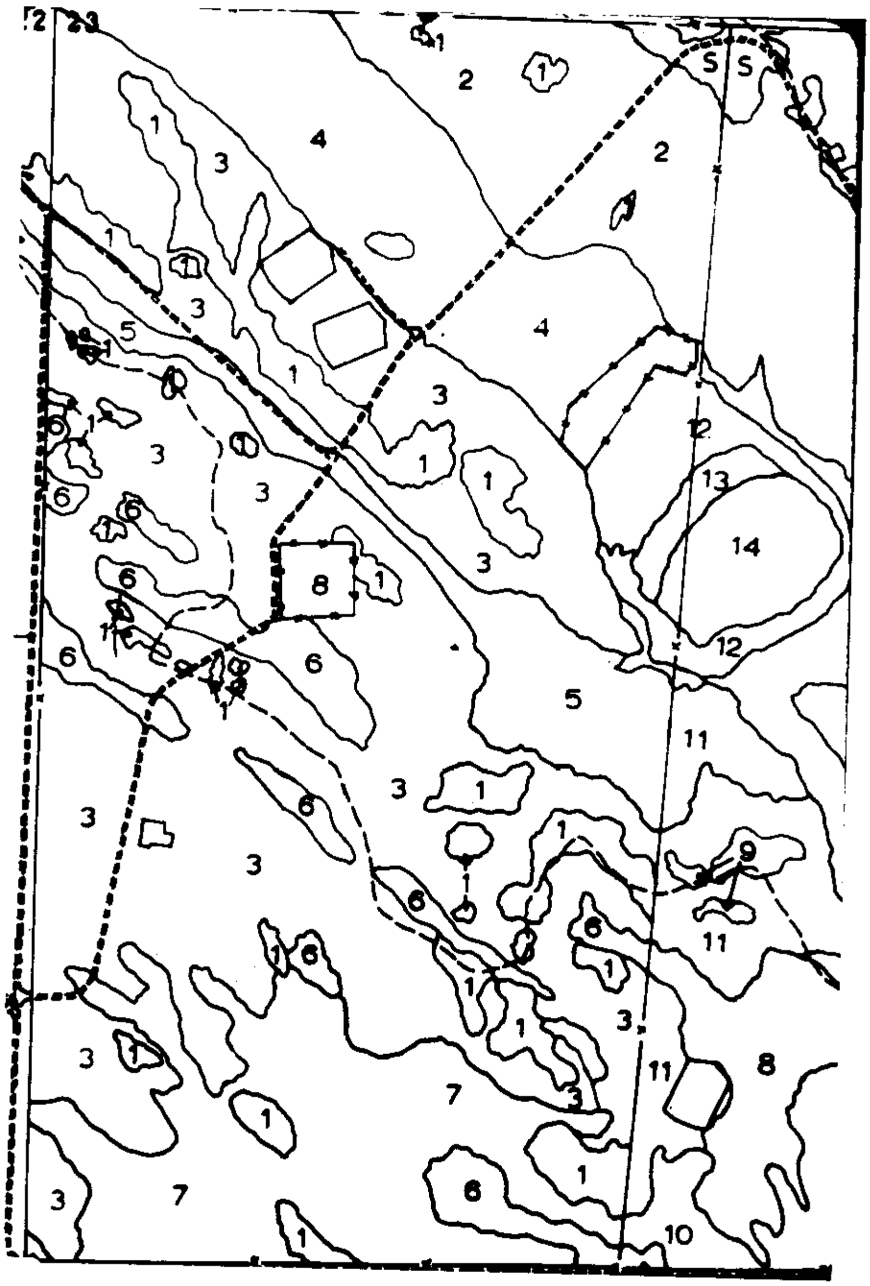


Figure 5. A detailed view of sub-type delineations in the light use pasture.

highs in the nineties and even in the hundreds are often recorded. Winters in this area are dry and cold, with vegetation seldom being covered by snow for any length of time.

Strong winds are the rule during the winter months. The months of June, July, and August are generally calm to moderately windy.

## Soils

The brown and dark brown soils of the semiarid Great Plains are characteristic of the soil groups in this area. Hyder et al. (1966) described seven range sites on this area based on interpretive soil groups. Of these seven groups, four were upland sites; these were Vona, Greeley, and Ascalon sandy loam, and Renohill loam. The bottomland soils were grouped into three groups as follows: Havre and Fort Collins loam, Unnamed and Nunn clay loam, and Unnamed saline-alkali. (For a more complete picture of the soils on this area, see the soils map, Appendix H.)

## METHODS AND PROCEDURES

Aerial photo coverage of the Pawnee Site was obtained from an early July, 1970 flight. From these photographs a total of 12 sampling-units (Appendix B) were distinguished on the study area. These 12 units were identified on the basis of grazing treatment, fenceline separations, and cultural developments and were assigned code letters as follows:

A. Light Grazed Pasture: W½ Sec. 23.

B. Medium Grazed Pasture: E½ Sec. 15.

C. Heavy Grazed Pasture: E½ Sec. 23.

D. W½ Sec. 24.

E. NE¼ Sec. 22.

F. SW¼ Sec. 14.

G. NW¼ Sec. 15.

H. E½ Sec. 9; SW¼ Sec. 10; NE¼ Sec. 16.

I. S½ Sec. 21. Environmental Stress Area (ESA) That portion not included in any of the following areas.

J. S½ Sec. 21; (ESA) Holding Pasture.

K. S½ Sec. 21; (ESA) Light Grazed Diet Pasture.

L. S½ Sec. 21; (ESA) Heavy Grazed Diet Pasture.

The system stress area (Appendix D) located in the southwest corner of section 21 was omitted from this study since vegetation on that area is undergoing constant changes due to intensive treatment applications.

Within each sampling-unit vegetation, "sub-type" delineations were utilized to distinguish areas of high uniformity due to topographic location, texture, tone, and pattern. These sub-types were all sampled individually with a point frame during the summer of 1971, from mid-June through the end of August.

## Photo Interpretation

### Kinds of Photography

Three kinds of imagery were used in the interpretive work. Panchromatic black and white prints with a scale of 1:5,800 were used as the basis for all interpretation work. These photographs were compared and contrasted with color and infrared prints of a slightly smaller scale as an aid in making more precise delineations.

### Delineation of Sub-types

Sub-type delineations were arrived at by use of steroscopic inspection of the aerial photos. Mirror and lens stereoscopes were employed in the interpretive work. The mirror stereoscope allows the viewer to inspect rather large areas with little magnification (Shaver and Fisser, 1971). First order designations of site and vegetation variations were derived from inspection with this instrument. The lens stereoscope, with 2-4 power magnification, provides a smaller field of view in which the interpreter can inspect in greater detail each area of the photo. Except for a few minor changes in type delineations which were made during sampling in the field, final designations of type differences were made through use of this detailed investigation.

The criteria listed by Avery (1968), mentioned previously in the Review of Literature, were an invaluable aid in arriving at type delineations. The most important factors which provided a basis for selecting sub-type boundaries on the Pawnee Site imagery were topographic location, texture, tone, and pattern. The following dichotomous key was prepared as an aid for objective decision making in the interpretive process.

Vegetation-Delineation Key for the Pawnee Site

1. Not a definite drainage area. Generally higher ground but in cases may be a lowland

    2. Definite ridge or hilltop

        3. Very smooth texture

            4. Extremely light grey

            4. Darker grey

        3. Rough texture

    2. Not a definite hilltop--Sidehills or level low areas

        5. Level low areas

            6. Smooth texture

            6. Texture not smooth

                7. Medium texture

                7. Very coarse texture

5. Sidehills

8. Smooth texture

8. Texture not smooth

9. Medium texture

9. Coarse texture

1. Lowland--Definite drainage area

10. Dark, deep tone (color)--Definite water holding pocket

10. Lighter tone--Usually not a definite pocket

11. Medium grey tone

12. Apparent intermittant stream bed or bed of ephemeral lake or pond

13. Intermittent stream bed

13. Ephemeral lake or pond bed

12. Not as above. Generally an apparent drainage area

11. Very light grey tone. Generally the boundary of an ephemeral lake or pond

This key was used to determine broad generic level appearances. It was not designed to key areas to definite sub-types but was used merely as an aid, with final delineations objectively made by comparison of the three photo types with site characteristics such as soils, slope, and exposure.

Transfer of Delineations to the Base-line Map

The black and white panchromatic prints (scale of 1:5,800) were similar in scale to the base-line map upon which the final delineations of vegetation types were to be transferred (map scale of 1:4,800). Drawing of the sub-type delineations was done on these black and white photos with a red pencil. This resulted in prints easily readable and the near equality in size facilitated the transfer of sub-type designations from the photo onto the map. The slight difference in scale between the photos and the base-line map however, did present a problem in the transfer process. To overcome this, a secondary photographic process was initiated. Utilizing a 35 mm camera and color slide film, pictures were taken of the panchromatic black and white photos each containing a pasture or study unit. The largest of these occupied no more than 130 hectares. The positioning of the camera was such that the specific unit, or aerial photograph, of which the slide was to be taken was centered in the viewfinder. The distance of the camera from the photo was great enough to result in only 1/4 to 1/3 of the subsequent colored slide being occupied by the photographic unit (Figure 6). This restriction was necessary to reduce, as much as possible, the influence of photographic displacement and distortion upon the imagery of the slides.

A projector was used to transfer the type lines to the base line map. The map was mounted on the wall and the slides were projected onto their corresponding map areas. The projector was mounted on a tripod to aid in positioning the slide image on the base line map. By moving the tripod back and forth and tilting of the platform on which the projector was placed, at least three pasture corners or location

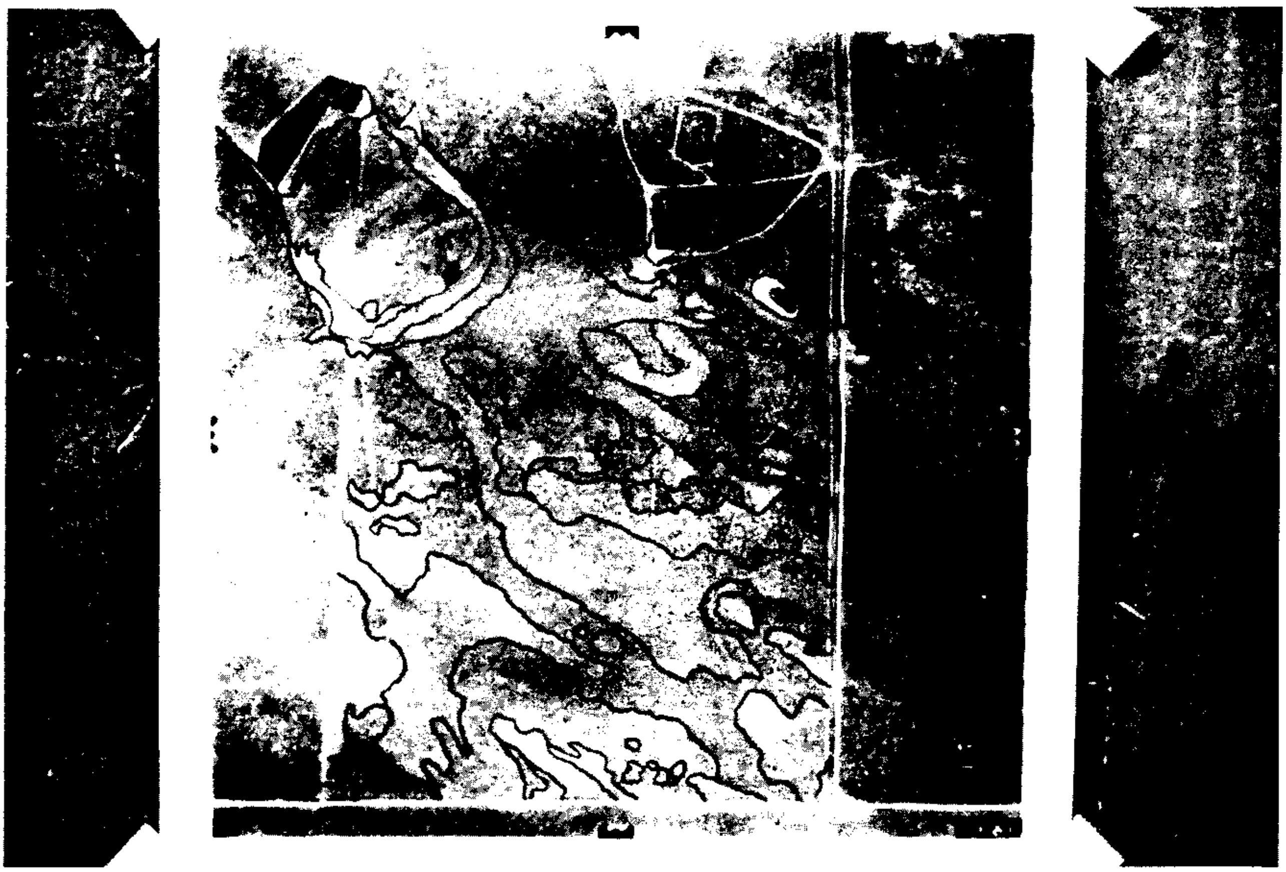

Figure 6. A slide in transfer of sub-type designations to the base-line map.

points could be properly aligned. Type lines were then traced onto the map. If only three location points were identically aligned for a rectangular pasture unit, the type lines were drawn only on one-half of that unit prior to repositioning the projector to align a fourth corner point and two previously aligned points. This process was repeated until the entire study area was reproduced on the base line map.

