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# GRASSLAND COMMUNITIES OF THE WICHITA MOUNTAINS WILDLIFE REFUGE

A DISSERTATION

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# GRASSLAND COMMUNITIES OF THE WICHITA MOUNTAINS WILDLIFE REFUGE

APPROVED BY

DISSERTATION COMMITTEE

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TABLE OF CONTENTS

LIST OF TABLES

## LIST OF ILLUSTRATIONS

# GRASSLAND COMMUNITIES IN THE WICHITA MOUNTAINS WILDLIFE REFUGE

## INTRODUCTION

Many studies describing the vegetation of the Wichita Mountains have been reported (Eskew 1938, Blair and Hubbell 1938, Bruner 1931, Diehl 1953, Larrance 1930, Koford 1958, Duck and Fletcher 1945). Such studies were primarily qualitative and not quantitative, however, and made only cursory mention of geology and soil types.

Many quantitative descriptions of herbaceous vegetation in different parts of the world have been recently published (Box 1961, Billings and Mark 1961, Houston 1961, Hurd 1961), but no reports of a quantitative nature correlating herbaceous vegetation with geological formations and soil types have been found by the author.

In this study, the grassland vegetation of the Wichita Mountains Wildlife Refuge was analyzed, qualitatively and quantitatively, in an attempt to correlate plant communities with the various soil types and geological outcrops. Only relatively undisturbed sites, (i. e., those which might be considered climax), were sampled. The primary goal was to determine whether geologic and soil types could be delineated on the basis of climax vegetation.

## DESCRIPTION OF AREA

The Wichita Mountains Wildlife Refuge is a 59,099 acre area located in Comanche County in Southwestern Oklahoma. It was set aside from the Apache--Kiowa--Comanche Indian Reservation on July 4, 1901, and placed under the Forest Service branch of the U. S. Department of the Interior. On January 24, 1905, it became a National Game Preserve. In 1935, it was placed under the auspices of the current management, the Fish and Wildlife Service branch of the U. S. Department of the Interior (Dana 1956).

The area has been protected from fire since its inception and there has been no grazing by domestic livestock since 1937. Among the more important fauna still maintained within the refuge are approximately 300 longhorn cattle, 800 bison, 500 elk, 3,000 deer, and 400 wild turkeys (Halloran 1961). Approximately two-thirds of the area is restricted from public use and is thus well protected.

The topography is that of relatively small talus-sloped mountains separated by rolling plains. The relief increases from northwest to southeast. The drainage is generally to the southeast and is controlled by joints (Hoffman 1930). The joints are the places of fastest rock disintegration. On many of the mountains, virtually the only soil accumulation is along joints and in the valleys. The highest point is Mt. Pinchot, 2,479 feet; the lowest is at the base of Mt. Scott, 1,140 feet. Most of the peaks are rounded, indicating a mature topography. There are few canyons.

Within the refuge boundary, the geology is that of igneous rocks with some sedimentary accumulations in the lowlands. The igneous rocks are pre-Cambrian, but younger than the quartzite which they have intruded. The sedimentary section is mostly Paleozoic with small patches of Pleistocene and Recent material on the surface (Hoffman 1930).

Several studies of the geology have been made, and there are some disagreements (Hoffman 1930, Chase 1954, Chase, et. al. 1956, Schoonover 1948, Ham, et. al. 1957). Chase categorized the geologic formations in this area as Gabbro, Lugert, Quanah, Carlton, Post Oak, and Alluvium. Herbaceous vegetation is found on all.

The Gabbroic rocks (Fig. 7) are mostly overlain by soil, but do outcrop in certain areas. Approximately 3% of the area is under the influence of Gabbro. Gabbroic rock varies from dark gray to black in color and the soil formed from it is black and very rich, supporting excellent tall grass prairies.

The Lugert Granite (Figs. 2, 3, 4) is found mostly on the mountains and talus slopes of the north half of the refuge. It is different from the originally described Lugert which occurs east of the refuge. According to Merritt (1962), the name will be changed to Mt. Scott Granite in the near future. It is pinkish in color and medium grained, forming reasonably good soils supporting both grasslands and forests. Approximately 58% of the refuge is under the influence of Lugert Granite.

The Carlton Granite occurs only in the southeastern part of the refuge and is characterized by rounded eroded hills. Only about 2% of the refuge is Carlton. This was disturbed and therefore not sampled.

The southwestern 14% of the refuge is Quanah Granite (Fig. 1) which is course grained and shows heavy exfoliation. Little soil is formed from this granite and the vegetation is generally poor.

The Post Oak Conglomerate (Fig. 5) is characterized by cobblestones up to 12 inches in diameter. It is more recently derived than the other granites. Post Oak is found on small hills scattered throughout the refuge. The cobblestones occupy an average of about 16% of the surface area.

The Alluvium found in lowlands (Figs. 6, 8, 9, 10), is a mixture of various granites eroded from higher areas. It usually gives rise to immature soils although some are sufficiently old to have developed some profile character. Several soil types are found in the Alluvium.

A recently completed survey of soil types by the Soil Conservation Service (1961) delineated eleven soil types within the refuge. They were designated as 27, 27s, 7c, 31r, 6-C, 1gB, 1gC, 1B, 1ΘB, 4, and 9. They are described briefly below.

Barren granite peaks or escarpments that have formed little or no soil and consequently support little or no vegetation were designated as Type 27 (Fig. 1).

Type 27s designates soil formed on the granite outcrops and has pockets of skeletal soil in the joints (Fig. 2, 3, 4). All 27s soils sampled for this study were derived from the Lugert since no mature grasslands were found on the other 27s granites. Both grasslands and forests are found on this soil, the best growth of vegetation being found in the joints.

Type 7c is a cobbly colluvial soil and is found only on the Post Oak geological outcrop. It is moderately deep, supporting fair to good grasslands. The A horizon is a brown loam with moderate medium granular struc ture, friable and non-calcareous, and a pH of 7.0.

Type 31r is an alluvial soil characteristic of drainage ways. The soil is typically shallow and immature in profile. Few grasslands are found on this soil type.

Lawton loam with a deep A horizon is designated as type 6-C. The texture varies from very fine sandy loam to silt loam. Trees are generally found on this soil type although a few small areas support grasslands.

Type 1g soils (Fig. 7, 8) are derived from Gabbro, Alluvium, or Post Oak and in general have an excellent A horizon; however, a clay pan occurs from 22 to 30 inches. Despite this, excellent grasslands are found on this soil type. Type 1gB and 1gC are differentiated by the slope, 1-3% in the former and 3-5% in the latter. The A horizon has a pH of about 7.0.

Type 1B (Fig. 9) varies from silty loam to silty clay and has good surface drainage but poor internal drainage. It is found only in the extreme northwestern part of the refuge on what is referred to as Alluvium. The profile is mature however. The pH of the A horizon varies from 7.5 to 8.0.

The 1θB type (Fig. 10) is a foard-solenetz complex with little or no A horizon and a very shallow clay pan. It is formed on both Post Oak and Alluvium and supports only shallow-rooted species. It is characterized by poor drainage both on the surface and internally. The A horizon has a pH of 6.0 contrasted with 8.0 for the B horizon.

Types 9 and 4 both occupy only small areas that have been disturbed and were not sampled.

The 55-year average annual precipitation (1906 through 1960) is 30.38 inches (Table I). Of this, an average of 19.87 inches falls during the six months period from April through September. The highest yearly rainfall was 57.52 inches in 1908 and the lowest 15.07 inches in 1910, a

Table I. Mean rainfall and temperature data

| Month | 55 Yr. Avg. Mean Rainfall in Inches | Mean Temp. °F. |
|---|---|---|
| January | 0.96 | 39.6 |
| February | 1.18 | 43.6 |
| March | 1.70 | 51.0 |
| April | 3.19 | 61.1 |
| May | 4.49 | 68.1 |
| June | 3.60 | 77.5 |
| July | 2.56 | 82.1 |
| August | 2.91 | 82.1 |
| September | 3.11 | 74.2 |
| October | 3.30 | 63.1 |
| November | 1.88 | 49.1 |
| December | 1.50 | 41.3 |
| Avg. Total | 30.38 | 61.1° F. |

Data on this page taken from the summary by the U. S. Weather Bureau of the Wichita Refuge Cooperative Station (1961) and the U. S. D. A. Yearbook (1941).

42.45 inch spread. In the last ten years (1951 through 1960), the average is 28.31, with a high of 39.90 inches in 1957 and a low of 18.01 in 1954, a spread of 21.89 inches.

The average mean annual temperature is 61.1° F. with a high of 82.1 in July and August and a low of 39.6° F. in January.

The prevailing winds are from the south in the spring, summer and fall and from the northwest in the winter.

