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Soil-Vegetation Relationships of A Blue Shale-Limy Upland Range Site in Ellis County, Kansas

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Biographical Sketch of the Author

Larry D. Zavesky earned his Bachelor of Science degree in Technical Agronomy (Soil Science) in 1959 from Kansas State University. In 1967, he received a Master of Science degree in Botany from Fort Hays Kansas State College. Currently he is a Soil Scientist with the Soil Conservation Service, United States Department of Agriculture.

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Larry D. Zavesky

Introduction

The relationship of grassland soils to the grass that covers them is close and complex. Many of the physical and chemical properties of the soil depend upon the kinds of grass it supports, and the quality and quantity of grass greatly depend upon the physical and chemical properties of the soil.

The Chernozem soils, which are common to the Mixed Prairie, show the maximum effect of grass on their formation by having dark colored A horizons and by being high in organic matter. Their fertility is high and they normally support a good cover of mid and tall grasses.

Since the weather, parent material, and topography were variable,

FIGURE 1. Erosion occurring on a shale lithosol. Note how erosion around the big bluestem plants has left them somewhat pedestalled with many exposed roots.

many different soils developed. Different soils normally will support diverse types of vegetation. Even similar soils may support kinds of vegetation that differ due to climate and physiography. Due to the soil variability in any particular grassland association, a knowledge of the relationship of soil to native vegetation is very important if there is to be a sound analysis of the range management problems.

Little study has been conducted on the blue shale-limy upland range site.[1] Management of this site is a problem because the range site is composed of five different soils that occur in such small areas that they cannot be feasibly managed separately; therefore, the soils are grouped together as a soil complex[2] and managed as one unit. Soil erosion is a serious problem when the range site is overgrazed (Fig. 1). When erosion has a strong foothold, revegetation is nearly impossible on the shale soils (Fig. 2).

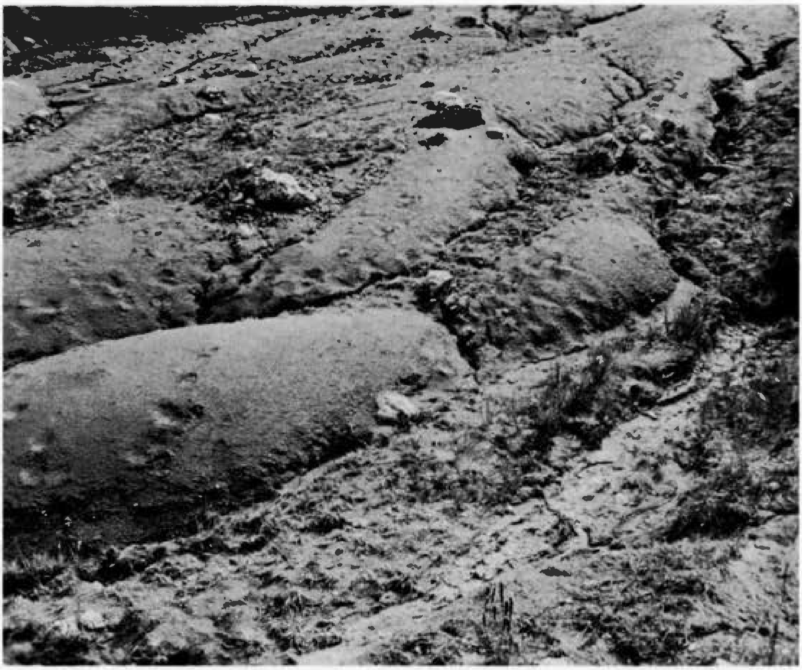

FIGURE. 2. Active soil erosion on a shale soil. Due to overgrazing, the soil has been eroded to where only the parent shale remains and note the very sparse vegetation. The shale is so unstable that plants cannot establish themselves for any length of time. Note the exposed septarian concretions.

1. The range site consists predominantly of two recognizable units which are the blue shale and limy upland range sites. The blue shale range site consists of noncalcareous soils developed from Blue Hill shale. The limy upland range site consists of regosolic soils that are calcareous throughout the profile.

2. Soil complex: A unit composed of two or more recognized soils.

The objective of this study was to determine the soil-vegetation relationships of a blue shale-limy upland range site. Vegetative composition and production were determined for each soil within the range site. Some of the more important physical and chemical properties, such as texture, depth of development, and general fertility, were determined for each soil.

Literature Review

Albertson (1937) divided the Mixed Prairie of west central Kansas into three general types of vegetation: (1) The short grass (*Buchloe-Bouteloua*), (2) the little bluestem (*Andropogon scoparius* Michx.), and (3) the big bluestem (*Andropogon gerardi* Vitman) types. The short grass type normally occurred on soil with rather heavy textured B horizons, while the little bluestem type occurred on immature soils, varying from a few inches to approximately 20 inches thick over limestone. The big bluestem type occurred on lowland sites that normally receive additional moisture from runoff.

Dietz (1953) found the vegetation on a Mixed Prairie in west central Kansas to be predominantly buffalo grass (*Buchloe dactyloides* (Nutt.) Engelm.) and blue grama (*Bouteloua gracilis* (H. B. K.) Lag ex Steud.) on the upland site. On the steep slopes, buffalo grass, blue grama, and hairy grama (*Bouteloua hirsuta* Lag.) were the major species present on the south facing exposures while little bluestem and sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.) were the dominant species on the north facing exposures. Big bluestem and switchgrass (*Panicum virgatum* L.) were dominant species on the lowland sites.

Glover, *et al.* (1966) studied the vegetative composition with respect to exposure on a site which included north, south, west, and east facing slopes. The soils were developed from materials of the Ogallala formation. They found that big bluestem and little bluestem were dominant on the north exposure while dominants on the south exposure were blue grama and side oats grama. The east and west exposures were predominantly covered by blue grama, sideoats grama, and little bluestem.

Nichols (1961) found little bluestem and big bluestem were dominant on north facing slopes while buffalo grass and blue grama were dominant on south facing slopes. Sideoats grama was common to both slopes. Woody plants were limited to north facing slopes. The soils were shallow and intermixed with fragments of limestone.

Sideoats grama was the dominant grass, making up 75 percent of the composition, on soils developed from colluvial-alluvial sediments from the Niobrara formation in Gove County, Kansas (Linnell, 1961). The soils were low in organic matter and the soil pH ranged from 7.1 to 7.8.

Smith (1963) studied the break site occurring on three limestones: (1) The Ash Hollow limestone, (2) the Fort Hays limestone, and (3) the Fencepost limestone. He found little bluestem to be the dominant grass on all three limestones.

Van Amburg (1964) reported the relationship of some factors to soil depth on a break site on the Niobrara formation. He found that the grass production and total cover increased with depth of soil.

Geologic material provides the minerals that compose the soil skeleton (Bidwell, 1964). The soil texture, mineralogical composition, and chemical fertility are largely determined by the minerals of the geologic material from which the soil develops.

Paliwal, *et al.* (1964) stated that most soils of Kansas contain montmorillonite clay minerals. The parent materials of the soils were loess, shale, and alluvial sediments. Promise soil, a soil developed from clayey sediments from the Pierre shale, had montmorillonite as the dominant clay mineral. It is mildly alkaline and low in organic matter.

Montmorillonite clay minerals are of moderate abundance in the Blue Hill shale (Hattin, 1962). These clay minerals have the ability to swell with additions of water and to shrink with the removal of water (Lutz and Chandler, Jr., 1957). Crumpton [3] states ". . . in general, samples of Blue Hill shale from Ellis, Rush, Trego, and Ness counties in Kansas contained from 30 to 60 percent clay size particles less than two microns in diameter."

Methods of Study

Only one area was studied because it was the only site where all five different soils could be studied as a complete unit. The area is typical of the blue shale-limy upland range site and had not been grazed for at least 25 years. The vegetation was assumed to be near climax.