Line matching resulting from the projector repositioning was sufficiently accurate to locate type lines with errors no greater than from one to two meters. On the ground comparison with identifiable check points were also able to show very little line position error.

Following the sampling season some of the original type lines were modified due to inconsistencies in what appeared on the photos and what could be actually observed on the ground. Areas of heterogeneity exhibiting a high degree of micro-biological variability were lumped into one sub-type in favor of less error in placement of delineations.

## Vegetational Sub-type Definition

### Leaf Area Index Computation

Each vegetation sub-type delineated by photo inspection was defined in terms of Leaf Area Index (LAI). Data for computation of LAI were collected during the summer of 1971 utilizing a motorized point frame (Figure 7) with a moveable pin, developed by Dr. Dennis Knight of the University of Wyoming. Samples were taken in each

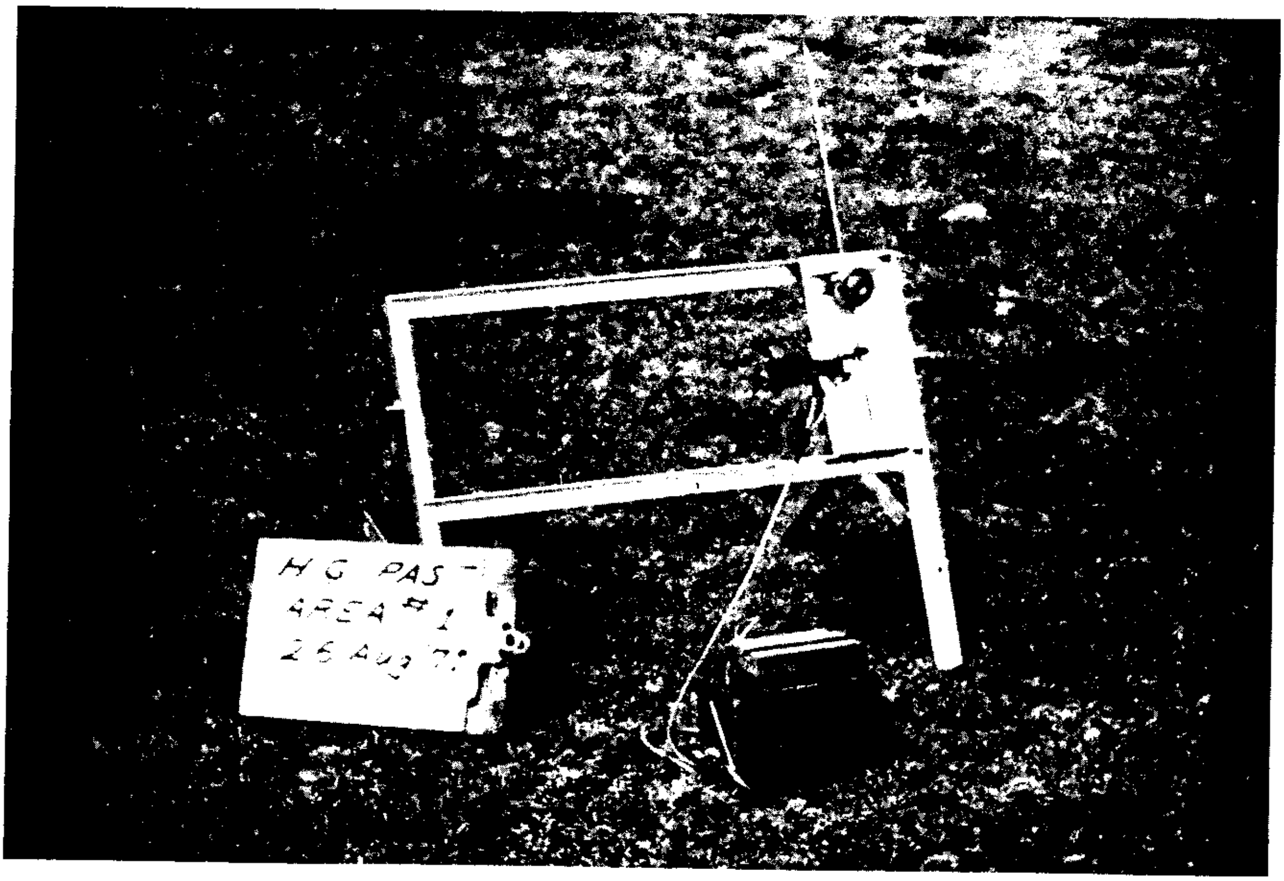

Figure 7. The motorized Point Frame used in collection of point contact data.

sub-type within each pasture or sampling unit. The frame settings were distributed using restricted random and systematic selection procedures. Ten pin-points were read at each frame setting and the frame was then moved to a new location which was randomly selected. For each pin the species and number of contacts of each with the pin point were recorded on a tape recorder. Figures 8 and 9 show the operation of the point frame and a vegetation-pin contact, respectively. The characteristic low growth form of the vegetation on the Pawnee Site is also noticeable in Figure 9. At the end of each day the data were transferred from the recorder to data sheets in the lab.

Sampling adequacy, in terms of numbers of points required to estimate LAI effectively, was determined through the use of the equational form:

$$N_p \text{ adequate when } S_{\bar{X}_p} < .10\,\bar{X}$$

where $N_p$ is the number of points required to adequately sample each sub-type and $S_{\bar{x}_p}$ is the standard error of the mean for herbaceous material contacts per pin. To simplify then, sampling was considered adequate only when sufficient point contact data had been obtained such that the standard error of the mean of herbaceous contacts per pin was less than 10 percent of the mean. The number of points required to adequately sample each sub-type varied from 400 to 600 depending on the denseness of vegetation. The number of points required was fewer for the more dense vegetation.

LAI values were computed by the procedure of Dr. Dennis Knight (1971). Near the end of the summer period however, it was noted that

Figure 8. The Point Frame in operation.

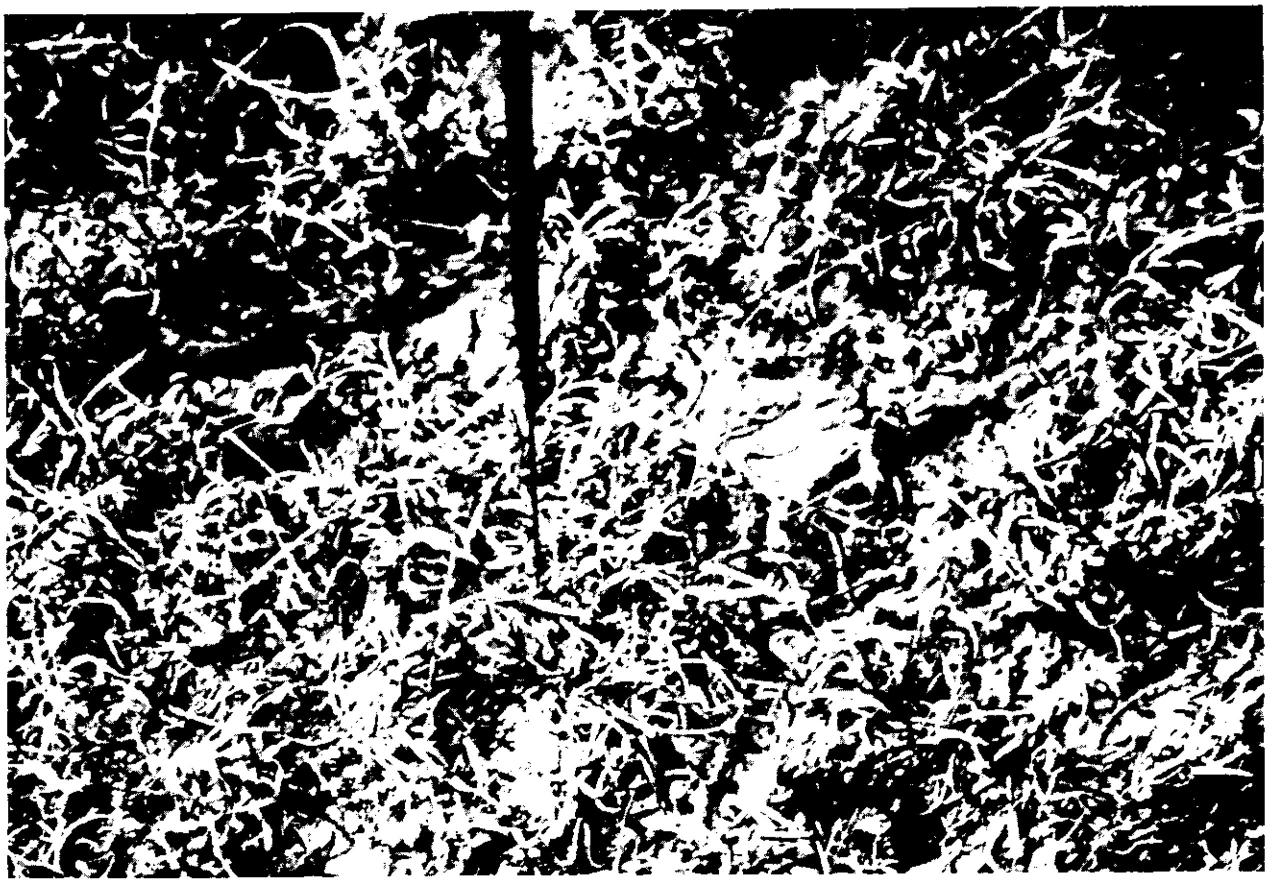

Figure 9. A vegetation-pin contact.

the point frames being used in collection of data had inadvertently been constructed such that the leg settings for 32.5° and 65° had been reversed. Since sampling of a majority of the sub-types had already been completed with the pin at 65° and since remaining time was insufficient for complete resampling, a secondary sub-sampling was initiated with the frame set at 32.5°. In addition to the point contact data which were obtained in each type area with the pin set at 65°, three areas were selected within which a replicate sample was taken with a 32.5° frame angle. Data were obtained for blue grama, buffalo grass, and the total of all species. Data were not used for other individual species since an LAI conversion coefficient was needed for only these three. The mean of all taxa among the three type areas sampled was then utilized as a conversion coefficient, C, for computation of LAI. The conversion coefficient equation, with "Rf" representing average number of hits per pin obtained from the three **sample replications** at 32.5° and 65°, is in the form:

$$C = \frac{Rf\ 32.5^\circ}{Rf\ 65^\circ}$$

Using the constant C then, LAI values for all areas were computed with the equation:

$$LAI = (C)\ (f65^\circ)\ (0.87)$$

Even though data were kept individually for each species encountered, LAI estimations were computed for only blue grama, buffalo grass, and the total of all species. There were two principal reasons for this. First, the more minor species were recorded so seldom that it was not thought that a sample adequate enough to warrant LAI estimation was taken. The second reason was based on growth form of the individual species. The value 0.87 used in the equation is an estimation for green total LAI and since blue grama and buffalo grass comprise most of the total, this value was used for these two species also. Other values would be needed for estimation of LAI for the minor species.