The vegetation is also quite variable. Short-grass, mixed-grass, and tall-grass prairies abound. Forests, varying from scrub oak woodlands to mature blackjack-post oak forests, can be found. Grasslands prevail over most of the area. Among the most abundant species are *Andropogon scoparius*,* *Andropogon gerardi*, *Sorghastrum nutans*, *Bouteloua hirsuta*, and *Bouteloua gracilis*. Forbs are also quite abundant and are useful as indicators. Among the most common are *Ambrosia psilostachya*, *Gaillardia pulchella*, *Coreopsis tinctoria*, *Thelesperma filifolium*, and *Helenium amarum*.

Generally, the north facing slopes of 27s support a more mesic vegetation than the south facing slopes (Figs. 2 and 4). The alluvial soils also have mesic vegetation except for the 10B which supports only shallow rooted species and many forbs. The 7c areas are typical of many mixed grass prairies except for the cobblestones. A detailed description is presented in the discussion.

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*The botanical nomenclature throughout will follow that of Waterfall, 1960, except that varietal names are not included.

Figure 1. Barren rock on Quanah Granite.

Figure 2. North facing slope of 27s soil showing the banding effect caused by jointing.

Figure 3. Flat 27s soil near the top of Moko Mountain.

Figure 4. South facing 27s in fore ground showing clumps of little bluestem. Alternating bands of tall and short grasses can be seen in the distance.

Figure 5. Mature grassland dominated by little bluestem and hairy grama on type 7c soil on Post Oak Conglomerate. Cobblestones which characterize these sites can be seen in the foreground.

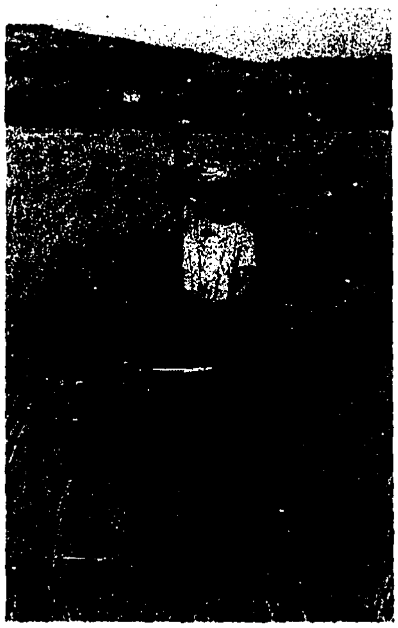

Figure 6. Type 31r soil on Alluvium showing robust tall grasses. Trees growing in soil formed in joints on 27s Lugert in background.

Fig. 7. Type 1g soil on Gabbro. The dark Gabbroic rock can be seen at the right.

Figure 8. Type 1g soil on Alluvium. The eroded 27s Lugert can be seen in the background.

Figure 9. Type 1B Alluvium in northwestern part of the refuge. This area may be a successional stage rather than an edaphic climax.

Figure 10. Type 10B soil near Cache Wye. Alkali spots can be seen on this shallow soil type. It is dominated by short grasses, annual plants, and shallow rooted mesic species.

# METHODS

Several week-ends were spent selecting areas to represent all geological outcrops, soil types, and slope exposures on which grasslands occur. Aerial photographs, soil maps, geological maps, and actual reconnaissance were employed in the selection. Only sites which were relatively free from disturbance were selected.

Two tools were utilized in the sampling of the grasslands. The point contact method as described by Hanson (1934) and Tinney, et. al. (1937) was utilized to measure the basal area and per cent composition. This tool was selected because of its mathematical and statistical reliability (Clark and Evans 1954, Whitman and Siggeirsson 1954, and Kemp and Kemp 1956). Fifteen hundred points were utilized in each area. These were taken at five-step intervals with the frame being placed down parallel with the body and with the left corner of the frame at the right toe. A species was recorded only when contact was made with a culm at ground level. Basal area was determined by dividing the number of contacts for each species by 1,500, the number of points. Per cent composition was determined by dividing the number of contacts for each species by the total number of contacts. Student's "t" test was used to determine the level of significance of the difference of means (Snedecor 1956).

The 0.1 square meter quadrat was utilized in determining the frequency of forbs. One hundred quadrats were sampled in each area. Each species of forb present in each quadrat was recorded. From these data, frequency and relative frequency could be determined. Relative frequency was determined by dividing the number of occurrences of each species by the total number of occurrences.

Fifty sites, representing the six edaphic types, showed some apparent differences due to degree of slope and slope exposure. Because of these differences, the number of types was increased. Type 27s was expanded into three types: south facing, north facing, and flat. These will be designated as 27s-SF, 27s-NF, and 27s-F, respectively. The lg type was separated as previously mentioned into lgB (1-3$^{\circ}$ slope) and lgC (3-5$^{\circ}$ slope).

The tabulated data are based on species which are dominants in at least some study areas and which have a high degree of frequency in the majority of sites. The sum totals for less important species are put under a miscellaneous category. The forbs (non-grassy herbs) were lumped since no single species had an appreciable basal area.

## RESULTS AND DISCUSSION

### Edaphic Effects on Vegetation

Type 1gC. Of the prominent grasslands in the Wichitas, the vegetation on type 1gC is probably most nearly like that of the tall grass prairie. Of the 36 species sampled, *Andropogon gerardi* (big bluestem) and *Andropogon scoparius* (little bluestem) are the dominants comprising 74.5% of the composition (Table III). No other species are of much importance on this soil type. The dominant forbs, of the 62 species which occurred, are *Ambrosia psilostachya* (western ragweed), *Aster ericoides* (heath aster), *Croton* spp. (croton), and *Psoralea tenuiflora* (wild alfalfa) (Table IV). These four species have a combined relative frequency of 70%. The soil with its relatively shallow clay pan (22-30 in.) is undoubtedly rich in available minerals as evidenced by the excellent vegetation which it supports. The dark soil color is reflected in the dark color of the vegetation.

The total basal area of 18.3% (Table II) is relatively high for a tall grass area and is probably influenced by occasional mowing. Hay is sometimes cut on these sites because they are relatively level and have few rock outcrops. This helps to remove mulch that might otherwise collect and retard the development of seedlings and also restrict the spread of clones.

Type 3lr. This lowland or drainageway area supports an abundance

Table II. Average per cent basal area for the important species on each soil type

| Soil Type | Age | Snu | Pvi | Sas | Asc | Bcu | Bgr | Bhi | Bda | Aol | Forbs | Misc. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1gC | 4.8 | 0.8 | 0.4 | 0.4 | 8.8 | 0.6 | 0.6 | 0.2 | 0.4 | | 0.2 | 1.1 | 18.3 |
| 31r | 7.4 | 2.1 | 1.8 | 1.1 | 1.6 | 0.6 | t | t | 0.2 | | 0.4 | 2.9 | 18.1 |
| 27s-NF | 4.1 | 0.4 | 0.3 | 0.3 | 4.1 | 0.2 | 0.6 | 1.5 | t | t | 0.6 | 1.4 | 13.6 |
| 1gB | 2.6 | 0.4 | 0.3 | 0.9 | 8.5 | 2.2 | 1.8 | 0.2 | 0.1 | t | 0.3 | 1.2 | 18.5 |
| 7c | 1.9 | 0.5 | 0.1 | 0.2 | 7.4 | 0.8 | 1.0 | 2.2 | t | | 0.4 | 1.3 | 15.8 |
| 27s-Flat | 1.9 | t | 0.2 | 0.2 | 3.2 | 0.8 | 1.6 | 1.8 | 0.5 | 0.1 | 1.0 | 1.7 | 13.0 |
| 1B | 2.4 | 0.3 | | 0.3 | 6.5 | 0.9 | 2.1 | 0.4 | 1.6 | | 0.3 | 4.7 | 19.5 |
| 16B | 0.3 | t | 0.1 | 1.4 | 0.2 | 0.3 | 3.6 | 1.0 | 10.4 | 2.9 | 1.2 | 5.6 | 27.0 |
| 27s-SF | 1.6 | 0.1 | t | t | 1.3 | 0.7 | 1.8 | 4.6 | 0.1 | | 0.9 | 2.1 | 13.2 |

Age - Andropogon gerardi
Snu - Sorghastrum nutans
Pvi - Panicum virgatum
Sas - Sporobolus asper
Asc - Andropogon scoparius
Bcu - Bouteloua curtipendula
Bgr - Bouteloua gracilis
Bhi - Bouteloua hirsuta
Bda - Buchloe dactyloides
Aol - Aristida oligantha
Misc. - miscellaneous
t - trace