The following characteristics were studied for each soil: (1) texture, (2) depth of development, (3) wilting point, (4) pH, (5) percentage of organic matter, (6) available P_2O_5, and (7) ex-

3. Letter from Carl F. Crumpton, State Highway Commission of Kansas, Topeka, Kansas, March 4, 1964. (Typewritten)

changeable K_2O. The vegetative studies conducted were: (1) basal cover, (2) percentage composition, and (3) yield.

Soils

At least two nearly uniform profiles of each different soil were taken, and each horizon was sampled. Descriptions were written for each horizon in accordance with procedures outlined in the *Soil Survey Manual* (U. S., 1951) and *The Supplement to the Soil Survey Manual* (U. S., 1962). The profiles of soils 1, 2, 3, 4, and 5 were taken from slopes of approximately 8, 10, 5, 6, and 8 percent, respectively.

Each horizon was sampled for particle size distribution which was determined by the hydrometer method (Bouyoucos, 1951).

The wilting point was determined on only the first two horizons because they contain most of the roots. The IEC pressure membrane was used to determine the percentage of moisture at 15 atmospheres tension (wilting point). The moisture percentages were determined as described in the *Agriculture Handbook No. 60* (U. S., 1954).

The soil pH was determined on all horizons. A saturated soil paste was made as described in the *Agriculture Handbook No. 60* (U. S., 1954).

The chemical determinations for percentage of organic matter, available P_2O_5, exchangeable K_2O, and pH were conducted by the soil testing laboratory, extension crops and soils, Kansas State University, Manhattan, Kansas (see appendix A for procedures). Since the roots are most prevalent in the upper horizons, generally only the first two horizons were tested. All samples were tested in duplicate and then an average taken.

Vegetation

The vegetation on each soil was sampled for basal cover and percentage composition by using a point frame (Levy and Madden, 1933). At least six transect lines were spaced approximately three feet apart, and the point frame was placed on the ground approximately every two steps along a transect line. Five thousand points were taken on each soil. On soils 1, 2, and 3, one additional stand was sampled for each soil. Three thousand points were taken on the duplicate stands using the same procedure mentioned above.

The forbs were determined by walking over each area during the spring, summer, and fall, observing the relative abundance of each species. A list was made in descending order of abundance (see appendix B).

Forage yields were determined by a micro-unit forage inventory method (Shoop and McIlvain, 1963). The yield per plot, in pounds per acre, was determined by multiplying the measured weight, in grams, of clipped vegetation by fifty.

Twenty plots were clipped on soils 2, 3, and 5, but thirty plots were clipped on soils 1 and 4 because the vegetation was less uniform. The vegetation was clipped at ground level, separated by species, and air-dried for six to eight weeks. The vegetation was clipped the last week of September for the years 1963 and 1964, but in 1965, it was clipped the first week of September because the study area was to be grazed.

The depth of root penetration was recorded for each soil profile. The approximate depth of root penetration was determined by digging into the soil with a soil auger and noting the depth where roots were no longer visible.

The nomenclature used for the grasses and forbs is that of Hitchcock (1950) and Rydberg (1932), respectively. The common names were obtained from Anderson (1961).

Soils and Geology

General

The blue shale-limy upland range site used in this study occurs in the Rolling Plains and Breaks Resource Area of the Central Great Plains Winter Wheat and Range Region of the United States (U. S. D. A., 1963). In Ellis County, Kansas, the range site occurs in the southwestern part and also along the Saline River east of U. S. Highway 183. It also extends into the neighboring counties northeast of Ellis county.

The study area is located fifteen miles north and six and one-half miles east of Hays, Kansas. The legal description is the northwest corner of the northwest quarter of Sec. 22, T. 11 S., R. 17 W., Ellis County, Kansas.

The mean annual temperature at Hays, Kansas is 54° F and ranges from 25° F in January to 80° F in July (Luebs, 1962). The average length of growing season or frost-free period is 170 days. The average annual precipitation at the Fort Hays Experiment Station, Hays, Kansas, from 1868 through 1958 was 22.90 inches. Seventy-seven percent of the annual rainfall occurs during the growing season (April to September).

The Blue Hill shale is the upper member of the Carlile shale and is about 300 feet thick (Moore, *et al.*, 1951). Below the Blue

Hill shale is the Fairport chalky shale which is also part of the Carlile shale. The Fairport chalky shale differs from the Blue Hill by being calcareous with thin layers of chalky shale while the latter is noncalcareous. Carlile shale is overlain by the Niobrara formation and rests upon the Greenhorn limestone.

Hattin (1962) described the Blue Hill shale as a blocky to fissile, slightly silty, clayey shale that weathers into small brittle flakes. The dominant color is dark gray, but locally the rock is light to dark olive gray. Swineford, McNeal, and Crumpton (1954) described the Blue Hill shale as a gray to bluish black, noncalcareous, silty shale with thin layers of sandstone in the upper part. Many calcareous septarian concretions [4] occur throughout the Blue Hill shale, especially in the upper portion. Hattin (1962) conducted much of his study in the vicinity of the research site used in this paper.

Hattin (1962) made X-ray studies of the Blue Hill shale from five samples along the Saline River valley, Ellis County, Kansas, and from two samples in Jewell County, Kansas. He found kaolinite to be the dominant clay mineral in five of the samples and present in the other two. Montmorillonite or a combination of illite and montmorillonite were dominant in the other two samples and occurred in nearly equal quantities in the five samples where kaolinite was most prevalent. Swineford, *et al.* (1954) found the minerals in the upper part of the Blue Hill shale in Ness County, Kansas, to be montmorillonite, quartz, kaolinite, feldspar, muscovite, and traces of chlorite.

The blue shale-limy upland range site is normally bordered by massive escarpments of buff colored Fort Hays limestone and the portion of the range site immediately below the limestone is normally very steep and eroded. Breaking away from the steep area, the range site then consists of relatively smooth shale ridges capped with outwash material (Fig. 3).

During the Pleistocene geologic period, the Niobrara formation was eroded away, exposing the Blue Hill shale which appears to have been later covered by a mantle of calcareous outwash material (Fig. 4). The outwash material is dominantly clay loam in texture with many fragments of soft chalk and limestone.

Through the processes of geologic erosion, the shale and outwash material probably were eroded in place, leaving many moderately steep to steep ridges of shale capped with the outwash

4. Septarian concretion: Large concretions cut by many veins filled with yellow to brown calcite and rarely other minerals, such as varite, gypsum, sphalerite, or quartz.

material. The ridges are approximately 200 to 800 feet wide with slopes ranging from 5 to 45 percent. The thickness of the outwash material ranges from 2 to 8 feet.

After geologic erosion had slowed sufficiently, soils developed on the shale and on the outwash material. A clay regosol and a clay lithosol developed on the shale while a calcareous loam to clay loam regosol developed on the outwash material. Many of the ridges have small drains (less than 100 feet wide) occurring on

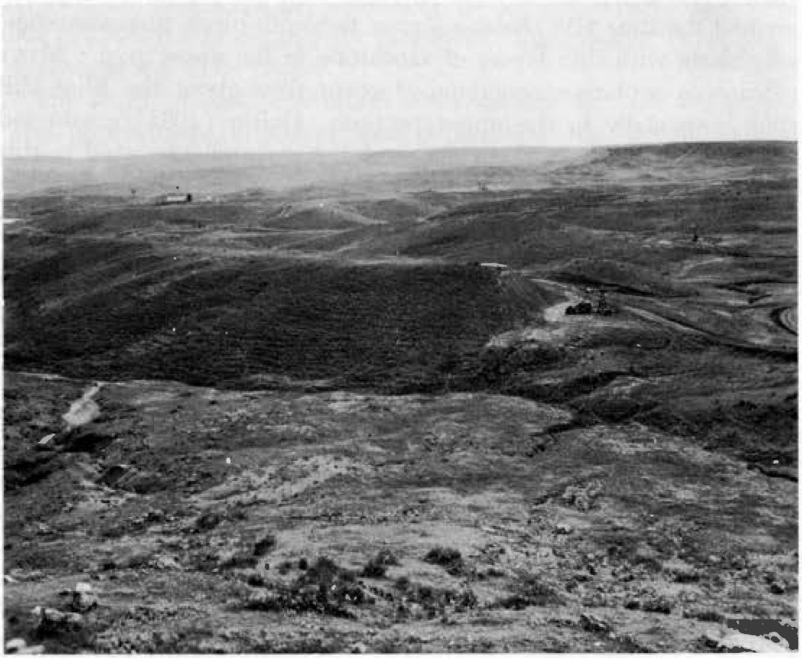

FIGURE 3. Typical landscape of the blue shale-limy upland range site with many smooth moderately steep to steep ridges. The photograph was taken towards the south. Note the soil erosion in the foreground.

their slopes where a clay colluvial-alluvial soil developed.