## Sub-type Surface Area Determination

A two-step method was utilized for determination of surface area in hectares of each sub-type. First, xerox copies were obtained of each sampling-unit from the final vegetation map. Each separate sub-type was cut out with a scissors and placed in a separate envelope. The individual sub-types were then weighed to the nearest .0001 gram. This procedure is similar to the gravimetric method for measuring leaf area (Kvet and Marshall, 1971).

Using these weights and the weight of a blank sheet of xerox paper having a known area, the area of each type was computed with the simple proportion:

$$\frac{X}{\text{weight of the unknown area}} = \frac{\text{known area (ha)}}{\text{weight of known area}}$$

with X being the area in hectares of the sub-type in question.

## Weighted Average LAI per Unit

To determine the weighted average LAI per pasture or sampling-unit, the percent of each sub-type within a pasture or sampling-unit was computed. By multiplying each of these percentages by the respective LAI values for each sub-type and summing these values for each sampling-unit, weighted average LAI values per pasture or sampling-unit were determined.

$$\text{Weighted average LAI/pasture} = \sum_{1}^{n} (\% \text{ of P}) \quad (\text{LAI})$$

where % of P = the percentage of the pasture in question which is included in the particular sub-type. This resulted in a weighted average LAI for blue grama, buffalo grass, and the TOTAL OF ALL SPECIES for each pasture.

## Analysis of Vegetation Types

Preliminary analysis of the vegetation sub-types determined through photo analysis was conducted by computer at the Grasslands Ecology Research Lab in Fort Collins, Colorado. An H GROUP program was used in this analysis. Using the 53 species (Appendix A) which were encountered during sampling in the analysis, it was determined that the resultant groupings were of no practical value due to influences of minor species. A selection of the 19 species which seemed to be most influential in the vegetation configuration of the area was then made, and an H GROUP analysis was conducted on these. These 19 species are identified in Appendix A.

The clustering technique used in the H GROUP program is:

$$\text{Distribution} = \sqrt{(X_1-Y_1)^2 + (X_2-Y_2)^2 + \ldots + (X_{19}-Y_{19})^2}$$

Two analyses of this type were made, the first using X and Y as actual numbers of hits recorded with the point frame and the second using standardized (scaled) values for X and Y. X and Y in each case are values for the same species in two different groups. The H GROUP program, after computing this value, then groups the two clusters of sub-types having the smallest distribution. A cluster analysis was also conducted on the data but was discarded since it was felt that the H GROUP resulted in a more realistic grouping of sub-types.

An F test was conducted on the groupings received from the H GROUP program. This test was designed to determine how many of the groups were significantly dissimilar to warrant consideration of the groups as different types. The general form of the hypotheses tested then were $H_o$: no apparent group differences exist based on the analysis of 19 species, or stated another way:

$$H_o:\ 1,1 = \cdots = 1,11$$
$$2,1 = \cdots = 2,11$$
$$\vdots$$
$$19,1 = \cdots = 19,11$$

and $H_1$: group differences do exist based on analysis of 19 species. This test was conducted for 11 groups, with an approximate F statistic (based on a multivariate likelihood ratio test, $\mu$) equal to 4.03 with a P value of 0.000 (Steinhorst, 1972).

# RESULTS AND DISCUSSION

## Effectiveness of Imagery

The imagery used for interpretive work in this study was found to be quite adequate. The panchormatic black and white photography was lacking in some detail but this was compensated for through use of the color and infrared prints. These two photo types reflected most of the detail which was observable on the ground and in some areas minute detail was visible on the photos which could not be located on the ground. This detail was necessary for making decisions of where to place delineation lines. Difficulty was encountered in placement of lines in certain areas where sub-types blended together without a definite break. In these few instances it was necessary to make arbitrary decisions concerning location of delineation lines.

The panchromatic scale used (1:5800) was adequate for the degree of precision necessary in this study. The photo resolution at this scale was very good. Through differences in texture and tone especially, areas on the ground as small as one-half meter in diameter were noticeable on all three photo types. Tone and texture changes were especially noticeable in areas having shrubby species as opposed to those areas in which the shrubby species were lacking. This was important in making many delineations. Comparison of the photo types would have been easier had the color and infrared prints been of the same scale however. The smaller scale of these two types was adequate, but location of the same sub-type delineations was at times difficult when the black and white photos failed to exhibit the same detail as the color prints.

The imagery used in this study provided an accurate and rapid method for making delineations. Nearly all of the delineations which were made on the photos were easily located with a minimum of ground search. This eliminated a lot of work which would have been necessary without the use of the aerial photos. One particular instance where much time was saved was in delineation of differences found on ridge tops. These differences were as easily seen on the photos as on the ground. To simply draw the sub-type lines on the photos was much faster than if each ridge has to be inspected in the field.

## Vegetation Map of the Pawnee Site

Photo inspection within each of the 12 sampling-units produced a total of 66 sub-types. These were delineated on the photos and mapped for the entire area. These 66 vegetation sub-types are presented on the vegetation map (Appendix G) with each described in Appendix F in terms of the species which were encountered most often during sampling. Where blue grama or buffalo grass are among the major species an LAI value is given, and for all other species abundance is presented as mean hits per pin from point frame data. Total LAI is also presented for each of the sub-types.

Blue grama is present as one of the major species in almost every sub-type and buffalo grass is quite prevalent also, appearing in a majority of them. This was expected as it is quite apparent that these two grasses, especially blue grama, are the dominant species over the entire area. This presented a problem in determination of vegetation "types" on the Pawnee Site since the entire area is grassland. Three "types" are easily recognized here. These three are blue grama dominant, buffalo grass dominant, and a mixture of the two species. Many of the areas which were delineated as being different due to variation in photo imagery were distinguishable as a result of varying ground cover percentages of each species rather than on differences in species composition.

In a few areas ground inspection did not reveal distinctions which had been noticeable during photo interpretation. Variations in soil properties and resultant imagery alteration due to these various soils and, in part, to slope of the photographed area, were the major cause of these inconsistencies between the photo imagery and observable ground conditions. It was necessary therefore, to make corrections and erasures in some of the delineation work. This loss of some vegetation type detail was compensated for by a reduction in error in the vegetation sampling procedure since it was virtually impossible to be sure that one was sampling within the area outlined on the aerial photograph prior to the corrections.

The 66 sub-types which make up the final 13 vegetation types are the result of very detailed photo inspection. Each of these 66 sub-types represent a real situation of homogeneity which is different from adjacent areas. These differences however, were slight in many instances, allowing sub-types to be lumped together with other sub-types which were similar, to arrive at the final 13 types. In most instances it could be readily seen, through visual inspection of the photos and in the field, which of the sub-types were similar. The H-Group analysis was implemented to augment the visual inspection.

## The Effect of Grazing on LAI

Grazing pressure which is applied to a pasture during any period of time will have a lowering effect on the LAI for the pasture. This could have had a definite effect on the results of this study since the light, medium, and heavy use pastures were being grazed throughout the sampling season. However, Knight (1970) found only slight differences between the LAI of the three management units on the Pawnee Site. The effect of the current years grazing on the results of this study should be very minimal, especially since the three treatment pastures were all sampled prior to the end of July in an effort to reduce this effect on the data which were gathered. It was impossible to complete all sampling in a shorter period of time. The values obtained by sampling during this period should be adequate for extensive survey work of this type.

## Seasonal Changes in LAI

Deterioration of the vegetation on the Pawnee Site as moisture conditions become unfavorable for continued growth also reduces LAI on the area. By restricting sampling in the three treatment pastures to the latter part of June and the month of July, this effect was reduced. However, maximum LAI on the Pawnee site is reached near the middle of June (Knight 1970). Consequently, the LAI values which are reported here do not reflect the maximum LAI in each case. The LAI values obtained for this study should not be used indiscriminantly without considering the date on which each value was determined (Appendix F). Unfortunately, it was not possible to make all determinations in a short time, and therefore the LAI values reported herein are not exactly comparable.

Sampling-units other than the three treatment pastures were sampled during the last of July and the month of August. These sampling-units were sampled after the three treatment pastures since it was felt that it was more essential to obtain an adequate estimate of LAI on the three treatment pastures earlier in the summer.

## Weighted Average LAI

The weighted average LAI values which are presented and discussed here are average values for entire sampling-units. Each of the three summer grazed pastures was a sampling unit. The following discussion then deals not with small homogeneous areas but is concerned with weighted average LAI values for comparatively large heterogeneous sampling-units, composed of as many as 15 sub-types and, following the determination of vegetation types, of as many as 10 vegetation types. LAI values which are presented in the description of vegetation types later on are also average values for rather extensive areas.

These average values are not maximum LAI values for these types since it was not possible to sample all of the sub-types solely during the middle few days of the month of June, nor are the values for the different types precisely comparable.

They do however reflect a "best estimation" of real life vegetation characteristics existing in the study area. Although sampling was conducted after the attainment of maximum LAI the time span involved can be assumed to have resulted in only a minimal proportional decrease because of seasonal changes or grazing impact. Additionally, the differential influence of sampling period span among sub-types, types, and especially the three pasture sample-units, could logically not have significantly changed the weighted average LAI values. It is contended therefore, that LAI data indicating differences among the sample-units (pastures) represent valid conditions subject to logical interpretation.

## Sampling-Unit Comparisons Based on Weighted Average LAI Data

Weighted Average LAI values for each separate sampling-unit have been computed (Appendix F) and to facilitate comparison are presented here in the form of a bar graph (Figure 10). Though, as pointed out earlier, the values here may not be precisely comparable due to the difference in sampling time, it is felt that this discussion is in order, keeping these time discrepancies in mind. An examination of all twelve sampling-units reveals a rather wide variation in values for each of blue grama, buffalo grass, and the TOTAL OF ALL SPECIES. Blue grama ranges from a high of .5910 in the northwestern corner of the study area (H) to a low weighted average value of .2399 in the holding pasture (J) on the south half of section 21 (Appendix E). The extremes of buffalo grass are less widespread than those of blue grama, with a

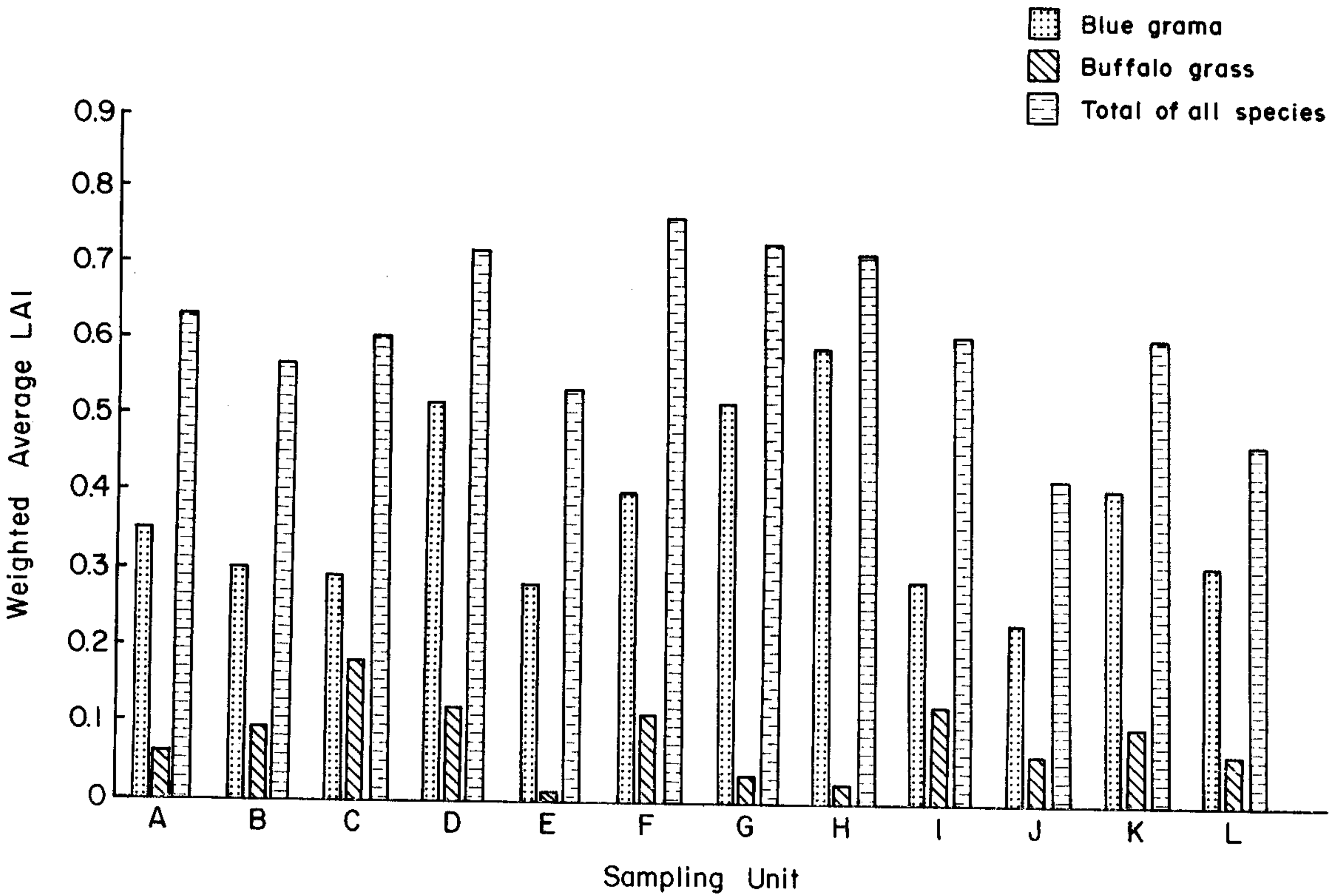


Figure 10. Weighted average LAI values for blue grama, buffalo grass, and the TOTAL OF ALL SPECIES for each pasture or sampling-unit on the Pawnee Site.