Table III. Average per cent composition for the important species on each soil type

| Soil Type | Age | Snu | Pvi | Sas | Asc | Bcu | Bgr | Bhi | Bda | Alo | Forbs | Misc. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1gC | 26.4 | 4.4 | 2.2 | 2.2 | 48.1 | 3.3 | 3.3 | 1.1 | 2.2 | | 1.1 | 6.0 | 100.3 |
| 31r | 40.1 | 11.8 | 9.9 | 6.1 | 8.8 | 3.3 | 0.2 | 0.2 | 1.1 | | 2.2 | 16.0 | 100.0 |
| 27s-NF | 30.1 | 2.9 | 2.2 | 2.2 | 30.1 | 1.5 | 4.4 | 11.0 | 0.2 | 0.2 | 4.4 | 10.3 | 99.5 |
| 1gB | 14.1 | 2.2 | 1.6 | 4.9 | 45.9 | 11.9 | 9.7 | 1.1 | 0.5 | 0.2 | 1.6 | 6.5 | 100.2 |
| 7c | 12.0 | 3.2 | 0.6 | 1.3 | 46.8 | 5.1 | 6.3 | 13.9 | 0.2 | | 2.5 | 8.2 | 100.1 |
| 27sFlat | 14.6 | 0.2 | 1.5 | 1.5 | 24.6 | 6.2 | 12.3 | 13.8 | 3.8 | 0.8 | 7.7 | 13.1 | 100.1 |
| 1B | 12.3 | 1.5 | | 1.5 | 33.3 | 4.6 | 10.8 | 2.0 | 8.2 | | 1.5 | 24.1 | 99.8 |
| 10B | 1.1 | 0.2 | 0.4 | 5.2 | 0.7 | 1.1 | 13.3 | 3.7 | 38.5 | 10.7 | 4.4 | 20.7 | 100.0 |
| 27s-SF | 12.1 | 0.8 | 0.2 | 0.2 | 9.8 | 5.3 | 13.6 | 34.8 | 0.8 | | 6.8 | 15.9 | 100.3 |

Table IV. Forb frequency on each soil type as determined with the 0.1 square meter quadrat

| Species | Soil Type | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1gC | 31r | 27s NF | 1gB | 7c | 27s F | 1B | 10B | 27s SF |
| Ambrosia artemisiifolia | | 44 | | | | | | 7 | |
| Ambrosia psilostachya | 58 | 14 | 32 | 57 | 31 | 26 | 62 | 68 | 28 |
| Artemisia ludoviciana | 1 | | 7 | 1 | | 2 | 12 | | 4 |
| Aster ericoides | 14 | 18 | 4 | 12 | 7 | 3 | 1 | 3 | 1 |
| Arenaria stricta | | | 2 | | 6 | 1 | | | 1 |
| Chaetopappa asteroides | | | 3 | 3 | 10 | 1 | | | 12 |
| Chrysopsis pilosa | 4 | | | 1 | | 11 | 6 | | |
| Chrysopsis villosa | | | 2 | | 9 | 6 | | | |
| Croton spp. | 8 | 2 | | 1 | 1 | | | 8 | 1 |
| Coreopsis tinctoria | | 11 | | | | | | 36 | |
| Daucus pusillus | 2 | 1 | 8 | 5 | 8 | 14 | 4 | 4 | 25 |
| Eriogonum annuum | 1 | | 4 | 1 | 8 | 5 | | | 6 |
| Evolvulus nuttallianus | | | 1 | | 5 | 5 | | | 1 |
| Echinacea angustifolia | | | | | 5 | | | | |
| Erigeron strigosus | 1 | | | 6 | | | | 1 | |
| Gutierrezia sarothrae | | | | | 2 | 2 | | 5 | |
| Gaillardia pulchella | | | 9 | | | 21 | | 1 | 13 |
| Grindelia squarrosa | 2 | | | 6 | | 2 | 2 | 6 | |
| Haplopappus ciliatus | | | 1 | 1 | | 7 | 1 | | 4 |
| Helenium amarum | | 1 | 10 | 4 | 1 | 18 | | 4 | 27 |
| Liatris punctata | | | | | 12 | 1 | 1 | | |
| Linum spp. | | | 3 | 2 | 8 | 10 | | | 5 |
| Lesquerella ovalifolia | | | | | 5 | | | | 1 |
| Lepidium sp. | | | 3 | | 3 | 5 | 1 | 2 | 4 |
| Lotus americanus | 1 | 2 | | | | | | 8 | |
| Plantago spp. | 1 | 1 | 18 | 2 | 11 | 30 | 1 | 6 | 23 |
| Paronychia jamesii | | | 5 | | 5 | 17 | | | 5 |
| Polygonum aviculare | | | | | 10 | 1 | | | 3 |
| Psoralea tenuiflora | 5 | | 1 | 4 | 1 | 1 | 10 | | |
| Ruellia spp. | 1 | 12 | | 3 | 13 | 1 | | | |
| Ratibida columnifera | 2 | 2 | | 5 | 2 | 7 | 1 | 4 | 9 |
| Schrankia uncinata | | | | 1 | 5 | 1 | | | 4 |
| Scutellaria resinosa | | | | | 5 | | | | 1 |
| Sabatia campestris | | 4 | 1 | | | | | 5 | 2 |
| Tragia ramosa | | 1 | 2 | 1 | 21 | 8 | | | 15 |
| Thelesperma filifolium | | 4 | 1 | 6 | 9 | 4 | | 1 | 5 |
| Vernonia baldwinii | 5 | 12 | 2 | 2 | | | 2 | | 1 |
| Xanthisma texanum | | | 6 | 1 | | | | | |
| Miscellaneous | 17 | 24 | 31 | 19 | 44 | 35 | — | 26 | 37 |
| Total Frequency | 123 | 153 | 156 | 144 | 247 | 245 | 122 | 195 | 238 |
| No. of Species | 62 | 37 | 71 | 51 | 90 | 51 | 21 | 69 | 69 |

of extremely robust tall grasses that are probably successional steps in the formation of a bottomland forest since most 31r areas are forested and even the grasslands are being encroached on by trees. The dominant species, of some 35 sampled, is big bluestem which has 40.1% of the relative composition (Table III). Important secondary species and relative compositions are Sorghastrum nutans (Indian grass) 11.8%, Panicum virgatum (switch grass) 9.9%, little bluestem 8.8%, and Sporobolus asper (tall dropseed) 6.1%. Of little abundance, but important as indicators because of their restriction to this soil type, are Tripsacum dactyloides (eastern gama grass), Tridens flavus (purpletop), and Setaria geniculatus (knotroot bristlegrass). The most prominent forbs are Ambrosia artemisiifolia (annual ragweed), heath aster, western ragweed, Vernonia baldwinii (ironweed), Ruellia spp. (wild petunia), and Coreopsis tinctoria (plains coreopsis) (Table IV). Only 37 species were found. The six listed above represent 73% of the relative frequency of forbs.

The basal area, 18.1%, is also somewhat high. A great deal of mulch is not abundant in these areas, possibly because the extra moisture collected causes a more rapid decay of dead plant material.

Type 27s-NF. The vegetation on this soil type is located on north facing slopes of the granite mountains. These slopes have alternating bands of short grass and tall grass, the latter found in the deeper soils formed in the joints. Fifty species were sampled by the point frame. The vegetation is dominated by big bluestem which has a relative composition of 30.1% and little bluestem also 30.1% and Bouteloua hirsuta (hairy grama) 11.0% (Table III). The forb composition of 4.4% is considerably higher than that on 1gC and 31r soils and is made up chiefly of western ragweed, Platago spp. (plantain), Helenium amarum (bitter sneezeweed), Gaillardia pulchella (Indian blanket), Daucus pusillus (wild carrot), and Artemisia ludoviciana (soft-leaf sage) (Table IV). Seventy one species of forbs were sampled by the quadrat method. The total relative frequency of the top six is 54%.

The basal area of 13.6% is low because of the abundance of rocks (25.8% of the surface area) which outcrop. These vary from small granite chips to huge boulders many feet in diameter. If the rocks were discounted, the basal area would be 18.3%. In the tall grass areas on the deeper soil, the mulch often builds up to layers 2-4 inches deep.

Type lgB. This area topographically different from lgC, in that the slope is less pronounced, seems to be less mesic than lgC. The vegetation is dominated by little bluestem with a relative composition of 45.9% (Table III). Twenty-eight species were sampled with the point frame. Important secondary species are big bluestem 14.1%, Bouteloua curtipendula (side oats grama) 11.9% and Bouteloua gracilis (blue grama) 9.7%. This indicated a trend toward a mixed grass prairie or at least an ecotone between tall and mixed grass prairies. The forb composition (51 species present) is quite similar to that of the lgC with western ragweed and heath aster dominating and Erigeron strigosus (daisy fleabane), Grindelia squarrosa (gumweed), Thelesperma filifolium (plains greenthread) and Ratibida columnifera (prairie coneflower) furnishing some aspect character (Table IV). The relative frequency of these seven species totals 67%.

The basal area of 18.5% approximates that of the vegetation on lgC. Also like lgC sites, these areas are occasionally mowed for hay and have a relatively light amount of mulch varying from 0-2 inches in depth.