The vegetative composition on the shale regosol is predominantly big bluestem on the north exposure and western wheatgrass (*Agropyron smithii* Rydb.) and sideoats grama on the south facing exposure. On the outwash soil, the dominant grasses are blue grama and sideoats grama. Meadow tall dropseed (*Sporobolus asper var. hookeri* (Trin.) Vasey) is the dominant grass on alluvial-colluvial soil which receives additional moisture from seepage along the bedding planes of the shale. Big bluestem and sideoats grama are the dominant grasses on the shale lithosol.

Throughout this paper, soils 1 and 2 will refer to the regosolic soils over the Blue Hill shale which occur on the south and north exposures, respectively. The regosolic soil on the outwash material is soil 3, and soil 4 will refer to the lithosolic soils on the shale. Soil 5 will refer to the clay colluvial-alluvial soils.

The blue shale-limy upland range site is composed of three separate range sites which are blue shale, limy upland, and clay lowland. Soils 1 and 4 fit into the blue shale range site with soil 1

FIGURE 4. The Blue Hill shale capped with several feet of calcareous outwash material. The light colored section represents the outwash material.

being most typical. Soils 2 and 3 fit into the limy upland range site with soil 3 being most typical. Soil 2 is considerably heavier textured than normal for limy upland range sites; however, the soil is calcareous and the vegetation is more typical of the limy upland. Soil 5 is included in the clay lowland range site. The range sites are those described by the Soil Conservation Service, Salina, Kansas.

The Soil Conservation Service, Hays, Kansas (unpublished data) studied 1,290 acres to determine the percentage of each soil in the blue shale-limy upland range site. The area studied is located in the W½ and SE¼ of Sec. 30 and Sec. 31, T. 11 S., R. 16 W., the W½ of Sec. 25, T. 11 S., R. 17 W., and portions of Sections 19 and 24, T. 11 S., R. 17 W., Ellis County, Kansas. The area was divided into ten separate study units (Table 1). The regosolic soils were not separated as to exposure; so soils 1 and 2 are shown together. Within each different soil area are inclusions of the other soils (less than 15 percent) which were added or subtracted to give an average percentage for each soil (Table 1). The average percentages of each soil were 42.3, 22.8, 21.2, and 13.6 on soils 1 and 2, 3, 4, and 5, respectively.

Soil Characteristics

Soils 1 and 2

Soils 1 and 2 are Vertic Haplustolls of the very fine, montmorillonitic, mesic family (U. S., 1967). They are developed from Blue Hill shale and the soil depth to nearly unweathered, noncalcareous, fissile shale was more than 20 inches. Soil 2 differs from soil 1 by being developed more deeply and by being calcareous. They differ from soil 3 by being more clayey textured and by being developed from shale. They differ from soil 4 by being developed

TABLE 1.—Percentage of each soil in the blue shale-limy upland range site.

Area	Soils 1 and 2, percent	Soil 3, percent	Soil 4, percent	Soil 5, percent
1	28.7	3.6	50.0	17.7
2	62.0	22.0	6.2	9.8
3	43.6	13.1	9.7	33.6
4	51.0	11.8	21.9	15.3
5	69.0	17.7	6.3	4.7
6	56.0	23.4	14.2	6.4
7	17.6	8.2	48.0	25.9
8	39.8	11.7	28.8	19.6
9	16.0	16.0	60.0	8.0
10	34.0	25.0	25.0	16.0
Average	44.0	15.0	25.0	16.0
Percent of inclusions in various soils.				
	15% Soil 3	none	15% Soil 1 and 2 5% Soil 3	15% Soil 1 and 2
Average percentage of each soil as a result of the inclusions.				
	42.3	22.8	21.2	13.6

more than 20 inches over shale. They differ from soil 5 by being developed from residual shale and by having more horizonation.

Soil Profile Soil 1 (Fig. 5)

Horizon	*Depth*	*Description* [5]
A1	0-6″	Gray (N 5/) clay; very dark grayish brown (2.5Y 3/2) when moist; moderate fine subangular blocky structure; very firm when moist; very hard when dry; matrix noncalcareous except for a few limestone fragments; some medium and fine roots; many ⅛ to ¼ inch cracks; clear smooth boundary to:
AC	6-15″	Gray (N 5/) clay; dark grayish brown (2.5Y 3.5/2) when moist; moderate medium subangular blocky structure; very firm when moist; very hard when dry; matrix calcareous to slightly calcareous; few minute to ¼ inch limestone fragments; some medium and fine roots; many ¼ to ¾ inch cracks; some cracks filled with surface material; gradual smooth boundary to:
C1	15-29″	Gray (5Y 5.5/1) clay; dark gray (5Y 4/1) when moist; weak coarse subangular blocky structure; very firm when moist; very hard when dry; matrix noncalcareous with a few minute to ¼ inch limestone fragments; few medium and fine roots; many disorientated weathered shale fragments; bedding planes evident in the lower portion of the horizon; diffuse smooth boundary to:
R	29-48″	Gray (5Y 6/1) noncalcareous, fissile Blue Hill shale; dark gray (5Y 4/1) when moist; limonitic staining along joints and bedding planes; roots penetrating to 37 inches, following bedding planes and joints; some gypsum along bedding planes.

5. Unless specified moist, color refers to dry soil.

Range in characteristics. The color of the A1 horizons was neutral to 5/2 when dry and 3/2 to 3.5/2 when moist in hue 2.5Y. The texture of the A1 and AC horizons was clay with over 73 percent clay (Table 2). In general, there was a slight increase from the A1 to the AC horizon and a slight decrease in clay from the AC horizon to the C1 horizon. The AC horizons had a color of neutral when dry and ranged in color from 3/2 to 3.5/2 when moist in hues 2.5Y and 5Y. The soil matrix was noncalcareous to slightly calcareous over acid shale. The depth to the Blue Hill shale ranged from 21 to 29 inches. Limestone fragments were common in all profiles, especially along old cracks which ranged from ¼ to ¾ inch in width. The surface is normally covered with a ½ to 1 inch granular mulch, clay in texture. Roots penetrated the soil to depths ranging from 35 to 42 inches, and they followed bedding planes in the R horizons. The C1 horizons had many disorientated flaky shale fragments in its matrix. Gypsum crystals were common in the C1 and R horizons. Due to the high clay content, moisture re-

TABLE 2.—Particle size distribution, percentage of water at 15 atmospheres tension, and some chemical properties of three profiles of soil 1.[1]

PROFILE	Depth, inches	Horizon	Sand, percent	Silt, percent	Clay, percent	Percent water (15 atm)	Organic matter, percent	Avail. P_2O_5 lb./acre	Exch. K_2O lb./acre	pH
1.............	0-4	A1	2.36	22.00	75.64	22.3	1.5	18	500+	7.7
	4-11	AC	2.00	18.14	79.86	26.8	1.0	14	500+	8.0
	11-21	C1	1.72	20.28	78.00	22.4	....	....	....	7.1[2]
	21-48	R	0.58	21.92	77.40	....	....	....	....	5.2[2]
2.............	0-6	A1	1.96	24.00	74.04	23.5	1.6	7	500+	7.9
	6-15	AC	1.80	21.08	77.12	25.1	1.1	6	500+	7.8
	15-29	C1	0.56	26.00	73.14	27.0	....	....	....	7.2[2]
	29-48	R	0.00	30.42	69.58	....	....	....	....	5.2[2]
3.............	0-6	A1	1.82	25.00	73.18	24.1	2.2	25	500+	7.6
	6-15	AC	1.46	21.00	77.54	20.5	1.1	3	500+	8.0
	15-29	C1	0.80	24.00	75.20	21.5	0.9	33	500+	7.9
	29-48	R	0.00	24.80	75.20	....	0.6	33	500+	5.3

1. Chemical determinations for organic matter, available P_2O_5, exchangeable K_2O, and pH were conducted by the soil testing laboratory, extension crops and soils, Kansas State University, Manhattan, Kansas.