minimum of .0072 in the northeast quarter of section 22 (E) and a maximum of .1892 in the heavy grazed pasture (C). The weighted average LAI for the TOTAL OF ALL SPECIES shows the most variation. It drops from a high of .7657 in the southwest quarter of section 14 (F) to a value of .4223 in the holding pasture (J). The lowest weighted average LAI for both the TOTAL OF ALL SPECIES and for blue grama appears in the same sampling-unit, that of the holding pasture (J). This is not really surprising because of the nature of this unit. It is a rather small pasture upon which much grazing use has been concentrated. A narrow valley runs down the middle which leads toward the corrals and watering area located at the northeast corner of the pasture. Consequently nearly all of the animal movement to and from this corner is confined to this small, rather natural pathway. The animal trampling effect and repeated grazing has resulted in a minimal vegetation cover over nearly half the length of this area. A second reason for the low weighted average LAI values here results from the topography and soil conditions in the pasture. The majority of the southern half of the area is taken up by hilltops and ridges breaking and sloping rather steeply into the before mentioned valley on the north. The soil on these ridges and slopes is a very coarse gravel and allows only a sparse vegetation cover. Low weighted average LAI values resulted for the entire pasture because these two conditions prevailed over a large portion of it.

There is quite an apparent fluctuation in weighted average LAI values from unit to unit and this can perhaps be explained in terms of the units themselves. The sampling units differ in size from approximately 130 hectares in the case of the light, medium, and heavy grazed pastures to as small as 5.0 hectares for the area sampled in the northeast quarter of section 22 (E). The number of diverse vegetation sub-types used in computation of weighted average LAI values varies from fifteen in the heavily grazed pasture to two in either of the two diet pastures. With this much variation in size and vegetative content between areas, the fluctuations which appear can be considered to be rather inherent.

There are some rather interesting occurences which manifest themselves if the data from the light, medium, and heavy grazed pastures (A,B,C) are examined aside from the other small areas. These three allow for good comparison as each unit is of nearly equal size. Each pasture has also been apportioned into quite a number of sub-types for which the weighted average LAI has been computed. Perhaps the best reason for comparison is the history of consistent intensity of grazing on each of these pastures.

Upon close scrutiny of the weighted average LAI data, three points are noticeable (Figure 11). These are the following: 1) weighted average LAI for blue grama is highest in the light use pasture and lowest in the heavy use pasture, 2) weighted average LAI for buffalo grass is lowest in the light use pasture and highest in the heavy use, and 3) the weighted average LAI for the TOTAL OF ALL SPECIES seems to simply fluctuate with the highest value found in the light use pasture and the low in the medium use pasture.

Perhaps the most interesting point is the trend in weighted average LAI of blue grama over the three treatments. The weighted average LAI drops from a high of .3536 in the light grazed treatment,

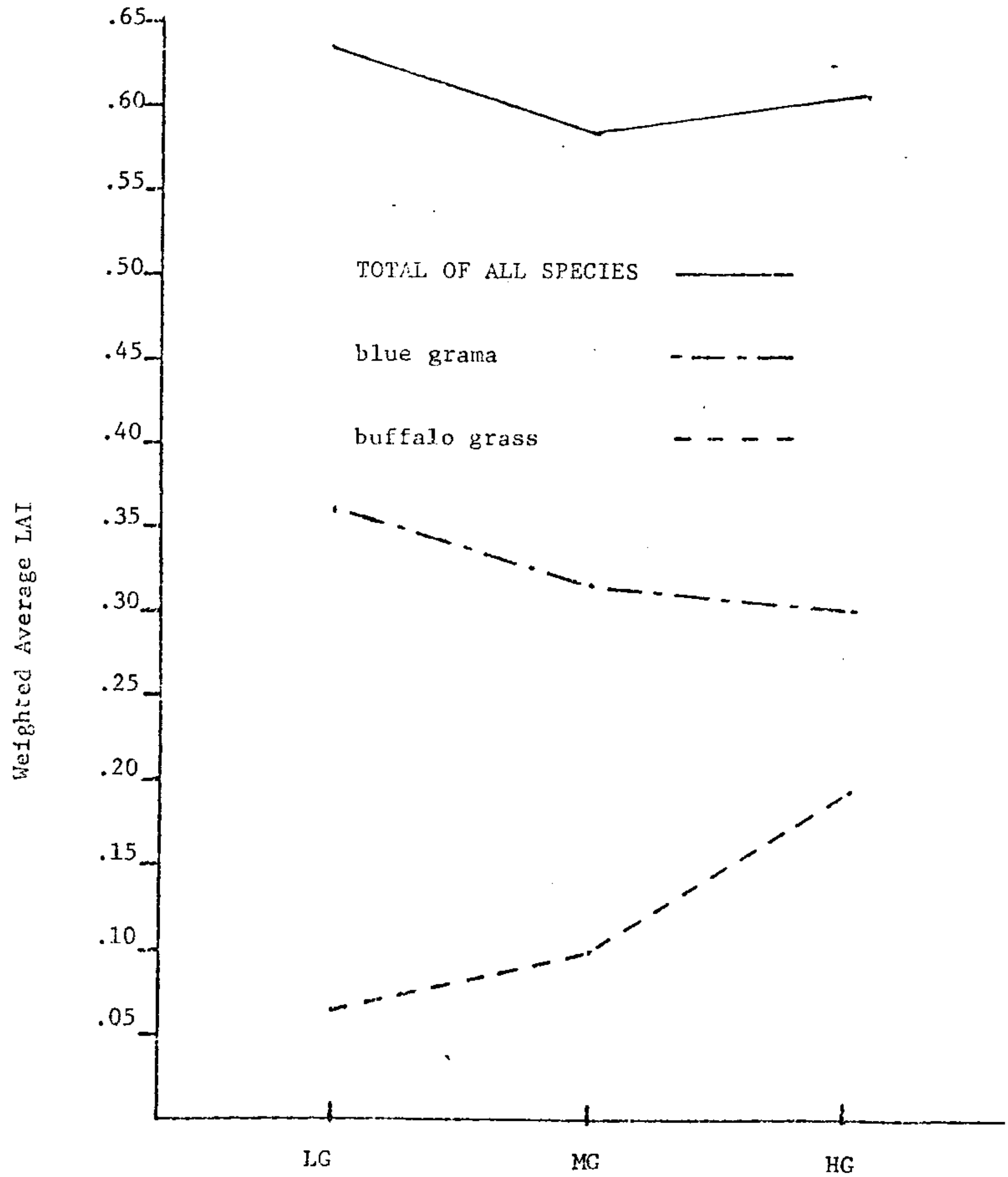


Figure 11. Weighted average LAI for blue grama, buffalo grass, and the TOTAL OF ALL SPECIES, for the light, medium, and heavy grazed pastures on the Pawnee Site.

to .3050 in the medium use pasture, to a low of .2916 in the heavy use pasture. This is a total decrease of .0620 over the three treatments. Blue grama is generally considered an increaser when subjected to grazing pressure but it should be noted that weighted average LAI is under consideration here. Blue grama is no doubt increasing in areas where it is present. These average weighted values imply that the distribution of blue grama is less widespread in the heavy and medium use pastures than in the light use pasture. This would explain the lower weighted values found in the medium and heavy use treatments. All of these values are weighted averages from data which were gathered during the latter part of June and the month of July.

If one sub-type having similar site characteristics is selected from each of the three treatments and actual LAI values are compared in place of weighted average values, a similar situation is noticeable. Sub-type 4 of the light grazed, 7 of the medium grazed, and 8 from the heavily grazed treatments all occupy approximately the same kind of site, that of a low drainage area with approximately the same soils sloping toward Lynn Lake in the heavy grazed pasture. The LAI values for sub-types 4, 7, and 8 for blue grama are .3549, .2142, and .1131, respectively, showing a definite decrease in blue grama LAI with grazing pressure.

If these same three sub-types are compared for LAI of buffalo grass, again the findings are consistent with the trend for the total area. The values of LAI from sub-types 4, 7, and 8, respectively are .0766, .1865, and .4252, again showing an increase in buffalo grass. It should be pointed out that other sub-types fail to exhibit these trends as clearly as do the three which are discussed. It is difficult to select three other sub-types which are as nearly similar in site characteristics as these three are, which was the reason for singling them out for comparison.

Total LAI is somewhat more complicated to discuss. For example, the total weighted LAI values range from .6379 in the light grazed pasture to a minimum of .5711 in the medium use pasture with the heavy use pasture about in the middle at .6029. For previously compared sub-types 4, 7, and 8, the total LAI values are .5906, .6199, and .6669, respectively, showing a definite increase from light to heavy use. Comparison of other sub-types also fails to show any definite tendency to increase, decrease, or remain relatively constant. The only conclusion which can be drawn is that total LAI seems to remain relatively stable regardless of grazing treatment.

## Significant Vegetation Types

A total of 13 separate and distinct types were recognized from the original 66 vegetation sub-types. Two of these types were separated out prior to subjection of the data to H-Group analysis.

One of these (Type 13) consisted of sub-types 6 and 7 in the heavy use pasture. This was termed a type due to the common presence of needle spikesedge (*Eleocharis acicularis* (L.) R. and S.) and torrey rush (*Juncus torreyi* Coville). These two species dominated the vegetation in these two adjoining areas and were essentially nonexistent over the remainder of the study area. Needle spikesedge appeared in minute quantities in just two other areas while torrey rush was not listed as being present anywhere except in this one small region.

The other type (12) discernable through visual inspection of the data occurred in two small, adjacent areas. As in the former case, the decision to lump these into a type was made on the basis of two common, dominant herbaceous species. Pinnate tansymustard (Descurainia pinnata (Walt.) Britt.) and skeletonleaf bursage (Franseria discolor Nutt.) appeared to be rather specific to this one limited site as the former was not recorded in any other area and the latter appeared sparsely in only two other locations.

Each of the two types mentioned above occurred on rather peculiar sites. Both of these are possibly best described as dried-up mud-holes. Both are located on undifferentiated medium and fine textured soils and have a very limited vegetational cover. Buffalo grass occurs in both types but is anything but abundant in either, with the average LAI for buffalo grass in each type being less than .10 in midsummer.

The remaining 11 types present more of a problem in justification and discussion. This is due to a homogeneity of species present in most of the remaining types with differences being more "quantitative" than "qualitative". In other words, there is more variation in abundance of each species present than there is in the species composition of each type.

These 11 types are a result of aerial photo inspection, extensive ground work, and the H-Group analysis (Appendix C). Along with photo and field inspection, a significant F value was computed for 11 groups from the H-Group analysis meaning that these 11 types are significantly dissimilar to warrant consideration as separate types. These types were numbered in descending order solely on the basis of average LAI for blue grama, with type 1 having the highest value and type 11 the lowest (Figure 12, Appendix C). This order was initiated in an effort to reveal any existing relationships of blue grama LAI to that of buffalo grass and/or TOTAL LAI. Figure 12 shows the approximate LAI values for blue grama, buffalo grass, and the TOTAL OF ALL SPECIES calculated as an average of all areas included in each of the 13 types.