Type 7c. Little bluestem furnishes 46.8% of the relative composition of 7c soils (Table III). Hairy grama 13.9%, big bluestem 12.0%, blue grama 6.3%, and side-oats grama 5.1% are other frequently encountered grasses. Forty-one species were sampled on this soil type. The vegetation is representative of many good mixed-grass prairie sites. Western ragweed, Tragia ramosa (stinging spurge), Liatris punctata (blazing star), plantain, Polygonum aviculare (prostrate knotweed), Chaetopappa asteroides (common leastdaisy), Chrysopsis villosa (hairy gold aster), and plains greenthread dominate the 90 species of forbs encountered with the 0.1 square meter quadrat (Table IV). The total relative frequency of these 9 species (10% of the species sampled) is 51%. Blazing star, doorstep knotweed, and hairy gold aster abound only on this soil type.

The basal area of 15.8% is the same as the percentage of the area covered with cobblestones. Discounting the rock, the average basal area would be 18.8%. There is little mulch on this soil, the mulch layer seldom exceeding 0.5 inch in thickness.

Type 27s-F. This topographic variation of 27s is, as might be expected, intermediate between 27s-NF and 27s-SF as far as moisture availability is concerned. These rocky flats are dominated by little bluestem which furnishes 24.6% of the relative composition, big bluestem 14.6%, hairy grama 13.8%, and blue grama 12.3%; with side-oats grama 6.2%, being the most important secondary species (Table III). Fifty-one species were sampled with the point frame. Of the 51 forbs occurring in the quadrats, the most frequently appearing were plantain, western ragweed, Paronychia jamesii (James' whitlow wort), bitter sneezeweed, Indian blanket, wild carrot, Chrysopsis pilosa (soft goldaster), and Linum spp. (flax) (Table IV). These 8 have a combined relative frequency of 60%.

As is the case with 27s-NF and 27s-SF soils, the outcropping stones occupy a large part of the surface area, 17.6%. This is less than either slope but still contributes to the low average basal area of 13.0%, 1.0% of which is forbs (Table II). Without the rocks, the basal area might be 15.8% which is considerably less than other 27s types. There is seldom any accumulation of mulch on this soil type, despite the fact that the heavy grazing animals (buffalo and longhorns) seldom frequent these areas because of their inaccessibility.

Type 1B. This soil type, found only in two quarter sections in the northwest part of the refuge, has as its major dominant little bluestem which furnishes 33.3% of the relative composition (Table III). Of the other 24 species sampled, big bluestem 12.3%, blue grama 10.8%, and Buchloe dactyloides (buffalo grass) 8.2%, are the important secondary species. Western ragweed is by far the most abundant forb with soft-leaf sage and wild alfalfa the only other species of importance.

The basal area of 19.5% is greatly influenced by the abundance of short grasses. These sites were among the last removed from the influence of grazing by domestic livestock. It is believed by the author and supported by the relatively constant and abundant amounts of diverse growth forms, that these areas might be seral in the development of tall grass prairie; however they have been protected for 25 years at the time of this writing and could possibly have become stable. There are mulch accumulations up to 2.5 inches in the tall grass zones.

Type 1ΘB. This extremely poor soil type is unique in the refuge in its vegetative composition. The dominant of the 51 species sampled (including 31 species of grass) was buffalo grass with a relative composition of 38.5%. Other important species were blue grama 13.3%, Aristida oligantha (annual three-awn) 10.7%, and tall dropseed 5.2%. Not abundant, but important as indicators are Panicum obtusum (vine mesquite), Sporobolus airoides (alkali sacaton), and Sporobolus neglectus (poverty grass). Most frequently occurring of the 69 species of forbs were western ragweed and plains coreopsis. Others important as indicators were Croton monanthogynus (one-seeded croton), Lotus americanus (deervetch) and annual ragweed. The plains coreopsis, during the period of anthesis, is an aspect dominant making these sites quite noticeable even from far off. Coreopsis and western ragweed had a combined relative frequency of 53%.

The average basal area of 27.0% is by far the highest of any soil type sampled. Also the basal area of forbs, 1.2% is the highest found on any soil type. The basal area is influenced by the abundance of short grasses (many stoloniferous) and annual plants. All species present are necessarily shallow-rooted because of the shallow hard pan. This soil type also has some alkaline areas that support only salt-tolerant species.

Type 27s-SF. This most xeric of the 27s soils is dominated by hairy grama with a relative composition of 34.8%. Important species and relative compositions are blue grama 13.6%, big bluestem 12.1%, little bluestem 9.8% and side-oats grama 5.3%. In addition to these five species, 39 other species were sampled. From the forb frequency data, it can be seen that western ragweed, bitter sneezeweed, wild carrot, plantain, stinging spurge, Indian blanket, common leastdaisy, and prairie coneflower have a combined relative frequency of 64% (Table IV). Sixty-nine species of forbs were found on this site.

As is the case with the other 27s soils, rock outcrops provide a substantial portion of the surface cover, 26.1%. This contributes to the low basal area of 13.2%. By extrapolation, we see that without the rocks the basal area might be 17.9%. The bands of tall grass have some mulch, 0.5-1.5 inches, but less than on the more mesic 27s-NF soils.

## Specific Differences Due to Soil Type

Despite the fact that certain grasses such as big bluestem serve as major dominants in more than one area, there are often significant differences in the relative importance of such species on the different soil types (Tables VII-XIII).

Big bluestem is a dominant species on three soil types and an important species on all except the 1ΘB soil type. The average basal area, however, as indicated by the mean number of point contacts on 31r soils is significantly higher than in any other soil type (Table V). Big bluestem is significantly more abundant on 1gC soils than on 7c, 27s-F, or 1ΘB. On the basis of this species alone, 31r and 1ΘB soils can be separated from all other soil types. The basal area of big bluestem is significantly higher on 27s-NF than on 27s-SF soil which shows the importance of slope exposure.

Little bluestem, the most abundant species on six soil types and an important species on two others, is another excellent indicator species (Table VI). This species attains its highest mean basal cover in 1gC, 1gB, 7c, and 1B soils and the difference in basal area between any two of these types is not significant. The mean basal area in each of these soil types is significantly higher than in nearly all other soil types, however.

Hairy grama is the next most important delineating species with Indian grass, tall dropseed, side-oats grama, and blue grama also showing several significant differences between plots (Tables VII-XIII). It is interesting to note that no soil types can be separated on the basis of switch grass (Table VIII).

Forbs are generally not very abundant in the Wichita Wildlife Refuge. The basal area of individual species is very low, so all forbs

Table V. Effects of soil type on basal area of <u>Andropogon gerardi</u> as indicated by the number of point contacts

* Significant at 5% level
/ Significant at 1% level

| Soil Type | N | Mean contacts with std. error | lgC | 31r | 27s-NF | lgB | 7c | 27s-Flat | 1B | 1θB |
|---|---|---|---|---|---|---|---|---|---|---|
| lgC | 7 | 68.0 ± 13.1 | | | | | | | | |
| 31r | 3 | 105.7 ± 6.9 | * | | | | | | | |
| 27s-NF | 6 | 61.5 ± 11.0 | | * | | | | | | |
| lgB | 3 | 39.7 ± 3.4 | | / | | | | | | |
| 7c | 10 | 28.4 ± 7.7 | * | / | * | | | | | |
| 27s-Flat | 3 | 28.3 ± 10.5 | / | / | | | | | | |
| 1B | 2 | 35.0 ± 13.0 | | * | | | | | | |
| 1θB | 7 | 4.3 ± 1.7 | / | / | / | / | / | * | * | |
| 27s-SF | 5 | 24.2 ± 2.4 | | / | / | / | | | | / |

Table VI. Effects of soil type on basal area of <u>Andropogon scoparius</u> as indicated by the number of point contacts

* Significant at 5% level
/ Significant at 1% level

| Soil Type | N | Mean contacts with std. error | lgC | 31r | 27s-NF | lgB | 7c | 27s-Flat | 1B | 1θB |
|---|---|---|---|---|---|---|---|---|---|---|
| lgC | 7 | 147.3 ± 18.9 | | | | | | | | |
| 31r | 3 | 25.7 ± 3.0 | / | | | | | | | |
| 27s-NF | 6 | 62.0 ± 13.6 | / | * | | | | | | |
| lgB | 3 | 117.0 ± 30.7 | | * | | | | | | |
| 7c | 10 | 111.7 ± 12.2 | | / | * | | | | | |
| 27s-Flat | 3 | 46.7 ± 22.3 | / | | | | * | | | |
| 1B | 2 | 96.5 ± 53.5 | | | | | | | | |
| 1θB | 7 | 2.4 ± 1.8 | / | / | / | / | / | | | |
| 27s-SF | 5 | 19.6 ± 4.6 | / | | * | * | / | | | / |