2. Soil pH determined by author at Fort Hays Kansas State College, Hays, Kansas.

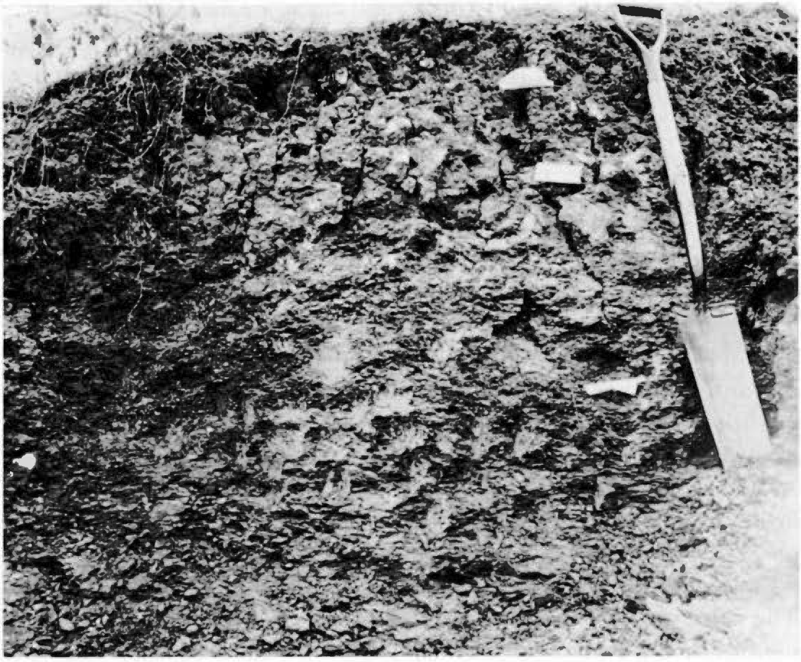

FIGURE 5. Soil profile of soil 1. Soil development occurs to the third marker, which is approximately 30 inches from the top of profile. Note extensive cracking in the upper portion of the profile.

tention percentages were high, ranging from about 21 to 27 percent (Table 2). Organic matter content and available P_2O_5 were low in the A1 and AC horizons while exchangeable K_2O was high. The percent organic matter decreased with depth. The A1, AC, and C1 were mildly to moderately alkaline over an acid R horizon.

SOIL PROFILE Soil 2

Horizon	*Depth*	*Description* [6]
A1	0-6"	Dark grayish brown (10YR 4/2) silty clay; very dark brown (10YR 2/2) when moist; moderate very fine subangular blocky structure; firm when moist; hard when dry; calcareous; many minute to ½ inch limestone fragments; some worm casts; many medium and fine roots; few coarse roots; gradual smooth boundary to:
AC	6-18"	Gray (N 5/) clay; dark gray (N 3/) when moist; moderate medium subangular blocky structure; very firm when moist; very hard when dry; some minute to ⅛ inch limestone fragments; some medium and fine roots; calcareous, few coarse roots, gradual smooth boundary to:
C1	18-40"	Gray (N 5/) clay; very dark grayish brown (2.5Y 3/2) when moist; weak medium subangular blocky structure; very firm when moist; very hard when dry; calcareous; few semi-indurated lime concretions and soft spots of segregated lime; few limonitic stains; few medium and fine roots; some disorientated highly weathered shale fragments; diffuse smooth boundary to:

Horizon	*Depth*	*Description* [6]
C2	40-48"	Gray (5Y 5.5/) clay; dark gray (N 4/) when moist; massive to platy structure; very firm when moist; very hard when dry; noncalcareous; much partially weathered shale; few roots following bedding planes; few limonitic stains; diffuse smooth boundary to:
R	48" +	Gray (5Y 5.5/1) noncalcareous, fissile Blue Hill shale; dark gray (5Y 4/1) when moist; limonitic staining along bedding planes; roots penetrating to about 50 inches, following bedding planes and joints; some gypsum along bedding planes.

6. Unless specified moist, color refers to dry soil.

Range in characteristics. The thickness of the A1 horizons ranged from 6 to 10 inches and the color ranged from neutral to 4.5/2 when dry and from 2/2 to 3/2 when moist in hues 10YR and 2.5Y. The texture ranged from silty clay to clay and there was generally at least an 18 percent difference in clay content from the A1 to the AC horizon (Table 3). All the other horizons, including the AC horizon, contained over 70 percent clay with the sand fraction being predominantly limestone. Color of the AC horizons was neutral when dry and ranged from neutral to 3.5/2 when moist in hue 2.5Y. The color of the C horizons was neutral when dry and ranged from neutral to 4/2 when moist in hues 2.5Y and 5Y. Depth to acid Blue Hill shale was 48 to over 50 inches and the soil was calcareous. Some cracks occurred within all profiles and ranged from ¼ to ½ inch wide in the first 20 inches. Some semi-indurated lime concretions and soft spots of segregated lime occurred in the C horizons, and some limestone fragments were common throughout the profile. Crystals of gypsum were common along bedding planes of the C2 and R horizons. Roots penetrated the soil to depths of more than 50 inches. The C2 horizons had many disorientated flaky shale fragments. Moisture retention percentages were high, ranging from about 23 to 26 percent (Table 3). Organic matter content and exchangeable K_2O were high while available P_2O_5 was very low. All profiles were mildly to moderately alkaline over acid shale.

TABLE 3.—Particle size distribution, percentage of water at 15 atmospheres tension, and some chemical properties of several profiles of soil 2.[1]

Profile	Depth, inches	Horizon	Sand, percent	Silt, percent	Clay, percent	Percent water (15 atm)	Organic matter, percent	Avail. P_2O_5 lb./acre	Exch. K_2O lb./acre	pH
1	0-9	A1	4.00	27.56	68.44	22.6	2.7	5	500+	7.7
	9-20	AC	1.00	26.38	72.62	25.2	1.8	1	500+	7.9
	20-35	C1	1.22	24.78	74.62	24.2	1.4	1	500+	7.9
	35+	C2	0.44	24.56	75.00					7.0[2]
2	0-10	A1	10.56	38.94	50.50					
	10-19	AC	2.05	23.77	74.18					
	19-35	C1	1.76	20.24	78.00					
	35-48	C2	1.00	26.42	72.58					
	48+	R	0.00	32.00	68.00					
3	0-6	A1	13.50	40.06	46.44	24.7	4.2	1	500+	7.7
	6-18	AC	8.54	26.40	70.20	25.3	2.0	0	500+	7.9
	18-40	C1	2.00	20.76	77.24	23.7				7.6[2]
	40-48	C2	1.06	20.94	78.06					7.1[2]
4	0-6	A1	16.04	39.26	44.70	26.2	3.7	3	500+	7.7
	6-17	AC	8.54	29.04	62.42	25.4	2.2	1	500+	8.0
	17-35	C1	1.00	25.74	73.26	22.0				7.6[2]
	35-50	C2	1.40	27.94	70.66					7.1[2]

1. Chemical determinations for organic matter, evailable P_2O_5, exchangeable K_2O, and pH were conducted by the soil testing laboratory, extension crops and soils, Kansas State University, Manhattan, Kansas.