Type 1 has an average LAI for blue grama of .5384. It also exhibits one of the highest values for TOTAL LAI (.7349) and one of the lowest values for buffalo grass (.0511). A total of 68.896 hectares are included in this type. The soil types are almost exclusively either Ascalon sandy loam or of the Shingle-Renohill complex. This type varies in elevation from approximately 5,370 feet to an upper limit around 5,510 feet with topography being mostly level to gently sloping. Most of the slope on the area is to the northeast. Species of vegetation rather well distributed throughout the type, other than blue grama and buffalo grass, include needleaf sedge, red three-awn, plains pricklypear (*Opuntia polyacantha* Haw.) and fringed sagewort (*Artemisia frigida* Willd.).

One of the largest types is type 2 which encompasses 256.594 hectares. One interesting feature is that almost the entirety of the light use pasture is included in this type. The average LAI for blue grama is only slightly lower than that of type 1 (.4783 or a drop of .0601) while the LAI for buffalo grass (.0330) and the total (.6395) is also slightly less than that found in type 1. The elevation for this type ranges from 5,390 feet in the light use pasture to a high of 5,550

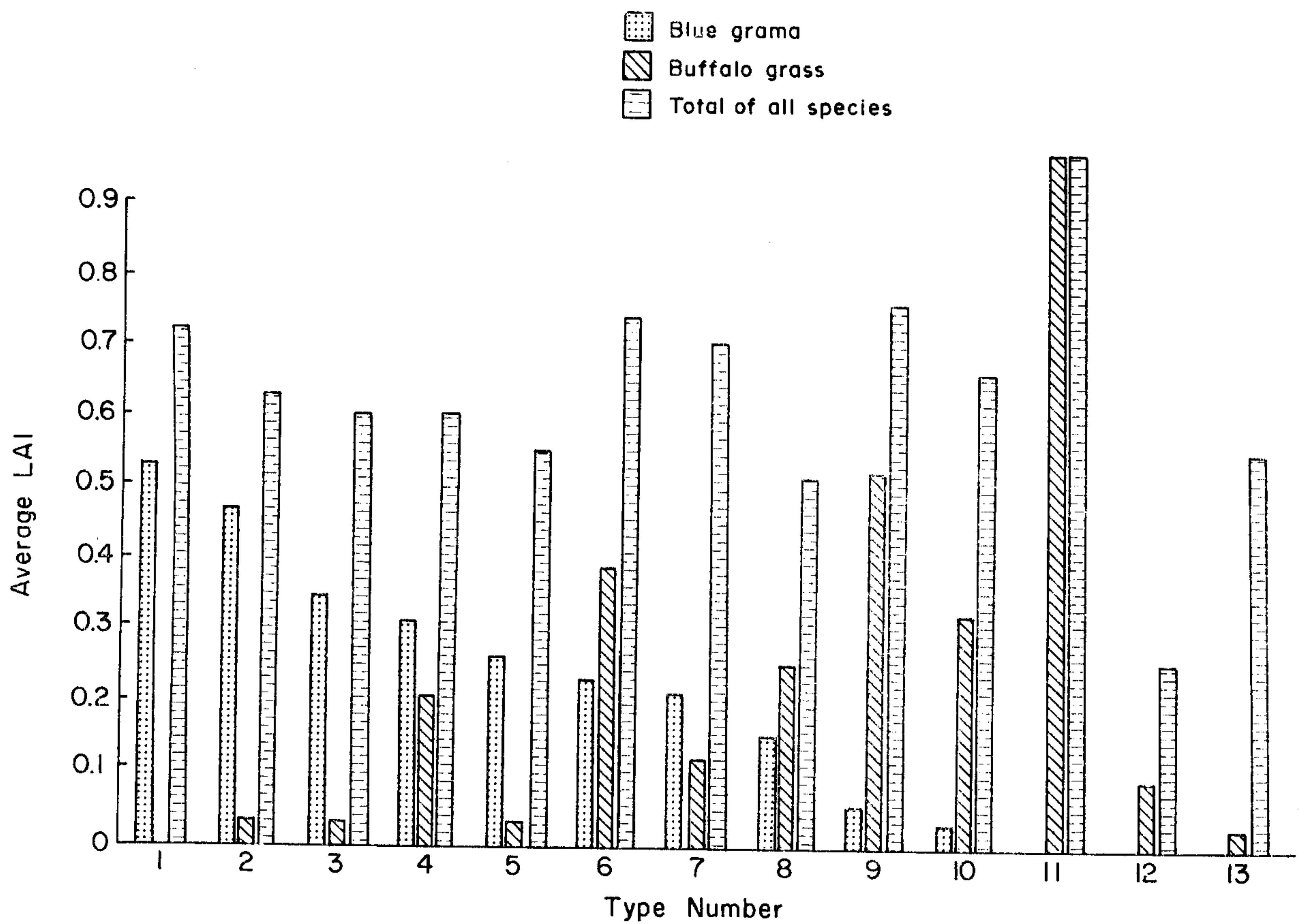


Figure 12. Average LAI values for blue grama, buffalo grass, and the TOTAL OF ALL SPECIES, for each of the thirteen significant vegetation types differentiated on the Pawnee Site.

feet in the northwestern end of the study area. Topography is level to gently sloping in nearly every direction. Soil types common to the area include Ascalon sandy loam, Renohill sandy loam, and those of the Shingle-Renohill complex. There is also an area occurring on medium and light textured soils. Other species common to this type include needleleaf sedge, red three-awn, plains pricklypear, sixweeks fescue (Vulpia octoflora Walt.), scarlet globemallow, and western wheatgrass.

A sizeable decline in average LAI for blue grama is noticeable from type 2 to type 3 (.4783 to .3520 or a difference of .1263). There is also quite a reduction in area as type 3 consists of only 77.638 hectares. The range in elevation within this type is again quite wide (5,390 to 5,520 feet) and topographical features include gently sloping ground to some of the steepest hillsides in the entire area, located in the soutwest quarter of section 14. Vona sandy loam, Renohill sandy loam, Shingle loam, and again the Shingle-Renohill complex soils are among the different soils included in this particular type. Species which are rather abundant include needleleaf sedge, red three-awn, fringed sagewort, and broom snakeweed (Gutierrezia sarothrae (Pursh) Britt. and Rusby).

The fourth vegetation type included in the area has average LAI values of .3175, .2102, and .6134 for blue grama, buffalo grass, and the TOTAL OF ALL SPECIES, respectively. This is a marked increase in buffalo grass over the three previously discussed types (Figure 12). A rather sizeable area of 137.394 hectares is covered by type 4. This type is found almost entirely on flat knolls with the exception of a few lowland areas. Inclusion of these lowland areas stretches the elevational range from a high of 5,510 feet to a low of 5,410 feet or a difference of 100 feet. The range of soils included in this type is also quite variable, including such soil configurations as undifferentiated medium and fine textured soils, Ascalon sandy loam, gravelly and cobbly lands, and the Shingle-Renohill complex. The associated vegetation is less variable in this area with needleleaf sedge being the most prevalent. Plains pricklypear, fringed sagewort, and broom snakeweed are rather common but to a lesser degree than is needleleaf sedge.

Type 5 is another rather small type covering a total of only 44.281 hectares. It is one of the more sparsely populated types in terms of vegetation with an average total LAI of .5576. Blue grama LAI is .2662 and buffalo grass is very limited, exhibiting an LAI of .0260. The elevational range is comparatively narrow for this type ranging from 5,420 feet to approximately 5,470 feet. Nearly the entire area is moderately sloped with a few areas of nearly level ground. Soils in this type are characteristically sandy loams including the Vona, Ascalon, and Renohill series. Some of the Shingle-Renohill complex is also included in this type. Associated vegetation is quite diverse in this type, including such species as needleaf sedge, red three-awn, needleandthread, fringed sagewort, and spreading wildbuckwheat (Eriogonum effusum Nutt.). One interesting feature about this type is that it includes the 30 year exclosures located in the light and medium use pastures but not the one located in the heavy grazed pasture. Considering that all three of these exclosures were placed on sites having similar soils and nearly equal elevation, this is difficult to comprehend. One reason that this one exclosure is not included is quite possibly due to inadequate methodology since the point frame method seemed to be unable to achieve an adequate sample of minor species. Other possible reasons are discussed later.

Buffalo grass achieves a dominance over blue grama in the sixth type, having an average LAI of .3941 to that of .2347 for the latter. The total LAI for type 6 is quite high (.7536). This area is fairly small, including only 8.582 hectares and is confined to a few hilltops and small drainage areas. A range of about 50 feet is covered in elevation with the extremes being 5,380 feet and 5,430 feet. Soils range from undifferentiated medium and fine textured at the lower extremity of one drainage area to Ascalon sandy loam to the Shingle-Renohill complex. Needleleaf sedge and red three-awn are quite prevalent over most of this type. Rubber rabbitbrush (Chysothamnus nauseosus (Pall.) Britt.) was also recorded as being of some importance on one small part of the area.

Type 7 is rather easy to discuss as it is comprised of only one area from the 66 sub-types originally delineated. It occurs in a narrow, gently sloping drainage area on medium textured soils. The area covered by this type is only 1.214 hectares. The LAI values on this area for blue grama, buffalo grass, and the TOTAL OF ALL SPECIES are .2130, .1175, and .7159, respectively. The species which sets this area aside, however, is western wheatgrass. It occurred rather abundantly, being recorded a mean of .10 times for each pin drop. Needleleaf sedge is quite prevalent in this type also.

Type 8 covers a total of 48.930 hectares. Blue grama and buffalo grass on the area show respective LAI values of .1532 and .2547 while the total LAI for the type is .5255. The elevational range of this type is about 60 feet, ranging from 5,410 feet to 5,470 feet. Soils range from loams to sandy loams to gravelly and cobbly lands. Most of the type is located on gravelly hilltops and sidehills with the exception of some loamy soils in the southwest corner of the medium grazed pasture and on the west side of the heavy use pasture. Red three-awn and needleleaf sedge are the predominant minor species which grow within this type.

Buffalo grass exhibits a real dominance in type 9, with an average LAI of .5334. Blue grama is limited in this type, showing a value of .0576 while total LAI is quite high at .7730. A total of 28.906 hectares make up this small type. The majority of the type is found on undifferentiated medium and fine textured soils although the type overlaps onto some Ascalon sandy loam sites. The elevational range of approximately 20 feet (5,400 feet to 5,420 feet) is one of the narrowest ranges of any of the 13 types. The entire type occurs on nearly level land. Needleleaf sedge is the species most commonly associated with buffalo grass in this type although needle spikesedge and silky sophora (Sophora sericea Nutt.) are found quite often in certain small areas within the type.

An average LAI of .3268 for buffalo grass shows that this species is again quite abundant in type 10. The total LAI is also quite high (.6726) while blue grama is virtually nonexistent (.0290). Undifferentiated medium and fine textured soils underlie the entire type. Again in this type there is a limited range of elevation (5,420 feet to 5,460 feet). This type occurs in narrow water receiving areas on rather level land. The type is a comparatively small one taking up only 13.632 hectares. The most commonly recorded species, other than buffalo grass, are western wheatgrass and needleleaf sedge. Needle spikesedge and hairy goldenaster (Heterotheca villosa (Pursh.) Skinners) are also quite frequent in two separate small areas of the type.

The last type to be discussed (Type 11) is the most peculiar of the 13 types. There are two reasons for this, the first being that buffalo grass was the only species encountered during sampling, and the second reason is that it has the highest total LAI (.9959) of any of the 13 types. This type is also limited to the undifferentiated medium and fine textured soils. It is a very small type of only 2.016 hectares and is located at an elevation of 5,390 feet, immediately surrounding the dry lake bed in the heavy grazed pasture. There are no species in association with buffalo grass in this type.

## Vegetation Types, Soils, Topography, and Grazing

Soil type, topography, and past grazing use all are intricately involved in the determination of the vegetation type. In a homogeneous grassland, such as is found on the Pawnee Site, the associational aspects are hidden to an extent, especially those of soil and topography. They are a reality, however, and will be discussed individually.