Table VII. Effects of soil type on basal area of <u>Sorghastrum nutans</u> as indicated by the number of point contacts

* Significant at 5% level
ƒ Significant at 1% level

| Soil Type | N | Mean contacts with std. error | lgC | 31r | 27s-NF | lgB | 7c | 27s-Flat | 1B | 1θB |
|---|---|---|---|---|---|---|---|---|---|---|
| lgC | 7 | 9.9 ± 3.9 | – | – | – | – | – | – | – | – |
| 31r | 3 | 29.3 ± 9.1 | | – | – | – | – | – | – | – |
| 27s-NF | 6 | 6.7 ± 3.9 | | * | – | – | – | – | – | – |
| lgB | 3 | 6.3 ± 5.8 | | | | – | – | – | – | – |
| 7c | 10 | 8.1 ± 1.9 | | | | | – | – | – | – |
| 27s-Flat | 3 | 0.7 ± 0.7 | * | * | | | ƒ | – | – | – |
| 1B | 2 | 4.0 ± 4.0 | | | | | | | – | – |
| 1θB | 7 | 0.7 ± 0.4 | * | * | | | | | | – |
| 27s-SF | 5 | 2.0 ± 1.3 | | * | | | * | | | |

Table VIII. Effects of soil type on basal area of <u>Panicum virgatum</u> as indicated by the number of point contacts

* Significant at 5% level
ƒ Significant at 1% level

| Soil Type | N | Mean contacts with std. error | lgC | 31r | 27s-NF | lgB | 7c | 27s-Flat | 1B | 1θB |
|---|---|---|---|---|---|---|---|---|---|---|
| lgC | 7 | 7.0 ± 4.1 | – | – | – | – | – | – | – | – |
| 31r | 3 | 19.0 ± 9.2 | | – | – | – | – | – | – | – |
| 27s-NF | 6 | 5.0 ± 4.8 | | | – | – | – | – | – | – |
| lgB | 3 | 4.3 ± 2.4 | | | | – | – | – | – | – |
| 7c | 10 | 1.8 ± 0.9 | | | | | – | – | – | – |
| 27s-Flat | 3 | 3.0 ± 3.0 | | | | | | – | – | – |
| 1B | 2 | 0.0 ± 0.0 | | | | | | | – | – |
| 1θB | 7 | 1.1 ± 0.7 | | | | | | | | – |
| 27s-SF | 5 | 0.6 ± 0.6 | | | | | | | | |

Table IX. Effects of soil type on basal area of <u>Sporobolus asper</u> as indicated by the number of point contacts

* Significant at 5% level
ǂ Significant at 1% level

| Soil Type | N | Mean contacts with std. error | lgC | 3lr | 27s-NF | lgB | 7c | 27s-Flat | 1B | 1θB |
|---|---|---|---|---|---|---|---|---|---|---|
| lgC | 7 | 5.7 ± 1.6 | | | | | | | | |
| 3lr | 3 | 13.0 ± 4.7 | | | | | | | | |
| 27s-NF | 6 | 4.3 ± 3.9 | | | | | | | | |
| lgB | 3 | 13.7 ± 6.4 | | | | | | | | |
| 7c | 10 | 3.0 ± 2.0 | | | | | | | | |
| 27s-Flat | 3 | 3.7 ± 1.9 | | | | | | | | |
| 1B | 2 | 5.0 ± 3.0 | | | | | | | | |
| 1θB | 7 | 21.1 ± 4.9 | * | | * | | ǂ | * | * | |
| 27s-SF | 5 | 0.0 ± 0.0 | ǂ | * | | | | | | ǂ |

Table X. Effects of soil type on basal area of <u>Bouteloua curtipendula</u> as indicated by the number of point contacts

* Significant at 5% level
ǂ Significant at 1% level

| Soil Type | N | Mean contacts with std. error | lgC | 3lr | 27s-NF | lgB | 7c | 27s-Flat | 1B | 1θB |
|---|---|---|---|---|---|---|---|---|---|---|
| lgC | 7 | 10.1 ± 2.1 | | | | | | | | |
| 3lr | 3 | 3.3 ± 2.8 | | | | | | | | |
| 27s-NF | 6 | 3.2 ± 0.4 | ǂ | | | | | | | |
| lgB | 3 | 32.7 ± 12.2 | | | * | | | | | |
| 7c | 10 | 12.5 ± 1.5 | | * | ǂ | | | | | |
| 27s-Flat | 3 | 12.3 ± 2.3 | | | ǂ | | | | | |
| 1B | 2 | 13.0 ± 4.0 | | | * | | | | | |
| 1θB | 7 | 5.1 ± 2.2 | | | | | * | | | |
| 27s-SF | 5 | 10.0 ± 2.7 | | | * | | | | | |

Table XI. Effects of soil type on basal area of Bouteloua gracilis as indicated by the number of point contacts

* Significant at 5% level
ƒ Significant at 1% level

| Soil Type | N | Mean contacts with std. error | lgC | 3lr | 27s-NF | lgB | 7c | 27s-Flat | 1B | 1θB |
|---|---|---|---|---|---|---|---|---|---|---|
| lgC | 7 | 12.9 ± 5.8 | | | | | | | | |
| 3lr | 3 | 0.3 ± 0.3 | | | | | | | | |
| 27s-NF | 6 | 8.7 ± 4.5 | | | | | | | | |
| lgB | 3 | 26.7 ± 12.5 | | | | | | | | |
| 7c | 10 | 15.6 ± 7.8 | | | | | | | | |
| 27s-Flat | 3 | 23.7 ± 15.7 | | | | | | | | |
| 1B | 2 | 32.0 ± 10.0 | | * | | | | | | |
| 1θB | 7 | 54.6 ± 8.5 | ƒ | ƒ | ƒ | | ƒ | | | |
| 27s-SF | 5 | 27.0 ± 11.9 | | | | | | | | |

Table XII. Effects of soil type on basal area of Bouteloua hirsuta as indicated by the number of point contacts

* Significant at 5% level
ƒ Significant at 1% level

| Soil Type | N | Mean contacts with std. error | lgC | 3lr | 27s-NF | lgB | 7c | 27s-Flat | 1B | 1θB |
|---|---|---|---|---|---|---|---|---|---|---|
| lgC | 7 | 3.1 ± 1.9 | | | | | | | | |
| 3lr | 3 | 0.3 ± 0.3 | | | | | | | | |
| 27s-NF | 6 | 22.2 ± 6.4 | * | * | | | | | | |
| lgB | 3 | 3.0 ± 3.0 | | | * | | | | | |
| 7c | 10 | 33.1 ± 5.7 | ƒ | ƒ | | ƒ | | | | |
| 27s-Flat | 3 | 27.7 ± 7.1 | ƒ | * | | * | | | | |
| 1B | 2 | 60.5 ± 5.5 | ƒ | ƒ | ƒ | ƒ | ƒ | * | | |
| 1θB | 7 | 15.1 ± 4.2 | * | | * | * | | | ƒ | |
| 27s-SF | 5 | 69.4 ± 7.7 | ƒ | ƒ | ƒ | ƒ | ƒ | ƒ | | ƒ |

Table XIII. Effects of soil type on basal area of forbs as indicated by the number of point contacts

* Significant at 5% level
† Significant at 1% level

| Soil Type | N | Mean contacts with std. error | lgC | 3lr | 27s-NF | lgB | 7c | 27s-Flat | 1B | 1ΘB |
|---|---|---|---|---|---|---|---|---|---|---|
| lgC | 7 | 3.3 ± 0.8 | | | | | | | | |
| 3lr | 3 | 4.3 ± 1.2 | | | | | | | | |
| 27s-NF | 6 | 9.0 ± 2.6 | | | | | | | | |
| lgB | 3 | 4.0 ± 0.0 | | | | | | | | |
| 7c | 10 | 5.7 ± 1.1 | | | | | | | | |
| 27s-Flat | 3 | 14.3 ± 5.2 | | | | | | | | |
| 1B | 2 | 4.0 ± 2.0 | | | | | | | | |
| 1ΘB | 7 | 19.0 ± 4.6 | † | * | | † | * | | * | |
| 27s-SF | 5 | 12.8 ± 1.8 | † | † | | † | † | | * | |

have been considered collectively (Table XIII). Forb cover is highest on 27s-Flat, 1ΘB, and 27s-SF soils. Such cover is significantly higher on 1ΘB and 27s-SF soils than on nearly all other soil types.

Of all soil types considered, 1ΘB supports the most distinctive vegetation. It is the only soil which supports substantial amounts of buffalo grass and annual three-awn. It can be delineated from all except 3lr and lgB soils on the basis of its high mean basal area of tall dropseed. A high basal area of blue grama and forbs is also characteristic of this area. Conversely, 1ΘB supports significantly less big bluestem than any other area and less little bluestem than all except 1B and 27s-F soils. Hairy grama occupies a significantly different basal area on this soil than on all except 3lr, 27s-NF, and 27s-F soils. Type 1ΘB soil is significantly different in mean basal area of at least four species from all soils except 27s-F from which it differs in three.