2. Soil pH determined by author at Fort Hays Kansas State College, Hays, Kansas.

Soil 3

Soil 3 is a Typic Haplustoll of the fine loamy, mixed, mesic family (U. S., 1967). It is a calcareous clay loam soil developed from calcareous local outwash from limestone and other plains sediments. They differ from the neighboring shale soils by being considerably more loamy and by not being developed from shale or colluvial-alluvial sediments from the shale.

SOIL PROFILE SOIL 3 (Fig. 6)

Horizon	*Depth*	*Description* [7]
A1	0-8"	Dark grayish brown (10YR 3.5/2) loam, very dark brown (10YR 2/2) when moist; moderate fine granular structure; friable when moist; slightly hard when dry; calcareous; many minute to ¼ inch limestone fragments; many medium and fine roots, porous; many worm casts; clear smooth boundary to:
AC	9-15"	Grayish brown (10YR 5/2) clay loam; very dark grayish brown (10YR 3/2) when moist; moderate fine granular structure; friable when moist; slightly hard when dry; strongly calcareous; many minute to ½ inch limestone fragments; some fine threads of segregated lime; porous; many worm casts; some medium and fine roots; gradual smooth boundary to:
ACca	15-25"	Pale brown (10YR 6.5/3) clay loam; yellowish brown (10YR 5/4) when moist; moderate very fine subangular blocky structure; friable when moist, hard when dry; strongly calcareous; many minute to ¼ inch limestone fragments; many soft and semi-indurated lime concretions; some spots and threads of segregated lime; some worm casts; porous; diffuse smooth boundary to:
C1	25+	Very pale brown (10YR 7/4) clay loam; yellowish brown (10YR 5/6) when moist; weak coarse prismatic structure; friable when moist; hard when dry; strongly calcareous; many minute to ½ inch limestone fragments; few soft lime concretions; few spots of segregated lime; few fine roots.

7. Unless specified moist, color refers to dry soil.

Range in characteristics. The thickness of the A1 horizons ranged from 5 to 8 inches. The color of the A1 horizons ranged from 3.5/2 to 4/2 when dry and from 2/2 to 2.5/2 when moist in hue 10YR. The texture of the A1 horizons was dominantly loam and the AC and C horizons were clay loams (Table 4). The IIC horizons were heavier primarily due to weathered shale. The AC horizons ranged in color from 5/2 to 6/2 when dry and from 3/2 to 3.5/2 when moist in hue 10YR. Color of the ACca and C1 horizons ranged from 6/3 to 7/4 when dry and from 4/3 to 5/6 when moist in hue 10YR. The soils were calcareous to the surface and contained soft and semi-indurated concretions along with spots of segregated lime. Moisture retention percentages ranged from about 17 percent in the A1 horizons to about 11 percent in the C1 horizons

TABLE 4.—Particle size distribution, percentage of water at 15 atmospheres tension, and some chemical properties of four profiles of soil 3.[1]

PROFILE	Depth, inches	Horizon	Sand, percent	Silt, percent	Clay, percent	Percent water (15 atm)	Organic matter, percent	Avail. P_2O_5 lb./acre	Exch. K_2O lb./acre	pH
1	0–5	A1	26.70	47.42	25.88	17.3	3.2	1	500	7.9
	5–10	AC	25.56	44.96	29.48	11.5	2.6	6	246	7.9
	10–25	ACca	39.38	30.48	29.78	9.1	....	....	....	7.8[2]
	25–40	C1	12.48	39.66	52.14	....	....	....	....	7.8[2]
	40+	IIC	1.05	19.89	79.06	....	....	....	....	7.8[2]
2	0–8	A1	26.02	49.04	24.94	17.6	2.8	1	404	7.9
	8–15	AC	27.28	43.14	29.58	16.1	1.8	2	215	8.0
	15–25	ACca	21.02	43.54	35.44	13.8	1.3	14	257	8.0
	25–50	C1	24.02	37.04	38.94	10.6	1.0	21	500+	8.2
3	0–6	A1	26.26	49.30	24.44	18.0	3.3	2	480	7.9
	6–13	AC	26.28	44.00	29.72	16.5	3.3	11	295	8.0
	13–23	ACca	23.10	40.18	36.72	11.5	....	....	....	8.1[2]
	23–50	C1	19.10	41.18	39.72	11.1	....	....	....	7.8[2]
4	0–6	A1	17.70	42.86	39.44	16.8	....	....	....	7.8[2]
	6–13	AC	18.30	38.26	43.44	13.8	....	....	....	7.9[2]
	13–21	C1	19.30	35.26	45.44	....	....	....	....	7.8[2]
	21–48	IIC	7.30	11.64	75.30	....	....	....	....	....

1. Chemical determinations for organic matter, available P_2O_5, exchangeable K_2O, and pH were conducted by the soil testing laboratory, extension crops and soils, Kansas State University, Manhattan, Kansas.

2. Soil pH determined by author at Fort Hays Kansas State College, Hays, Kansas.

FIGURE 6. Soil profile of soil 3. The distance to the first marker represents the dark colored A1 horizon which is about 10 inches. The light colored spots in the lower portion of the profile are limestone fragments and lime concretions.

(Table 4). Even though the texture increased with depth, the moisture percentages decreased with depth. Organic matter of the A1 and AC horizons was high and decreased with depth. Available P_2O_5 was very low and exchangeable K_2O was high. The horizons were mildly to moderately alkaline throughout the profiles.

Soil 4

Soil 4 is a Typic Haplustoll of the clayey, montmorillonitic, mesic, shallow family (U. S., 1967). They are developed from Blue Hill shale and are less than 20 inches thick over the shale. They differ from soils 1 and 2 by having less than 20 inches of soil development over shale. Soil 3 is developed from loamy outwash and is less clayey textured and soil 5 is developed from clayey colluvial-alluvial sediments.

Range in characteristics. Thickness of the A1 horizons ranged from 6 to 10 inches. Color of the A1 horizons was neutral when dry and ranged from neutral to 3/2 when moist in hue 5Y. Texture of all horizons was clay, containing over 73 percent clay (Table 5).

TABLE 5.—Particle size distribution, percentage of water at 15 atmosphers tension, and some chemical properties of two profiles of soil 4.[1]

Profile	Depth, inches	Horizon	Sand, percent	Silt, percent	Clay, percent	Percent water (15 atm)	Organic[2] matter, percent	Avail.[2] P_2O_5 lb./acre	Exch.[2] K_2O lb./acre	pH
3	0–6	A1	1.88	24.90	73.22	21.4	1.4	26	500+	6.5[3]
	6–11	C1	0.38	20.30	79.22	25.6	....	....	....	6.5[3]
	11+	R	0.00	23.78	76.22	....	....	....	....	4.0[3]
4	0–6	A1	2.52	22.12	76.38	26.4	1.5	40	500+	6.8[3]
	6–11	C1	1.84	22.16	76.00	23.7	....	....	....	5.9[3]
	11+	R	0.56	21.06	78.38	....	....	....	....	4.2[3]

1. Chemical determinations for organic matter, available P_2O_5, exchangeable K_2O, and pH were conducted by the soil testing laboratory, extension crops and soils, Kansas State University, Manhattan, Kansas.
2. Chemical determinations were made on the first ten inches of soil.
3. Soil pH determined by author at Fort Hays Kansas State College, Hays, Kansas.

SOIL PROFILE Soil 4 (Fig. 7)

Horizon	*Depth*	*Description* [8]
A1	0-6"	Gray (N 5/) clay; very dark gray (N 3/) when moist; weak medium subangular blocky structure; very firm when moist; very hard when dry; noncalcareous except for a few septarian fragments; few crystals of calcite; some coarse and medium roots; clear smooth boundary to:
C1	6-11"	Gray (N 5/) clay; very dark gray (N 3/) when moist; weak medium subangular blocky to platy structure; very firm when moist; very hard when dry; noncalcareous except for a few septarian fragments; few calcite crystals; some medium and fine roots; diffuse smooth boundary to:
R	11-48"	Gray (5Y 5/1) Blue Hill shale; very dark gray (5Y 3/1) when moist; roots penetrating to 35 inches and following bedding planes.