Soils

Soil type probably has a more pronounced effect on vegetation than does any other single factor. This effect, however, is one of the most difficult to recognize due to the similarity in soil types of this region. Of the 11 soil types presented on the soils map (Appendix H), four are classified as some type of sandy loam, four of them as loams, leaving only three not described as a loam of some sort. This results in a rather homogeneous soils map representing a minimum in variation due to the soil. If the three non-loam soils are inspected, especially the undifferentiated medium and fine textured soils, and the gravelly and cobbly lands, other associations of soils and vegetation are noticeable.

Vegetation types 4, 6, 7, and 9 through 13 are all located, at least partially, on undifferentiated medium and fine textured soils. These types also have the highest LAI values for buffalo grass and some of the lowest blue grama values. Types 12 and 13 are exceptions to the rule of abundance of buffalo grass but this is easily explained. Each lies in a water holding pocket where the soil would be very moist during periods of high precipitation. The vegetation is so sparse because of these extremely wet periods that it offers no protection from sun and wind thus allowing the ground to essentially "bake" during periods of little moisture. Moisture then becomes a limiting factor causing the slight vegetation cover.

Where these medium and fine soils appear there is also a minimum amount of blue grama. Where the entire type, such as types 10 and 11, is found on this one soil type, blue grama is virtually non-existent.

The gravelly and cobbly lands also seem to provide a good site for growth of buffalo grass. Types 4 and 8 are prime examples of this. Each of these types are located primarily on hilltops and sandy to rocky slopes. These soils also prove to be sites where blue grama and buffalo grass occur as co-dominants.

Topography

The effect which topography has on the vegetation is more apparent than that of soil type. Though there is really not much relief over the entire study area, what little there is has a definite effect on the quality and quantity of the vegetation.

Those types which occur on the level to gently sloping upland areas are definitely dominated by blue grama with only small patches of buffalo grass. An abundance of blue grama is apparent in types 1, 2, 3, and 5 as is a definite lack of any appreciable amounts of buffalo grass. All four of these types have relief features similar to those described above. Each of these types also has similar associated species and the variation in types is due almost entirely to density of vegetation.

If type 4 is taken as an example, one point is noticeable. Included in this type are two extremes in topography, that of ridge tops and definite low drainage areas. A rather high LAI for buffalo grass is found on this area as is a high LAI of blue grama. This condition is found in type 6 also, which is rather similar in topographic layout. The difference between these two types is that significantly more buffalo grass appears in the latter type. Other types having similar topographic features also have blue grama and buffalo grass as co-dominants.

When a type lies in a low drainage area, buffalo grass is the dominant species. There are some exceptions to this which have already been pointed out in the discussion of soil types. Here again the differences in types are intricately tied to denseness of the vegetation since associated species are very similar in each of the lowland types.

Grazing

Only two points are discussed here. The first of these has been discussed earlier when it was brought out that the weighted average LAI of blue grama is lowest in the heavily grazed pasture and that of buffalo grass is highest. An inspection of the 13 types seems to substantiate this since a majority of the area in the light grazed pasture is found in type 2 which has the second highest LAI for blue grama of the 13 types. A good portion of the heavy use pasture is likewise included in types which show an abundance of buffalo grass. One additional factor should be mentioned here. The heavy grazed pasture is located in such a manner that more sites, such as lowland having medium to fine textured soils, are included within its boundaries. This would also have the effect of depressing blue grama LAI while increasing that of buffalo grass.

The 30 year exclosures are the basis for further discussion of grazing. It was stated earlier that the exclosure in the heavy use pasture is grouped into a type separate from that which includes the light and medium use exclosures. One possible explanation for this, especially since these exclosures are 30 years old, is the influence of the surrounding vegetation on that within the exclosure. Seedling establishment in the exclosure would definitely depend on available seeds and those from surrounding vegetation would be more available than any other. There also seems to be quite a bit of personnel traffic in and out of this exclosure during the sampling season, more so than in either of the other exclosures. It is possible that this movement and subsequent trampling effect may offer an explanation for the difference in vegetation within this exclosure.

## SUMMARY

Each of the three types of imagery used in this study gave excellent results. The color and infrared prints were slightly more useful in making very detailed delineations. Areas which were discernable on the photos were generally easily recognized in the field and areas which looked similar on the photos also appeared similar on the ground. This was a great aid in the interpretation of the H-Group analysis and in the subsequent grouping of sub-types.

On the basis of denseness of vegetation, there are 13 separate vegetation types on the Pawnee Site. These, at least some of them, are difficult to recognize visually because they are distinguished due to quantitative measures to a greater extent than they are to qualitative aspects.

The Point Frame method employed was perhaps not the best method for this kind of project. It was noted that sub-types could not be sampled in a short period of time thus making LAI values incomparable to an extent. This method also did not adequately sample many of the minor species, at times missing some quite noticeable species altogether. This made it necessary to pay more attention to quantity of encountered species rather than species present when typing the areas.

The weighted average LAI of blue grama was found to be highest in the light use pasture and lowest in the heavy use pasture while that of buffalo grass was found to be the opposite. Grazing naturally has a lowering effect on LAI as does seasonal advancement as growing conditions,

especially availability of moisture, become less favorable. These factors must be taken into consideration when evaluating the LAI data which were gathered. Since the majority of the heavy use pasture was sampled in late June or early July (Appendix F) when grazing animals had been on the area for only a short time it was felt that the grazing pressure would have had only a minimal effect on LAI at this time. The light use pasture was sampled later in July consequently the deterioration of vegetation and decreased LAI because of seasonal advancement would have been greater than earlier in the season. Since the weighted average LAI in the light use pasture was greater even under these conditions it is felt that a valid assumption can be drawn from this data. Long term heavy grazing seems to lower the weighted average LAI of blue grama. This is reasonable when the effect of heavy grazing over a thirty year period and consequent trampling of vegetation is taken into account. It would seem reasonable that blue grama vigor in the heavy use pasture would be less than in the light use treatment thus accounting for the lower LAI. The total weighted average LAI for the three pastures is nearly equal regardless of grazing treatment. Since these three pastures have been under the same intensity of grazing for more than thirty years a stable condition now exists in each of them. The loss of LAI exhibited by some species (such as blue grama) has evidently been compensated for by an increase in LAI for other species. Buffalo grass is one such species which has increased in LAI from light to heavy grazing pressure. Other of the more minor species have perhaps also increased, especially those which are not especially palatable to cattle. Therefore the reduction in average LAI of blue grama would have been offset by this increase accounting for the total average LAI being nearly equal in each of the three treatment pastures.

Upland sites offer more favorable conditions for growth of blue grama than do lowland sites. Consequently Leaf Area Index is greater for this species on the upland sites. The opposite is true for buffalo grass except that ridges also support a good amount of buffalo grass.

Soil type is evidently the major deciding factor in vegetation type. This and topography intermingle, however, to cause the large scale pattern of vegetation types found on the Pawnee Site.

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# APPENDIXES

# APPENDIX A

Codes and scientific names of plants found on the study area.

| Code | Scientific Name |
|---|---|
| AGSM** | *Agropyron smithii* Rydb. |
| ARFR** | *Aremisia frigida* Willd. |
| ARLO** | *Aristida longiseta* Steud. |
| ASMI | *Astragalus missouriensis* Nutt. |
| ASMO | *Astragalus mollissimus* Torr. |
| ASSP | *Astragalus spatulatus* Sheld. |
| ASTA | *Aster tanacetifolius* H. B. K. |
| ATCA | *Atriplex canescens* (Pursh) Nutt. |
| BAOP** | *Bahia oppositifolia* (Nutt.) Dc. |
| BOGR** | *Boutelous gracilis* (H. B. K.) Lag. |
| BRJA | *Bromus japonicus* Thunb. |
| BRTE | *Bromus tectorum* L. |
| BUDA** | *Buchlöe dactyloides* (Nutt.) Engelm. |
| CAEL** | *Carex eleocharis* Bailey |
| CAFI** | *Carex filifolia* Nutt. |
| CHDI | *Chenopodium desiccatum* A. Nels. |
| CHNA** | *Chrysothamnus nauseosus* (Pall.) Britt. |
| CIAR | *Cirsium arvense* (L.) Scop. |
| DEPI | *Descurainia pinnata* (Walt.) Britt. |
| DIST | *Distichlis stricta* (Torr.) Rydb. |

** The 19 species which were used in the H GROUP analysis are double starred.

| Code | Scientific Name |
|---|---|
| ELAC | Eleocharis acicularis (L.) R. + S. |
| ERCA | Erigeron canadensis L. |
| EREF** | Eriogonum effusum Nutt. |
| EVNU | Evolvulus nuttallianus Roem. + Schult. |
| FRDI | Franseria discolor Nutt. |
| GACO | Gaura coccinea Nutt. ex Pursh |
| GUSA** | Gutierrezia sarothrae (Pursh) Britt. + Rusby |
| HEVI** | Heterotheca villosa (Pursh) Skinners |
| HEHO | Heterotheca horrida |
| JUTO | Juncus torreyi Coville |
| LARE | Lappula redowskii (Hornem.) Greene |
| LEDE** | Lepidium densiflorum Schrad. |
| LIPU | Liatris punctata Hook. |
| LYJU | Lygodesmia juncea (Pursh) D. Don. |
| MAVI | Mammillaria vivipara (Nutt.) Haw. |
| MUTO** | Muhlenbergia torreyi (Kunth) Hitchc. |
| OECO | Oenothera coronopifolia Torr. + Gray |
| OPPO** | Opuntia polyacantha Haw. |
| OXSE | Oxytropis sericea Nutt. |
| PLPU | Plantago purshii Roem. + Schult. |
| POAV | Polygonum aviculare L. |
| PSTE | Psoralea tenuiflora Pursh |
| RACO | Ratibida columnaris (Sims.) D. Don. |
| SAKAT | Salsola kali tenuifolia Tausch. |
| SCPA | Schedonnardus paniculatus (Nutt.) Trel. |

| Code | Scientific Name |
|---|---|
| SIHY | *Sitanion hystrix* (Nutt.) J. C. Smith |
| SOSE** | *Sophora sericea* Nutt. |
| SPCO** | *Sphaeralcea coccinea* (Pursh) Rydb. |
| SPCR | *Sporobolus cryptandrus* (Torr.) A. Gray |
| STCO** | *Stipa comata* Trin. and Rupr. |
| THTR | *Thelasperma trifidum* (Poir.) Britt. |
| VUOC** | *Vulpia octoflora* Walt. |
| YUGL | *Yucca glauca* Nutt. |

## APPENDIX B

The coding system used for the 12 sampling-units and respective sub-type designations in the H GROUP analysis.

| Code | Sampling Unit or Area* |
|---|---|
| A01 through A08 | Light Grazed Pasture: W½ Sec. 23. |
| B01 through B12 | Medium Grazed Pasture: E½ Sec. 15. |
| C01 through C15 | Heavy Grazed Pasture: E½ Sec. 23. |
| D01 through D07 | W½ Sec. 24. |
| E01 | NE¼ Sec. 22. |
| F01 through F04 | SW¼ Sec. 14. |
| G01 through G03 | NW¼ Sec. 15. |
| H01 and H02 | E½ Sec. 9; SW¼ Sec. 10; and NE¼ Sec. 16. |
| I01 through I06 | S½ Sec. 21. That portion not included in any of the following areas. |
| J01 through J04 | S½ Sec. 21. Holding Pasture. |
| K01 and K02 | S½ Sec. 21. Light Grazed Diet Pasture |
| L01 and L02 | S½ Sec. 21. Heavy Grazed Diet Pasture |

* With the exception of the light, medium, and heavy use pastures and the S½ of Section 21, these areas were sampled only in that portion of them which was included in the Central Basin Watershed.