Type 31r soil has a significantly higher basal area of big bluestem than any other soil. It has significantly less little bluestem, however, than 27s-NF, lgC, lgB, and 7c soils. The abundance of Indian grass and tall dropseed help to delineate it from other soils. The 31r soils on Alluvium are drainage ways and hence have more available water. This probably is the primary reason for the abundance of robust tall grasses. Type 31r soil also supports a lower mean basal area of hairy grama than all other soils and based on this species is significantly different from all soils except 10B, lgB and lgC. It is significantly different in the relative basal area of at least three species from all soil types except lgB and lgC from which it differs in two.

Type lgC soil supports a very mesic vegetation having significantly higher mean basal areas of big bluestem and little bluestem than most other soils. The relatively small amount of hairy grama delineates it from all soils except 31r, lgB, and 27s-F. Types 31r and lgB are visually most nearly like lgC from a vegetational standpoint; however 31r soil has significantly more big bluestem than lgC. Type lgB is not significantly different from lgC soil in the mean basal areas of any of the species considered. Type lgC differs significantly from 10B in the mean basal areas of seven of the species considered (Tables V-XIII).

The vegetation of lgB soil, which is not significantly different from that of lgC soil, is different from 7c, 27s-F and 1B soils only in that it has a significantly lower basal area of hairy grama. Type lgB soil can, however, be distinguished from 7c and 27s-F soils by physiographic differences. It also has significantly less hairy grama than 27s-SF, 10B and 27s-NF soils. Big bluestem and little bluestem are other fair indicators.

Of the 27s soils, type 27s-NF is the most mesic. It supports a high mean basal area of big bluestem, little bluestem and hairy grama. Hairy grama is probably the best delineating species, with 27s-NF soil supporting significantly more of this grass than lgC, lgB, and 3lr soils and significantly less than 27s-SF and lB soils. The small amount of side-oats grama on this soil separates it from all others except lθB and 3lr. Both 27s-F and 27s-SF have significantly more side-oats grama than 27s-NF. Type 27s-SF has significantly less big bluestem and little bluestem than its north-facing counterpart and significantly more hairy grama than either 27s-NF or 27s-F. Hairy grama is the best delineating species for both 27s-F and 27s-SF soils. Type 27s-F is vegetationally distinct from lB and lgB soils only on the basis of relative amounts of this species, but is quite distinct from other soils. Only the higher mean basal area of forbs on 27s-SF differentiates it from lB.

Type 7c soil, with its cobblestoned surface, is best delineated by the high relative frequency of little bluestem and hairy grama. The two soils which are least vegetationally distinct from it on the basis of the species considered are lgB and lB. Type lgB soil has significantly less hairy grama while lB soil has significantly more.

As previously mentioned, lB soil seems to be in a seral state of plant succession. It can be separated from five soil types, lgC, lgB, 7c, 27s-F and 27s-SF by only one species, hairy grama. However, it is distinctly different from the other three soils from a vegetational standpoint.

In summary, all soil types in the Refuge except three support distinctive types of grassland when constituent species are considered on a quantitative basis. As previously indicated, the vegetation on lgB and lgC soils is similar and that on lB soil is extremely variable.

## Geological Effects

When the soil types were separated on the basis of their geological origin, many significant differences in species composition and cover were found to be due to differences in geological formations (Tables XIV-XXII). Big bluestem, little bluestem, hairy grama, blue grama, and forbs all show many significant differences due to geology. Even switch grass, which has no significant differences due to soil type, shows some differences due to geology.

The mature grasslands found on 27s soil are restricted to Lugert Granite. The bands of tall grass, consisting mostly of big bluestem and little bluestem, are separated by short grasses, mostly hairy grama. The basal areas of these three species and the forbs best delineate this type. It is somewhat intermediate in the relative amounts of the two bluestems. It has significantly less big bluestem than 31r Alluvium, but significantly more than 1θB Alluvium and 1θB Post Oak. Little bluestem serves to delineate 27s Lugert from all except lB Alluvium; however again the mean basal area is intermediate. Only lB Alluvium has a higher mean basal area of hairy grama. All other types, except 1θB Alluvium and 7c Post Oak, have significantly less hairy grama than 27s Lugert.

Type lg soils are found on three geologic formations, Post Oak, Gabbro, and Alluvium. Little bluestem is the most abundant species on all three with big bluestem and side-oats grama being the second and third most important. The lg soils on Alluvium have significantly more big bluestem than the lg soils on other geological formations and significantly more blue grama than lg soils on Gabbro. The lg gabbroic soils have a

Table XIV. Effects of geological formations on basal area of *Andropogon gerardi* as indicated by the number of point contacts

* Significant at 5% level
† Significant at 1% level

| Geol. Form. and Soil Type | N | Mean contacts with std. error | 27 s Lugert | 1g Post Oak | 1g Gabbro | 1g Alluvium | 31r Alluvium | 1θB Post Oak | 1θB Alluvium | 1B Alluvium |
|---|---|---|---|---|---|---|---|---|---|---|
| 27s Lugert | 13 | 42.7 ± 7.4 | | | | | | | | |
| 1g Post Oak | 2 | 38.5 ± 5.5 | | | | | | | | |
| 1g Gabbro | 2 | 42.0 ± 0.0 | | | | | | | | |
| 1g Alluvium | 6 | 72.3 ± 14.6 | | * | * | | | | | |
| 31r Alluvium | 3 | 105.7 ± 6.9 | † | † | † | | | | | |
| 1θB Post Oak | 4 | 6.0 ± 2.4 | † | † | † | † | † | | | |
| 1θB Alluvium | 3 | 2.0 ± 2.0 | † | † | † | † | † | | | |
| 1B Alluvium | 2 | 35.0 ± 13.0 | | | | * | † | * | * | |
| 7c Post Oak | 10 | 28.4 ± 7.7 | | | * | † | † | † | † | |

Table XV. Effects of geological formations on basal area of *Andropogon scoparius* as indicated by the number of point contacts

* Significant at 5% level
† Significant at 1% level

| Geol. Form. and Soil Type | N | Mean contacts with std. error | 27s Lugert | 1g Post Oak | 1g Gabbro | 1g Alluvium | 31r Alluvium | 1θB Post Oak | 1θB Alluvium | 1B alluvium |
|---|---|---|---|---|---|---|---|---|---|---|
| 27s Lugert | 13 | 44.7 ± 8.2 | | | | | | | | |
| 1g Post Oak | 2 | 130.0 ± 11.0 | † | | | | | | | |
| 1g Gabbro | 2 | 166.5 ± 7.6 | † | * | | | | | | |
| 1g Alluvium | 6 | 136.5 ± 25.7 | † | | | | | | | |
| 31r Alluvium | 3 | 25.7 ± 3.0 | * | † | † | † | | | | |
| 1θB Post Oak | 4 | 3.5 ± 3.2 | † | † | † | † | † | | | |
| 1θB Alluvium | 3 | 1.0 ± 1.0 | † | † | † | † | † | | | |
| 1B Alluvium | 2 | 96.5 ± 53.5 | | | | | | | | |
| 7c Post Oak | 10 | 111.7 ± 12.2 | † | | † | | † | † | † | |

Table XVI. Effects of geological formations on basal area of <u>Panicum virgatum</u> as indicated by the number of point contacts

* Significant at 5% level
/ Significant at 1% level

| Geol. Form. and Soil Type | N | Mean contacts with std. error | 27s Lugert | 1 g Post Oak | 1g Gabbro | 1 g Alluvium | 31r Alluvium | 1ΘB Post Oak | 1ΘB Alluvium | 1B Alluvium |
|---|---|---|---|---|---|---|---|---|---|---|
| 27s Lugert | 13 | 3.2 ± 2.3 | | | | | | | | |
| 1g Post Oak | 2 | 15.0 ± 13.0 | | | | | | | | |
| 1g Gabbro | 2 | 9.5 ± 6.5 | | | | | | | | |
| 1g Alluvium | 6 | 2.3 ± 1.4 | | | | | | | | |
| 31r Alluvium | 3 | 19.0 ± 9.2 | | | | | | | | |
| 1ΘB Post Oak | 4 | 1.8 ± 1.8 | | | | | | | | |
| 1ΘB Alluvium | 3 | 0.3 ± 0.3 | | | | | * | | | |
| 1B Alluvium | 2 | 0.0 ± 0.0 | | | | | | | | |
| 7c Post Oak | 10 | 1.8 ± 0.9 | | | | | * | | | * |