8. Unless specified moist, color refers to moist soil.

Color of the C1 horizons ranged from neutral to 5/1 when dry and from neutral to 3/1 when moist. Many weathered flaky shale fragments were common, especially in the C1 horizons. Depth to unweathered fissile shale ranged from 8 to 19 inches. Roots penetrated the soil from 28 to 40 inches, primarily along bedding planes of the shale. The surface had a granular clayey textured mulch

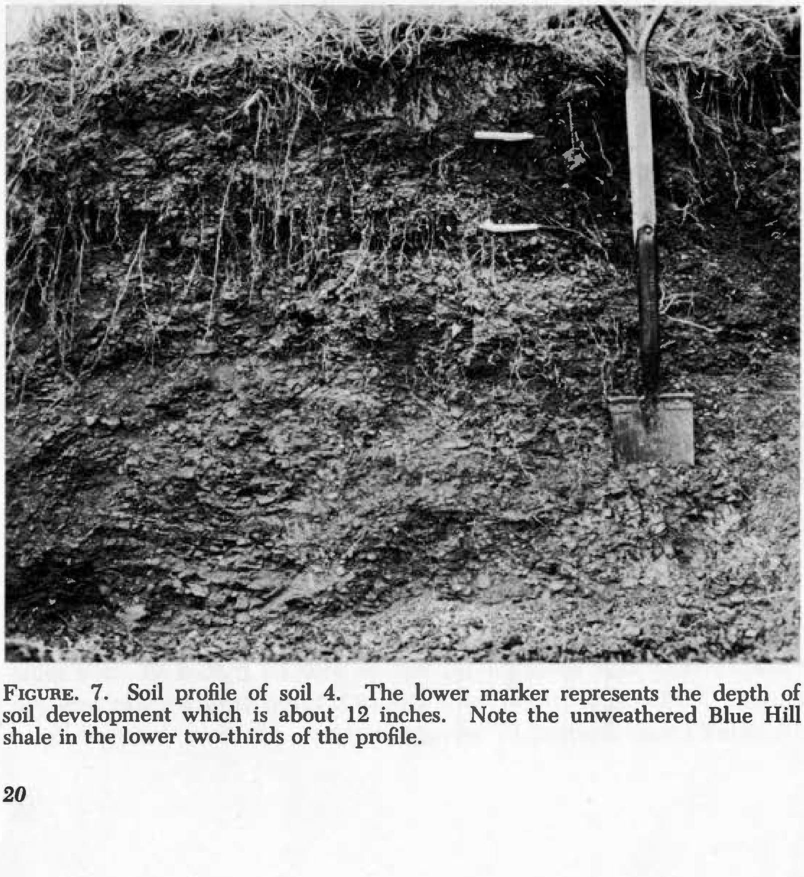

FIGURE. 7. Soil profile of soil 4. The lower marker represents the depth of soil development which is about 12 inches. Note the unweathered Blue Hill shale in the lower two-thirds of the profile.

which varied from ½ to ¾ inch in thickness. Moisture retention percentages were high, ranging from about 21 to 25 percent (Table 5). Of the first 10 inches of soil, organic matter content and available P_2O_5 were low while exchangeable K_2O was high. The profiles were neutral to slightly acid in reaction.

Soil 5

Soil 5 is a Vertic Haplaquoll of the very fine, montmorillonitic, calcareous, mesic family (U. S., 1967). This classification is tentative. They are clayey textured soils developed from clayey colluvial-alluvial sediments from the shale and outwash material. The soil occurred along shallow drains (generally less than 125 feet wide) that intersect soils 1 and 2 and receives additional moisture from seepage along the bedding planes of the shale. They differ from soils 1 and 2 by being developed from colluvial-alluvial sediments rather than residual shale. They differ from soil 3 by being more clayey textured, and they differ from soil 4 by being more alkaline and by being over 20 inches thick over shale.

Soil Profile Soil 5

Horizon	*Depth*	*Description* [9]
A1	0-8″	Dark gray (N 4.5/) clay; very dark gray (N 3.5/) when moist; moderate fine subangular blocky structure; very firm when moist; very hard when dry; matrix slightly calcareous; many uniformly distributed minute to ¼ inch limestone fragments; many medium to fine roots; few coarse roots; diffuse smooth boundary to:
AC	8-27″	Dark grayish brown (2.5Y 4/2) clay; very dark gray (N 3/) when moist; moderate medium subangular blocky structure; very firm when moist; very hard when dry; matrix slightly calcareous with many uniformly distributed minute to ¼ inch limestone fragments; few cracks; limestone fragments somewhat stratified; many medium and fine roots; few spots of segregated lime; diffuse smooth boundary to:
C1	27-43″	Dark gray (N 4.5/) clay; very dark grayish brown (2.5Y 3/2) when moist; weak coarse blocky to massive structure; very firm when moist; very hard when dry; matrix slightly calcareous; few minute to ¼ inch limestone fragments; few identifiable shale fragments; few fine roots; few crystals of gypsum; diffuse smooth boundary to:
R	43″+	Dark gray (5Y 4/1) noncalcareous Blue Hill shale; very dark gray (5Y 3.5/1) when moist.

9. Unless specified moist, color refers to dry soil.

Range in characteristics. The color of the A1 horizons was neutral when dry or moist. The texture of the soil was clay throughout (Table 6). Thickness of the A1 horizons ranged from neutral to 5/2 when dry and from neutral to 3/2 when moist in hue 2.5Y. Some profiles may show no evidence of an AC horizon. The

TABLE 6.—Particle size distribution, percentage of water at 15 atmospheres tension, and some chemical properties of three profiles of soil 5.[1]

PROFILE	Depth, inches	Horizon	Sand, percent	Silt, percent	Clay, percent	Percent water (15 atm)	Organic matter, percent	Avail. P_2O_5 lb./acre	Exch. K_2O lb./acre	pH
1............	0-13	A1	1.76	25.68	72.56	24.7	1.9	25	500+	7.6
	13-36	AC	1.00	26.44	72.56	20.2	....	....	....	7.5[2]
	36-48	C1	14.26	25.68	60.06	....	....	....	....	7.3[2]
2............	0-8	A1	2.80	29.50	67.70	20.9	1.9	16	500+	7.6
	8-27	AC	2.54	26.30	71.06	24.5	....	....	....	7.6[2]
	27-43	C1	1.00	22.12	76.88	....	....	....	....	7.2[2]
3............	0-11	A1	2.20	26.58	71.22	22.1	1.4	16	500+	7.3
	11-30	AC	1.40	24.58	75.22	22.3	....	....	....	7.3[2]
	30+	R	....	....	....	....	....	....	....	5.4[2]

1. Chemical determinations for organic matter, available P_2O_5, exchangeable K_2O, and pH were conducted by the soil testing laboratory, extension crops and soils, Kansas State University, Manhattan, Kansas.

2. Soil pH determined by author at Fort Hays Kansas State College, Hays, Kansas.

stand 2, big bluestem occurred only where better moisture conditions prevailed. Small patches and single young plants of buffalo grass were present on both stands. Other grasses found in small amounts were meadow tall dropseed, tall dropseed (*Sporobolus asper* (Michx. Kunth), and three-awns (*Aristida* spp. L.). The principal forbs were western ragweed (*Ambrosia psilostachya* Gray) and prickly pear (*Opuntia macrorhiza* Engelm.).

FIGURE 8. Mosiac of vegetated landscape of soils 1, 2, 3, and 5. The light colored portion represents the area occupied by soil 5 and the dominant grass is meadow tall dropseed. The dark portion in the foreground is dominantly big bluestem on soil 2. The dark portion in the center represents soil 1 and soil 3 is represented in the background along the ridge.