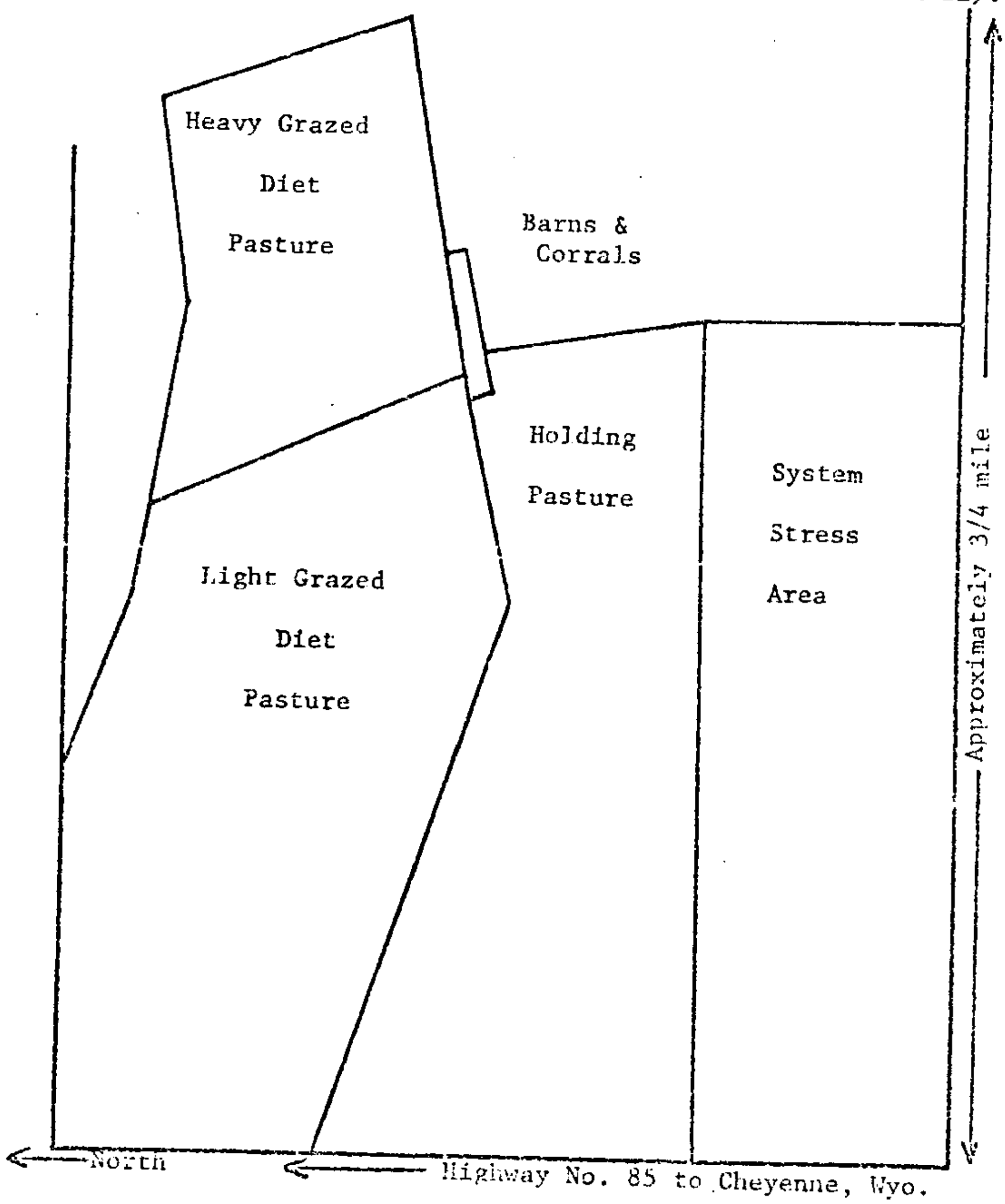
## APPENDIX C

The thirteen significant vegetation types present on the Pawnee Site with code designation of all sub-types.

| Type | A Listing of the Coded Sub-types Included in Each Type |
|---|---|
| 1 | C01, D04, G01, and G02 |
| 2 | A02, A03, A04, A06, A07, B08, C04, C15, D01, D05, D06, F04, H01, H02, I05, K02, and L02. |
| 3 | A05, B01, F03, I03, J02, J03, and L01. |
| 4 | B07, C03, C10, D03, D07, F01, F02, G03, J04, and K01. |
| 5 | A08, B03, B06, B12, C11, and E01. |
| 6 | C02, D02, and I04. |
| 7 | I02. |
| 8 | A01, B04, B05, B09, B11, and C09. |
| 9 | B10, C05, and C08. |
| 10 | B02, I01, I06, and J01. |
| 11 | C12. |
| 12 | C13 and C14. |
| 13 | C06 and C07 |

# APPENDIX D

Developments on the Environmental Stress Area ($S\frac{1}{2}$ of Section 21).



# APPENDIX E

Weighted average LAI values for each sampling-unit.

| Sampling-unit (code) | Weighted LAI values blue grama | buffalo grass | Total |
|---|---|---|---|
| A | .3536 | .0638 | .6379 |
| B | .3050 | .0950 | .5711 |
| C | .2916 | .1892 | .6029 |
| D | .5165 | .1268 | .7204 |
| E | .2836 | .0072 | .5362 |
| F | .4040 | .1196 | .7657 |
| G | .5172 | .0362 | .7346 |
| H | .5910 | .0141 | .7203 |
| I | .2914 | .1286 | .6099 |
| J | .2399 | .0631 | .4223 |
| K | .4110 | .0972 | .6097 |
| L | .3147 | .0624 | .4702 |

# APPENDIX F

Description of Vegetation Sub-Types for the Vegetation Map of the IBP Pawnee Site: The number in parenthesis following each species is, in the case of BOGR and BUDA, the respective LAI value, and for all other species it represents the mean number of hits per pin. It should be remembered that these LAI values are not the maximum LAI on the area since the maximum occurs about the middle of June (Knight 1970). The sampling dates provide a guide to indicate how much after the middle of June these values were obtained and the LAI would have decreased accordingly with time.

Table 1. W½ Sec. 23. Light Grazed Pasture, CODE A

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface Area (Ha) |
|---|---|---|---|---|
| 1 | July 7 | BUDA (.3396),BOGR (.1148)<br>ARLO (.0125),CAEL (.0125) | .5232 | 11.686 |
| 2 | July 7 | BOGR (.5738)<br>CAEL (.0175),ARLO ).0125) | .7435 | 10.695 |
| 3 | July 17 | BOGR (.3640)<br>CAEL (.0283),ARLO (.0217)<br>OPPO (.0217) | .6884 | 57.504 |
| 4 | July 8 | BOGR (.3549),BUDA (.0766)<br>CAEL (.0283) | .5906 | 14.087 |
| 5 | July 7 | BOGR (.3855)<br>ARFR (.0475),CAEL (.0350) | .6976 | 6.590 |
| 6 | July 8 | BOGR (.4002)<br>CAEL (.0320),ARLO (.0160) | .5764 | 7.100 |
| 7 | July 20 | BOGR (.4406)<br>CAEL (.0275),THTR (.0150) | .5370 | 15.378 |
| 8 | July 8 | BOGR (.2019)<br>STCO (.0440),CAEL (.0260)<br>ARFR (.0260) | .4956 | .838 |
| S | | | | .675 |
| corral | | | | 1.097 |
| 12 | July 6 | | | 2.989 |

APPENDIX F (Cont.)

Table 1. (Cont.)

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface Area (Ha) |
|---|---|---|---|---|
| 13 | July 30 | Sub-Types 12, 13, and 14 have the same description as in the heavy grazed pasture. | | .475 |
| 14 | July 30 | | | .228 |
| | | | Total area = | 129.342 |

APPENDIX F (Cont.)

Table 2. E½ Sec. 15. Medium Grazed Pasture. CODE B

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface Area (Ha) |
|---|---|---|---|---|
| 1 | July 9 | BOGR (.4176)<br>EREF (.0525),ARLO (.0400) | .8031 | 13.537 |
| 2 | July 9 | BUDA (.4176)<br>CAEL (.0900),HEVI (.0550) | .8949 | .482 |
| 3 | July 19 | BOGR (.2800)<br>ARFR (.0500),CAEL (.0425) | .6058 | .841 |
| 4 | July 19 | BOGR (.1652),BUDA (.3213)<br>CAEL (.0475) | .6517 | 9.573 |
| 5 | July 19 | BOGR (.1652),BUDA (.1928)<br>CAEL (.0400) | .4956 | 14.919 |
| 6 | July 20 | BOGR (.2800),BUDA (.0918)<br>ARLO (.0400) | .6012 | 18.523 |
| 7 | July 21 | BOGR (.2142),BUDA (.1865)<br>CAEL (.0317) | .6119 | 11.105 |
| 8 | July 20 | BOGR (.3855)<br>CAEL (.0183),ARLO (.0100) | .5017 | 60.281 |
| 9 | July 21 | BOGR (.1652),BUDA (.1652)<br>CAEL (.0275),HEVI (.0275) | .4865 | 2.498 |
| 10 | July 22 | BUDA (.5416)<br>CAEL (.0450),SOSE (.0425) | .8536 | 1.469 |
| 11 | July 23 | BOGR (.1652),BUDA (.2891)<br>AGSM (.0375) | .6012 | 2,942 |
| 12 | July 23 | BOGR (.2249)<br>ARLO (.0400),HEVI (.0500) | .5828 | 2.026 |
| S | | | | .200 |
| | | | Total area = | 138.396 |

APPENDIX F (Cont.)

Table 3. E½ Sec. 23. Heavy Grazed Pasture. CODE C

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface Area (Ha) |
|---|---|---|---|---|
| 1 | June 28 | BOGR (.4406), BUDA (.0979)<br>CAEL (.0183) | .6548 | 32.068 |
| 2 | June 28 | BOGR (.3075), BUDA (.4131)<br>CAEL (.0350) | .8536 | 2.020 |
| 3 | June 29 | BOGR (.3167), BUDA (.2433)<br>CAFI (.0050), OPPO (.0050) | .5966 | 4.158 |
| 4 | June 29 | BOGR (.4635)<br>CAEL (.0150), VUOC (.0200) | .5966 | 9.388 |
| 5 | June 30 | BUDA (.6334)<br>CAEL (.0475), ELAC (.0250) | .7986 | 1.832 |
| 6 | June 30 | BUDA (.0519)<br>AGSM (.0217), ELAC (.3266) | .7343 | .259 |
| 7 | June 30 | ELAC (.0750)<br>FRDI (.0283), JUTO (.1100) | .3916 | .025 |
| 8 | July 1 | BOGR (.1131), BUDA (.4252)<br>CAEL (.0380) | .6669 | 25.605 |
| 9 | July 1 | BOGR (.1437), BUDA (.2203)<br>ARLO (.0100) | .3947 | 7.312 |
| 10 | July 2 | BOGR (.3415), BUDA (.1579)<br>OPPO (.0220) | .6094 | 19.230 |
| 11 | July 2 | BOGR (.3258)<br>CAEL (.0275), EREF (.0150) | .5277 | 17.373 |
| 12 | July 6 | BUDA (.9959) only species | .9959 | 2.016 |
| 13 | July 30 | BUDA (.1744)<br>DEPI (.0333), FRDI (.0400) | .3334 | .528 |
| 14 | July 30 | BUDA (.0092), DEPI (.0117)<br>FRDI (.0800), POAV (.0050) | .1867 | 3.198 |
| 15 | July 6 | BOGR (.5186), BUDA (.0125)<br>CAEL (.0175) | .6058 | .985 |
| S | | | | 1.216 |
| | | | Total area = | 127.163 |

APPENDIX F (Cont.)

Table 4. W½ Sec. 24. CODE D

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface Area (Ha) |
|---|---|---|---|---|
| 1 | Aug. 25 | BOGR (.5507),BUDA (.0276) CAEL (.0250) | .6838 | .194 |
| 2 | Aug. 25 | BOGR (.2386),BUDA (.4131) ARLO (.0225) | .7940 | .888 |
| 3 | Aug. 25 | BOGR (.3213),BUDA (.3029) CAEL (.0125) | .6562 | .006 |
| 4 | Aug. 24 | BOGR (.6884),BUDA (.0367) ARLO (.0125),OPPO (.0125) | .7940 | 1.291 |
| 5 | Aug. 24 | BOGR (.6012),BUDA (.0780) CAEL (.0375) | .7710 | 1.463 |
| 6 | Aug. 25 | BOGR (.5461),BUDA (.0505) ARLO (.0550) | .6792 | 3.231 |
| 7 | Aug. 24 | BOGR (.4452),BUDA (.2111) CAEL (.0100) | .6976 | 2.425 |
| S | | | | .053 |
| | | | Total area = | 9.551 |

Table 5. NE¼ Sec. 22. CODE E

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface Area (Ha) |
|---|---|---|---|---|
| 1 | Aug 4 | BOGR (.2846) ARLO (.0425),CAEL (.0250) | .5324 | 4.680 |
| 1-LG | | 1-LG and 5-LG have the same description as 1 and 5 in the light grazed pasture | | .106 |
| 5-LG | | | | .191 |
| S | | | | .022 |
| | | | Total area = | 4.999 |

APPENDIX F (Cont.)