Table XVII. Effects of geological formations on basal area of <u>Sorghastrum nutans</u> as indicated by the number of point contacts

* Significant at 5% level
/ Significant at 1% level

| Geol. Form. and Soil Type | N | Mean contacts with std. error | 27s Lugert | 1g Post Oak | 1g Gabbro | 1g Alluvium | 31r Alluvium | 1ΘB Post Oak | 1ΘB Alluvium | 1B Alluvium |
|---|---|---|---|---|---|---|---|---|---|---|
| 27s Lugert | 13 | 3.8 ± 2.2 | | | | | | | | |
| 1g Post Oak | 2 | 5.0 ± 5.0 | | | | | | | | |
| 1g Gabbro | 2 | 8.5 ± 7.5 | | | | | | | | |
| 1g Alluvium | 6 | 10.2 ± 4.9 | | | | | | | | |
| 31r Alluvium | 3 | 29.3 ± 9.1 | / | * | | * | | | | |
| 1ΘB Post Oak | 4 | 1.2 ± 0.8 | | | | * | / | | | |
| 1ΘB Alluvium | 3 | 0.0 ± 0.0 | * | | | * | * | | | |
| 1B Alluvium | 2 | 4.0 ± 4.0 | | | | * | | | | |
| 7c Post Oak | 10 | 8.1 ± 1.9 | | | | * | / | / | | |

Table XVIII. Effects of geological formations on basal area of *Sporobolus asper* as indicated by the number of point contacts

* Significant at 5% level
† Significant at 1% level

| Geol. Form. and Soil Type | N | Mean contacts with std. error | 27s Lugert | 1g Post Oak | 1g Gabbro | 1g Alluvium | 31r Alluvium | 1θB Post Oak | 1θB Alluvium | 1B Alluvium |
|---|---|---|---|---|---|---|---|---|---|---|
| 27s Lugert | 13 | 2.5 ± 1.8 | | | | | | | | |
| 1g Post Oak | 2 | 6.5 ± 3.5 | | | | | | | | |
| 1g Gabbro | 2 | 12.5 ± 0.4 | † | | | | | | | |
| 1g Alluvium | 6 | 7.2 ± 3.7 | | | | | | | | |
| 31r Alluvium | 3 | 13.0 ± 4.7 | * | | | | | | | |
| 1θB Post Oak | 4 | 25.8 ± 6.3 | † | * | * | * | | | | |
| 1θB Alluvium | 3 | 15.0 ± 7.5 | | | * | | | | | |
| 1B Alluvium | 2 | 5.0 ± 3.0 | | | † | | | * | | |
| 7c Post Oak | 10 | 3.0 ± 2.0 | | | | | * | † | | |

Table XIX. Effects of geological formations on basal area of *Bouteloua curtipendula* as indicated by the number of point contacts

* Significant at 5% level
† Significant at 1% level

| Geol. Form. and Soil Type | N | Mean contacts with std. error | 27s Lugert | 1g Post Oak | 1g Gabbro | 1g Alluvium | 31r Alluvium | 1θB Post Oak | 1θB Alluvium | 1B Alluvium |
|---|---|---|---|---|---|---|---|---|---|---|
| 27s Lugert | 13 | 6.8 ± 1.4 | | | | | | | | |
| 1g Post Oak | 2 | 31.5 ± 25.5 | | | | | | | | |
| 1g Gabbro | 2 | 15.5 ± 4.5 | * | | | | | | | |
| 1g Alluvium | 6 | 12.5 ± 2.9 | * | | | | | | | |
| 31r Alluvium | 3 | 3.3 ± 2.8 | | | * | * | | | | |
| 1θB Post Oak | 4 | 6.8 ± 3.3 | | | | | | | | |
| 1θB Alluvium | 3 | 3.0 ± 3.0 | | | | * | | | | |
| 1B Alluvium | 2 | 13.0 ± 4.0 | | | | | | | | |
| 7c Post Oak | 10 | 12.5 ± 1.5 | † | | | | † | | † | † |

Table XX. Effects of geological formations on basal area of <u>Bouteloua gracilis</u> as indicated by the number of point contacts

* Significant at 5% level
ƒ Significant at 1% level

| Geol. Form. and Soil Type | N | Mean contacts with std. error | 27s Lugert | 1g Post Oak | 1g Gabbro | 1g Alluvium | 3lr Alluvium | 1ΘB Post Oak | 1ΘB Alluvium | 1B Alluvium |
|---|---|---|---|---|---|---|---|---|---|---|
| 27s Lugert | 13 | 15.6 ± 5.4 | | | | | | | | |
| 1g Post Oak | 2 | 14.5 ± 14.5 | | | | | | | | |
| 1g Gabbro | 2 | 3.0 ± 1.0 | * | | | | | | | |
| 1g Alluvium | 6 | 22.5 ± 7.6 | | | * | | | | | |
| 3lr Alluvium | 3 | 0.3 ± 0.3 | ƒ | | * | ƒ | | | | |
| 1ΘB Post Oak | 4 | 49.2 ± 15.0 | * | | * | | ƒ | | | |
| 1ΘB Alluvium | 3 | 61.7 ± 2.3 | ƒ | * | ƒ | ƒ | ƒ | | | |
| 1B Alluvium | 2 | 32.0 ± 10.0 | | | * | | * | | * | |
| 7c Post Oak | 10 | 15.6 ± 7.8 | | | | | * | * | ƒ | |

Table XXI. Effects of geological formations on basal area of <u>Bouteloua hirsuta</u> as indicated by the number of point contacts

* Significant at 5% level
ƒ Significant at 1% level

| Geol. Form. and Soil Type | N | Mean contacts with std. error | 27s Lugert | 1g Post Oak | 1g Gabbro | 1g Alluvium | 3lr Alluvium | 1ΘB Post Oak | 1ΘB Alluvium | 1B Alluvium |
|---|---|---|---|---|---|---|---|---|---|---|
| 27s Lugert | 13 | 40.4 ± 7.8 | | | | | | | | |
| 1g Post Oak | 2 | 4.5 ± 4.5 | ƒ | | | | | | | |
| 1g Gabbro | 2 | 0.5 ± 0.4 | ƒ | | | | | | | |
| 1g Alluvium | 6 | 3.5 ± 2.2 | ƒ | | | | | | | |
| 3lr Alluvium | 3 | 0.3 ± 0.3 | ƒ | | | | | | | |
| 1ΘB Post Oak | 4 | 7.8 ± 1.8 | ƒ | | ƒ | | ƒ | | | |
| 1ΘB Alluvium | 3 | 25.0 ± 5.6 | | * | ƒ | ƒ | ƒ | ƒ | | |
| 1B Alluvium | 2 | 60.5 ± 5.5 | * | ƒ | ƒ | ƒ | ƒ | ƒ | ƒ | |
| 7c Post Oak | 10 | 33.1 ± 5.7 | | ƒ | ƒ | ƒ | ƒ | ƒ | | ƒ |

Table XXII. Effects of geological formations on basal area of forbs as indicated by the number of point contacts

* Significant at 5% level
/ Significant at 1% level

| Geol. Form. and Soil Type | N | Mean contacts with std. error | 27s Lugert | 1g Post Oak | 1g Gabbro | 1g Alluvium | 3lr Alluvium | 1θB Post Oak | 1θB Alluvium | 1B Alluvium |
|---|---|---|---|---|---|---|---|---|---|---|
| 27s Lugert | 13 | 11.0 ± 1.6 | | | | | | | | |
| 1g Post Oak | 2 | 24.5 ± 0.4 | / | | | | | | | |
| 1g Gabbro | 2 | 5.5 ± 1.5 | * | / | | | | | | |
| 1g Alluvium | 6 | 2.8 ± 0.7 | / | / | | | | | | |
| 3lr Alluvium | 3 | 4.3 ± 1.2 | / | / | | | | | | |
| 1θB Post Oak | 4 | 23.5 ± 6.7 | * | | * | / | * | | | |
| 1θB Alluvium | 3 | 12.7 ± 4.0 | | * | | * | | | | |
| 1B Alluvium | 2 | 4.0 ± 2.0 | / | / | | | | * | | |
| 7c Post Oak | 10 | 5.7 ± 1.1 | / | / | | * | | * | | |

significantly higher mean basal area of little bluestem than the 1g Post Oak soils even though it is the major dominant in both types. The mean basal area of forbs is significantly higher on 1g Post Oak than on either of the other 1g soils. All three types are significantly different from other types in having significantly different mean basal areas of from two to seven of the species considered.

All 3lr soil sites are found on Alluvium. They are characterized by their high basal area of big bluestem which delineates them from all other types. Type 3lr Alluvium differs vegetationally from 1B Alluvium only on this basis and in having significantly less hairy grama. From four to seven species serve to delineate 3lr Alluvium from each of the other geological types.