Soil 2

Two stands were sampled and the basal cover was approximately 8 percent for both stands (Table 8). The dominant grass was big bluestem which made up over 75 percent of the composition on both stands (Fig. 8). Sideoats grama was uniformly distributed throughout both stands while little bluestem occurred on small open ridges. Indiangrass occurred along the lower third of the slope on both stands. Switchgrass (*Panicum virgatum* L.), buffalo grass, blue grama, and three-awns were present on stand 1 but were

TABLE 8.—Basal cover and percentage composition of vegetation on two stands on soil 2 of the blue shale-limy upland range site.

Species	Basal cover		Percentage composition	
	Stand 1	Stand 2	Stand 1	Stand 2
Big bluestem	6.90	6.56	78.58	77.26
Sideoats grama	.80	1.03	9.11	12.15
Little bluestem	.76	.80	8.65	9.41
Indiangrass	.12	.10	1.36	1.17
Switchgrass	.10	....	1.13	....
Tall dropseed	.06	....	.68	....
Buffalo grass	.02	....	.22	....
Blue grama	.02	....	.22	....
Total	8.78	8.49	99.95	99.99

not observed on stand 2. The principal forbs were silverleaf scurf-pea (*Psorelea argophylla* Pursch.) and leadplant (*Amorpha canescens* Pursch.).

Soil 3

Two stands were sampled and the basal cover was about 11 and 10 percent on stands 1 and 2, respectively (Table 9). Sideoats grama, blue grama, and big bluestem were dominant for both stands and they together comprised over 75 percent of the composition of stand 1 and about 72 percent on stand 2 (Fig. 8). Sideoats grama was distributed uniformly over each stand while blue grama was found predominantly on soils more than three feet thick

TABLE 9.—Basal cover and percentage composition of vegetation on two stands on soil 3 of a blue shale-limy upland range site.

Species	Basal cover		Percentage composition	
	Stand 1	Stand 2	Stand 1	Stand 2
Sideoats grama	3.48	2.83	34.05	25.52
Blue grama	2.26	3.33	22.11	30.03
Big bluestem	1.66	1.76	16.24	15.91
Buffalo grass	1.08	1.03	10.56	9.30
Little bluestem	.78	.76	7.63	6.90
Hairy grama	.30	.60	2.93	5.40
Western wheatgrass	.26	.33	2.54	3.00
Three-awns	.20	.30	1.95	2.70
Hairy dropseed	.16	.10	1.56	.90
Tall dropseed	.04	.03	.39	.30
Total	10.22	11.07	99.96	99.96

over shale. Big bluestem normally occupied the soils that had shale within 2 to 3 feet of the soil surface. Buffalo grass occurred intermixed with the blue grama and comprised about 10 percent of the composition on both stands. Little bluestem was present throughout both stands, but it occurred predominantly where the soil was thin over the shale or where the soil was gravelly. Hairy grama was uniformly distributed over stand 2, but on stand 1, it was restricted to the south side and where the soil was gravelly. Western wheatgrass occurred intermixed with the sideoats grama and blue grama while the three-awns were distributed uniformly throughout both stands. Other grasses found in small amounts were hairy dropseed (*Sporobolus asper* var. *pilosus* (Vasey) Hitch.) and tall dropseed. The principal forbs were western ragweed, leadplant, small soapweed (*Yucca glauca* Nutt.), and black samson (*Echinacea angustifolia* DC.).

Soil 4

Basal cover was 6.38 percent with the dominant grasses being big bluestem and sideoats grama (Fig. 9), and together they made up about 79 percent of the composition (Table 10). Little bluestem occurred predominantly on a small northwest facing ridge but was present over the entire area. Indian grass and switchgrass occupied soils that were developed more deeply and/or received additional moisture from runoff. Other grasses present in small amounts were buffalo grass, three-awns, tall dropseed, western wheatgrass, blue grama, and hairy grama. The principal forbs were western ragweed and leadplant.

TABLE 10.—Basal cover and percentage composition of vegetation on one stand on soil 4 of the blue shale-limy upland range site.

Species	Basal cover	Percentage composition
Big bluestem	3.03	46.27
Sideoats grama	2.07	32.27
Little bluestem	.60	9.38
Indiangrass	.27	4.31
Switchgrass	.20	3.75
Buffalo grass	.06	1.12
Three-awns	.06	1.12
Tall dropseed	.04	.75
Western wheatgrass	.03	.56
Blue grama	.01	.18
Hairy grama	.01	.18
Total	6.38	99.99

FIGURE 9. Vegetative cover on soil 4. The grass shown is dominantly big bluestem along with a few plants of indiangrass and little bluestem. Erosion appears to be common on this soil even the vegetation is near climax.

Soil 5

Basal cover was slightly over 9 percent and the dominant grass was meadow tall dropseed (Fig. 8) which made up over 75 percent of the composition (Table 11). Western wheat grass was intermixed with the meadow tall dropseed; however, nearly pure communities of western wheatgrass did exist. Most of the sideoats

TABLE 11.—Basal cover and percentage composition of vegetation on one stand on soil 5 of the blue shale-limy upland range site.

SPECIES	Basal cover	Percentage composition
Meadow tall dropseed	7.06	75.26
Western wheatgrass	.84	8.95
Big bluestem	.60	6.39
Sideoats grama	.56	5.97
Tall dropseed	.12	1.27
Switchgrass	.08	.85
Buffalo grass	.06	.64
Silver bluestem	.06	.64
Total	9.38	99.97

grama and big bluestem occurred in the transition zone between soils 1 and 5, but sideoats grama was also distributed in lesser amounts uniformly throughout the area. Other grasses present in small amounts were tall dropseed, switchgrass, buffalo grass, and silver bluestem (*Andropogon saccharoides* Swartz). Western ragweed was the dominant forb.

Yield and Composition by Weight

Precipitation records were taken for 1963, 1964, and 1965 from the Fort Hays Experiment Station which recorded the precipitation throughout the year and from the Soil Conservation Service which recorded only the precipitation during the growing season. Local farmers, using federal rain gages, provided the Soil Conservation Service the rainfall amounts. The farmer recording stations were located from 4 to 7 miles from the study area. The rainfall distribution 4 miles east of the study area was thought to be most similar to that of the study area (Table 12).

Precipitation of 1963, 1964, and 1965 was quite variable. The annual precipitation recorded at Fort Hays Experiment Station, Hays, Kansas, was near normal in 1963, below normal in 1964, and above normal in 1965. Distribution of the precipitation during 1963 and 1964 was not favorable for production of grass. Precipitation during the first few months of the growing seasons of 1963 and 1964 was considerably below average and this is the period when most grass production occurs in western Kansas (Tomanek and Albertson, 1957). Although precipitation was below average in April of 1965, the remainder of the growing season was quite favorable for grass production; therefore, yields in 1963 and 1964 were much lower than in 1965.

TABLE 12.—Precipitation at four locations in Ellis County, Kansas.

Month	Location 1 [1]			Location 2 [2]			Location 3 [3]			Location 4 [4]		
	1963	1964	1965	1963	1964	1965	1963	1964	1965	1963	1964	1965
Jan.	.15	.01	.18	...	...	...	...	...	...	...	...	...
Feb.	.11	.78	.72	...	...	...	...	...	...	...	...	...
Mar.	1.70	.88	.99	...	...	...	...	...	...	...	...	...
Apr.	.05	.49	.76	.13	.63	.31	...	.50	.60	.05	.54	.33
May	.95	2.42	3.93	1.76	2.45	3.77	.73	1.65	3.74	1.63	2.03	3.49
June	3.07	6.76	6.52	2.01	2.86	9.63	1.57	3.30	12.00	3.02	2.83	10.11
July	5.00	1.28	4.92	5.26	1.53	1.19	3.70	.77	4.08	5.14	1.31	3.53
Aug.	.90	1.96	2.16	.83	.63	2.29	.47	1.40	2.17	1.28	4.21	2.45
Sept.	8.54	3.41	2.03	6.81	3.03	3.61	5.52	4.20	2.47	6.09	3.06	2.86
Oct.	1.17	.10	1.52	...	...	...	...	...	...	...	...	...
Nov.	.30	1.51	...	...	...	...	...	...	...	...	...	...
Dec.	.23	.17	...	...	...	...	...	...	...	...	...	...