Table 6. SW¼ Sec. 14. CODE F

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface area (Ha) |
|---|---|---|---|---|
| 1 | Aug. 30 | BOGR (.3075),BUDA (.2846) ARFR (.0325) | .7389 | 7.981 |
| 2 | Aug. 31 | BOGR (.3764),BUDA (.1652) GUSA (.0250) | .6150 | 5.584 |
| 3 | Aug. 31 | BOGR (.4039),BUDA (.0643) ARFR (.0725) | .8582 | 13.001 |
| 4 | Aug. 31 | BOGR (.5140) ARFR (.0350),SPCO (.0275) | .7480 | 8.408 |
| | | | Total area = | 34.974 |

Table 7. NW¼ Sec. 15. CODE G

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface area (Ha) |
|---|---|---|---|---|
| 1 | Aug. 18 | BOGR (.4920),BUDA (.0367) ARFR (.0200),CAEL (.0420) | .7710 | 11.311 |
| 2 | Aug. 18 | BOGR (.5324),BUDA (.0331) CAEL (.0340) | .7196 | 23.791 |
| 3 | Aug. 19 | BOGR (.3341),BUDA (.2092) CAEL (.0100) | .5911 | .397 |
| | | | Total area = | 35.499 |

Table 8. E½ Sec. 9; SW¼ Sec. 10; & NE¼ Sec. 16. CODE H

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface area (Ha) |
|---|---|---|---|---|
| 1 | Sept. 2 | BOGR (.5920) AGSM (.0125),ATCA (.0100) | .7205 | 32.041 |
| 2 | Sept. 2 | BOGR (.5599),BUDA (.0367) ARFR (.0300) | .6884 | .213 |
| FIELD | | | | 72.546 |
| | | | Total area = | 104.800 |

APPENDIX F (Cont.)

Table 9. S½ Sec. 21. CODE I

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface area (Ha) |
|---|---|---|---|---|
| 1 | Aug. 5 | BUDA (.3534)<br>AGSM (.0675),CAEL (.1450) | .7756 | 9.031 |
| 2 | Aug. 17 | BOGR (.2130),BUDA (.1175)<br>AGSM (.1000) | .7159 | 1.214 |
| 3 | Aug. 5 | BOGR (.3855),BUDA (.0321)<br>CAEL (.0200) | .5874 | 24.428 |
| 4 | Aug. 5 | BOGR (.1579),BUDA (.3561)<br>CHNA (.0120) | .6131 | 5.674 |
| 5 | Aug. 11 | BOGR (.3782),BUDA (.0807)<br>CAEL (.0140) | .5874 | 20.030 |
| 6 | Aug. 5 | BUDA (.2937)<br>CAEL (.0850),ELAC (.0700) | .6012 | .855 |
| S | | | | .477 |
| Headquarters | | | | .570 |
| | | | Total area = | 62.279 |

Table 10. S½ Sec. 21. Holding Pasture. CODE J

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface area (Ha) |
|---|---|---|---|---|
| 1 | Aug. 11 | BUDA (.2423)<br>AGSM (.0300),CAEL (.0300) | .4186 | 3.264 |
| 2 | Aug. 11 | BOGR (.2732)<br>ARFR (.0500),GUSA (.0160) | .4773 | 5.711 |
| 3 | Aug. 11 | BOGR (.3121)<br>GUSA (.0120),OPPO (.0100) | .3855 | 7.278 |
| 4 | Aug. 10 | BOGR (.2130),BUDA (.1652)<br>GUSA (.0120) | .4369 | 1.926 |
| Corrals and Barns | | | | .149 |
| | | | Total area = | 18.328 |

APPENDIX F (Cont.)

Table 11. S½ Sec. 21. Light Grazed Diet Pasture. CODE K

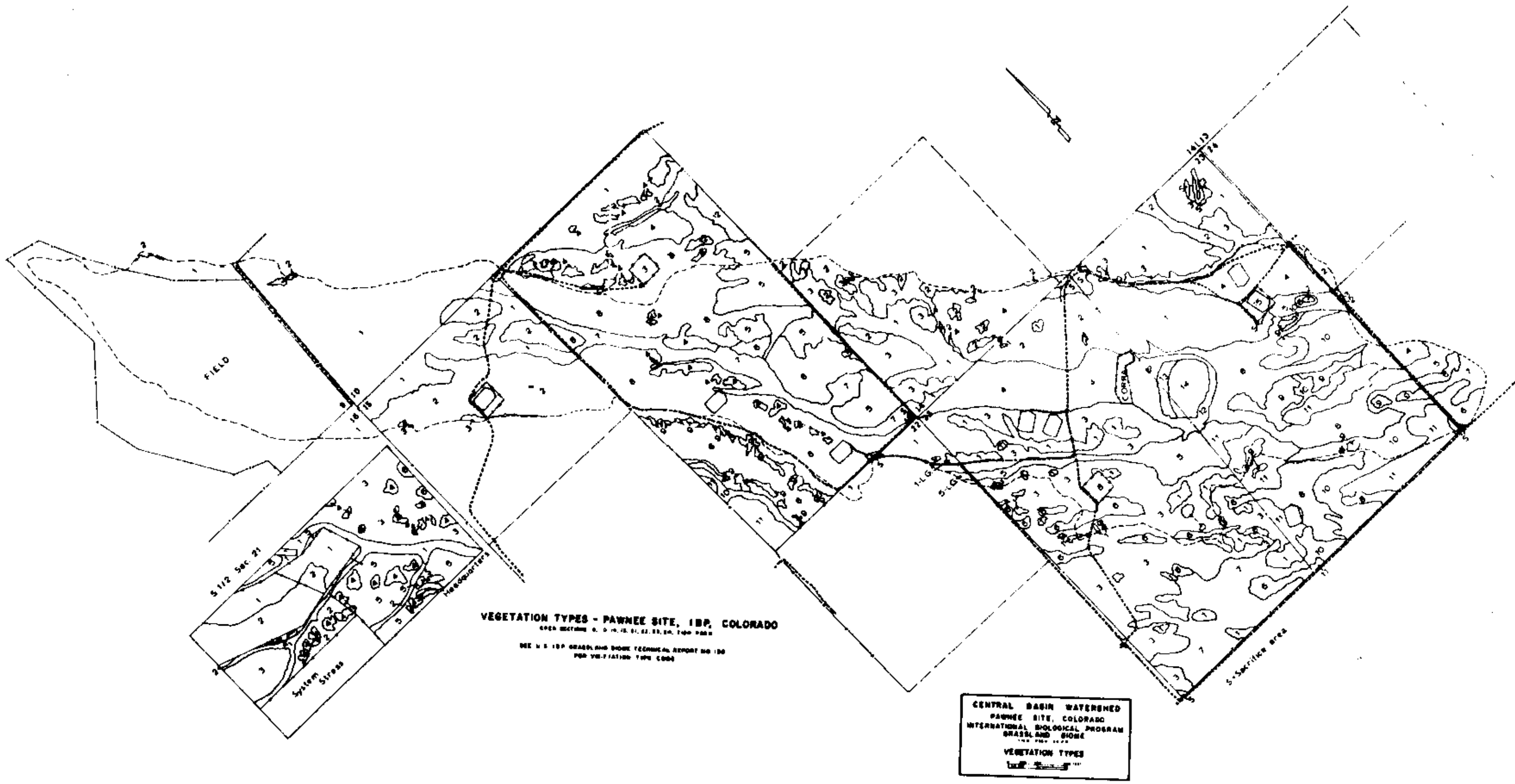
| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface area (Ha) |
|---|---|---|---|---|
| 1 | Aug. 17 | BOGR (.3048),BUDA (.1763) ARFR (.0300) | .5801 | 6.944 |
| 2 | Aug. 17 | BOGR (.4626),BUDA (.0587) VUOC (.0220) | .6241 | 14.272 |
| | | Total area = | | 21.216 |

Table 12. S½ Sec. 21. Heavy Grazed Diet Pasture. CODE L

| Sub-Type No. | Sampling Date | Most Common Species | Total LAI | Surface area (Ha) |
|---|---|---|---|---|
| 1 | Aug. 16 | BOGR (.2864),BUDA (.0661) ARFR (.0200) | .4553 | 7.093 |
| 2 | Aug. 16 | BOGR (.4259),BUDA (.0478) GUSA (.0120) | .5287 | 1.809 |
| | | Total area = | | 8.902 |

System Stress Area = 18.775 Hectares

Total Area for the South ½ of Section 21 = 129.500 Hectares

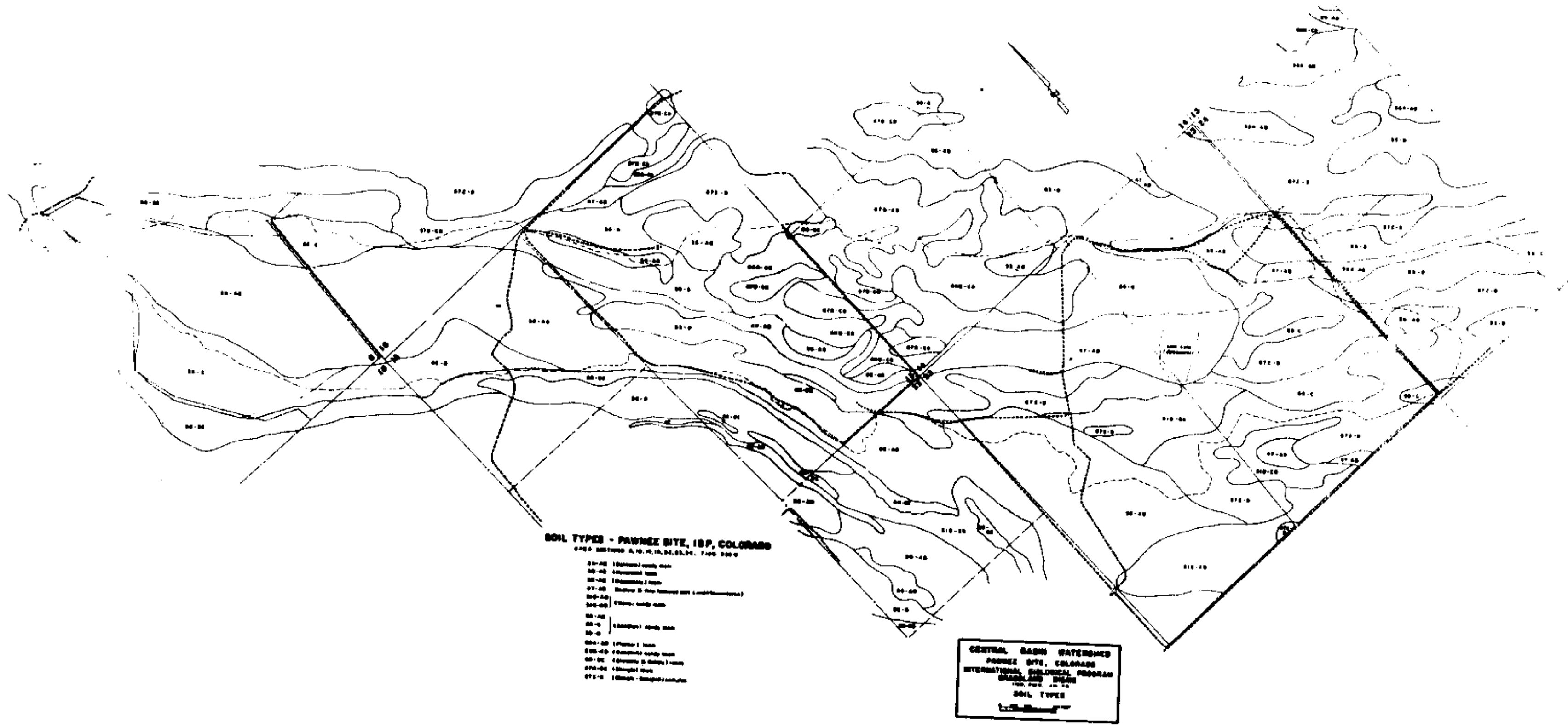



## APPENDIX G

Map of vegetation types of the Pawnee Site.


APPENDIX H

Map of soil types of the Pawnee Site.




APPENDIX I

Map of topography of the Pawnee Site.