The 1θB soils are found on two geological outcrops, Post Oak and Alluvium. The vegetation is distinguishable only in that the 1θB on

Alluvium has significantly more hairy grama than the 1ΘB on Post Oak. Of the species considered, blue grama and tall dropseed are the most conspicuous indicators, although buffalo grass and annual three-awn are abundant only on these sites. Type 1g Post Oak is the only other edaphic-geologic type related to 1ΘB Post Oak and it is different in having a significantly higher mean basal area of both big bluestem and little bluestem. From three to seven species occur in significantly different amounts on each of the other geological types when compared with 1ΘB Alluvium and 1ΘB Post Oak.

The vegetational relationship of the 1B Alluvium to 27s Lugert, 1g Post Oak and 31r Alluvium has already been mentioned. This diverse vegetational type is dominated by little bluestem and hairy grama and has moderate amounts of big bluestem and blue grama. It has a significantly higher amount of hairy grama than any other type. When the soil types are separated on the basis of their geological parent material, this type becomes distinctly different from all other types.

All 7c soil sites occur on Post Oak. They are characterized by a large amount of little bluestem with hairy grama as another important species. The 1g soil on Post Oak differs from the 7c soil on Post Oak in having a significantly higher basal area of forbs and a significantly lower basal area of hairy grama. No less than three of the species considered in detail serve to delineate 7c Post Oak from each of the other types.

The results described above indicate quite clearly that definite correlations exist in the Refuge between the geological formations and the grassland vegetation. In fact, the vegetation on a given soil type varies with the geological formation from which it was derived.

## SUMMARY

The basal area and relative composition of the grassland communities of the Wichita Mountains Wildlife Refuge were measured by means of the point-contact method. The basal area varies from 13 to 16% on communities with a considerable amount of exposed rock, from 18 to 20% on tall grass sites, and finally to a maximum of 27% on the shallow-soiled short-grass communities.

It is concluded that within this area, based on the relative abundance of the most frequently encountered species, there are nine distinct grassland communities on six soil types and four geological formations. If topography is considered, further delineations can be made raising the total to eleven.

The vegetation on 27s soils on Lugert Granite can be divided into three topographic communities. The north facing slopes are dominated by big bluestem and little bluestem with hairy grama an important secondary species. The flat ridges are dominated by little bluestem with big bluestem, blue grama, and hairy grama being important. Hairy grama dominates the south facing slopes with big bluestem, little bluestem, and blue grama being of lesser importance.

Vegetationally the lg soils are delineated into three communities on three geologic outcrops. Little bluestem is the dominant on all three with big bluestem the most important secondary species. However, there

are differences in relative composition on the different lg soil types. The lg soil on Post Oak supports about as much side-oats grama as big bluestem and has the highest basal area of forbs. Blue grama is the third most important species found on lg soil on Alluvium. The lg Gabbro-derived soil has the highest basal area of little bluestem.

Type 1θB soils are found on both Post Oak and Alluvium. Buffalo grass and blue grama are dominants on both with annual three-awn and tall dropseed being important secondary species. However, the third most important species on the 1θB on Alluvium is hairy grama while this species is not important on 1θB soil derived from Post Oak.

The cobblestone-covered 7c soils found on Post Oak are dominated by little bluestem with big bluestem and hairy grama being important secondary species.

Big bluestem is the only really important species found on the 31r alluvial soils. Little bluestem and Indian grass are secondarily of some importance.

Possibly a stable vegetational type has not become established on the 1B soils on Alluvium due to disturbance in the past. Such soils support a large amount of little bluestem with big bluestem, blue grama, and hairy grama all providing substantial basal cover.

Although several of the areas support the same major dominants, there are often significant differences in the relative abundance of the dominants on such areas. Little bluestem which furnishes from 24 to 48% of the relative composition on eight of the eleven community types, big bluestem which furnishes from 12 to 40% on ten types, and hairy grama which makes up from 11 to 35% of the relative composition on four types, are the major dominants. A total of 50 species of grasses, 4 genera of sedges, and 64 species of forbs were sampled with the point frame on all sites combined.

Forbs play an important role as aspect indicators. One hundred-forty species of forbs were sampled with a 0.1 square meter quadrat. Twelve of these were legumes. Western ragweed is the most abundant species over-all, but is not very valuable as an indicator. Such species as plains coreopsis, hairy goldaster, blazing star, Indian blanket, and ironweed are valuable seasonal indicators of specific soil types.

Definite correlations are found to exist between soil types and vegetation and between geological formations and vegetation. The correlation of vegetation with a combination of soil type and geological formation is better, however, than with the soil type alone.

## LITERATURE CITED

Billings, W. C., and A. F. Mark. 1961. Interractions between alpine tundra vegetation and patterned ground in the mountains of southern New Zealand. Ecology 42(1): 18-30.

Blair, W. F., and T. H. Hubbell. 1938. The biotic districts of Oklahoma. Am. Midland Naturalist. 20: 425-454.

Box, T. W. 1961. Relationships between plants and soils of four range plant communities in South Texas. Ecology 42(4): 794-810.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecol. Monographs. I: 99-188.

Chase, G. W. No date. Unpublished map of the geology of the Wichita Mountains. Map File of the Oklahoma Geological Survey.

Chase, G. W. 1954. Permian conglomerate around Wichita Mountains, Oklahoma. Bull. Am. Assoc. Pet. Geol. 38 (9): 2028-2035.

Chase, G. W., E. A. Frederickson, and W. E. Ham. 1956. Resume of the geology of the Wichita Mountains, Oklahoma. Petroleum geology of southern Oklahoma. Am. Assoc. Pet. Geol. pp. 36-55.

Clark, P. J., and F. C. Evans. 1954. Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology 35: 445-453.

Dana, S. T. 1956. Forest and range policy: Its development in the United States. McGraw-Hill Book Company. New York, N. Y.

Diehl, S. G. 1953. The vegetation of the Wichita Mountains Wildlife Refuge. Unpublished Master's Thesis. Oklahoma State University, Stillwater, Oklahoma.

Duck, L. G., and J. B. Fletcher. 1945. A survey of the game and fur bearing animals of Oklahoma. Oklahoma Game and Fish Dept. Okla-City, Oklahoma.

Eskew, C. T. 1938. The flowering plants of the Wichita Mountains Wildlife Refuge, Oklahoma. Am. Midland Naturalist. 20: 695-703.

Halloran, A. H. 1961. Personal Communication.

Ham, W. E., C. A. Merritt, and E. A. Frederickson. 1957. Oklahoma Geological Survey Guide Book V, Field Conference on Geology of the Wichita Mountain Region. Panhandle Geological Society, Oklahoma Geological Survey.

Hanson, H. C. 1934. A comparison of the methods of botanical analyses of the native prairie in North Dakota. J. Agr. Res. 49: 815-842.

Hanson, H. C. 1938. Ecology of the grassland. Botan. Rev. 4: 51-52.

Hoffman, M. G. 1930. Geology and petrology of the Wichita Mountains. Oklahoma Geological Survey, Bull. No. 52.

Houston, W. R. 1961. Some interrelations of sagebrush, soils and grazing intensity in the northern Great Plains. Ecology 42(1): 31-37.

Hurd, R. M. 1961 Grassland vegetation in the Big Horn Mountains, Wyoming. Ecology 42(3): 459-467.

Kemp, C. D., and A. W. Kemp. 1956. The analysis of point quadrat data. Australian J. Botany, 4: 167-174.

Koford, C. B. 1958. Prairie dogs, whitefaces, and blue grama. Wildlife Monographs. 3: 1-78.

Larrance, F. 1930. The Wichita National Forest and Game Preserve. Southwest Wilds and Waters. 2(4): 12-14.

Merritt, C. A. 1962. Personal Communication.

Schoonover, F. E. 1948. The igneous rocks of the Fort Sill Reservation, Oklahoma. Unpublished Master's Thesis, University of Oklahoma.

Snedecor, G. W. 1956. Statistical Methods, 5th Ed. State College Press, Ames, Iowa.

Soil Conservation Service. 1961. Soils map of the Wichita Mountains Wildlife Refuge, unpublished, on file at Lawton, Oklahoma Soil Conservation Service.

Tinney, F. W., O. S. Aamodt, and H. Algren. 1937. Preliminary report of a study of methods used in botanical analysis of pasture swards. J. Am. Soc. Agr. 29: 835-840.

USDA Yearbook. 1941. Climate and Man. U. S. Government Printing Office, Washington, D. C.

Waterfall, U. T. 1960. Keys to the flora of Oklahoma. Oklahoma State University, Stillwater, Oklahoma.

Whitman, W. C., and E. I. Siggeirsson. 1954. Comparison of line interception and point contact methods in the analysis of mixed grass range vegetation. Ecology 35: 431-436.

Wichita Mountains Wildlife Refuge. 1961. Climatic summary on file in office records.