1. Fort Hays Experiment Station, Hays, Kansas.
2. Precipitation received during the growing season 7 miles west of the study area.
3. Precipitation received during the growing season 4 miles east of the study area.
4. Precipitation received during the growing season 7 miles southwest of the study area.

Soil 1

Forage yields from 1963 through 1965 increased from about 750 to 2000 pounds per acre, respectively (Table 13). Although the yield of sideoats grama increased slightly, the percentage composition by weight of this species decreased from 1963 to 1965. The decrease in composition resulted from a large increase in yield of western wheatgrass. From 1963 to 1965, the yield of western wheatgrass increased nearly fortyfold. In 1963, the soil was so dry in the spring that western wheatgrass did not make much initial growth, but some growth was made after the fall rains. During the following years, moisture conditions were adequate for good spring growth thus producing higher yields. In 1963 only 2 percent of the yield was attributed to western wheatgrass, while in 1965, it contributed 35 percent of the yield. Other grasses contributing to the forage yield were big bluestem, buffalo grass, blue grama, tall dropseed, three-awns, and silver bluestem. Most of the yield from forbs was western ragweed. The average forage yield for the three years (1963-1965) was 1304.9 pounds per acre.

TABLE 13.—Forage yield and percentage composition by weight of vegetation on soil 1 of the blue shale-limy upland range site.

Species	Yield lbs./acre			Percentage composition by weight		
	1963	1964	1965	1963	1964	1965
Sideoats grama	411.7	481.5	559.4	54.93	41.25	27.99
Western wheatgrass	18.3	300.4	710.4	2.44	25.74	35.55
Big bluestem	74.7	116.2	146.0	9.96	9.95	7.30
Buffalo grass	21.5	63.1	116.2	2.86	5.40	5.81
Blue grama	24.9	16.6	....	3.32	1.42	....
Tall dropseed	....	....	68.0	....	....	3.40
Meadow tall dropseed	127.8	76.4	....	17.05	6.54	....
Silver bluestem	....	29.9	6.6	....	2.56	.33
Forbs	74.4	83.0	391.7	9.52	7.11	19.60
Total	749.4	1167.0	1998.3	100.08	99.97	99.98

Soil 2

Forage yields from 1963 through 1965 increased from about 1000 to nearly 3000 pounds per acre, respectively (Table 14) and big bluestem accounted for over 58 percent of the yield. Yields of sideoats grama and little bluestem increased from 1963 to 1964 but decreased from 1964 to 1965. Competition was probably greater during 1965 since the big bluestem was taller and more leafy. Other grasses contributing to the forage yield were indiangrass, switch-grass, tall dropseed, buffalo grass, blue grama, and three-awns and a few forbs, especially leadplant, were also included in the yield. The average yield for the three years was 1849.3 pounds per acre.

TABLE 14.—Forage yield and percentage composition by weight of vegetation of soil 2 of the blue shale-limy upland range site.

Species	Yield lbs./acre			Percentage composition by weight		
	1963	1964	1965	1963	1964	1965
Big bluestem	710.0	918.0	2110.0	70.64	58.83	71.01
Sideoats grama	42.5	109.6	102.5	4.22	7.02	3.45
Little bluestem	132.5	152.7	315.0	13.18	9.78	10.60
Indiangrass	....	114.5	50.0	....	7.33	1.68
Switchgrass	7.5	....	17.5	.74	....	.59
Tall dropseed	....	46.5	30.0	....	2.98	1.01
Three-awns	12.5	....	....	1.25	....	....
Leadplant	100.0	162.7	170.0	9.95	10.42	5.73
Forbs	....	56.4	177.0	....	3.61	5.97
Total	1005.0	1560.4	2972.5	99.98	99.97	100.04

Soil 3

In 1963 and 1964, the forage yield was approximately 1200 pounds per acre, but in 1965, the forage yield was much higher with over 3000 pounds (Table 15). Over 63 percent of the total yield was

TABLE 15.—Forage yield and percentage composition by weight of vegetation on soil 3 of the blue shale-limy upland range site.

Species	Yield lbs./acre			Percentage composition by weight		
	1963	1964	1965	1963	1964	1965
Sideoats grama	390.0	225.0	584.0	31.22	19.06	18.03
Blue grama	122.0	175.0	312.5	9.76	14.83	9.63
Big bluestem	280.0	385.0	975.0	22.41	32.62	30.06
Buffalo grass	35.0	95.0	162.5	2.80	9.05	5.01
Little bluestem	192.5	150.0	487.5	15.41	12.71	15.03
Hairy grama	17.5	10.0	50.0	1.40	.84	1.54
Western wheatgrass	10.0	37.5	67.5	.80	3.17	2.08
Three-awns	22.5	45.0	230.0	1.80	3.81	7.09
Hairy dropseed	22.5	10.0	35.0	1.80	.84	1.07
Tall dropseed	20.0	....	7.5	1.60	....	.23
Silver bluestem	....	....	95.0	....	....	2.92
Leadplant	35.0	15.0	57.5	2.80	1.27	1.77
Forbs	102.5	32.5	177.5	8.20	2.75	5.47
Total	1249.0	1180.0	3243.5	99.98	99.98	99.93

attributed to sideoats grama, big bluestem, and little bluestem. Even though blue grama was one of the dominant species, it generally contributed less to the total production than any of the above species. The more important species increased in yield from 1963 to 1965 except little bluestem which decreased from 1963 to 1964. Other grasses contributing to the yield were buffalo grass; hairy grama, western wheatgrass, three-awns, hairy dropseed, tall dropseed, and silver bluestem, while leadplant and other forbs, especially western ragweed, also contributed. The average forage yield for the three years was 1890.8 pounds per acre.

Soil 4

Forage yields from 1963 through 1965 increased from about 750 to nearly 1900 pounds per acre, respectively (Table 16). Big bluestem, little bluestem, and indiangrass produced more forage in 1965 than for either of the previous years with over one-third of the yield

TABLE 16.—Forage yield and percentage composition by weight of vegetation on soil 4 of the blue shale-limy upland range site.

Species	Yield lbs./acre			Percentage composition by weight		
	1963	1964	1965	1963	1964	1965
Big bluestem	338.6	402.5	692.2	44.94	39.81	38.15
Sideoats grama	177.6	138.5	194.2	23.57	13.69	10.70
Little bluestem	84.6	199.6	376.8	11.22	19.74	20.77
Indiangrass	11.6	46.7	189.2	1.53	4.61	10.42
Switchgrass	11.6	19.3	....	1.53	1.90	....
Buffalo grass	19.9	11.3	13.3	2.64	1.11	.73
Three-awns	4.9	19.3	9.9	.65	1.90	.54
Tall dropseed	24.9	96.6	87.9	3.30	9.55	4.84
Leadplant	71.5	51.5	151.0	9.47	5.09	8.30
Forbs	8.3	25.7	99.6	1.10	2.54	5.49
Total	753.4	1011.0	1814.1	99.95	99.94	99.94

attributed to big bluestem. As on soil 3, the yield of sideoats grama decreased from 1963 to 1964 but increased in 1965. Other grasses contributing to the yield were switchgrass, buffalo grass, three-awns, and tall dropseed. Leadplant and other forbs also contributed to the yield. The average forage yield for the three years was 1218.3 pounds per acre.

Soil 5

Forage yields from 1963 through 1965 increased from nearly 2000 to over 3000 pounds per acre (Table 17), and over half the yield was attributed to meadow tall dropseed. As the moisture conditions improved, western wheat grass and big bluestem produced more forage until over 10 percent of the yield was attributed to each species in 1965. Sideoats grama increased in yield from 1963 to 1964 but decreased in 1965. The decrease in yield of sideoats grama was probably due to competition with the dense growth of meadow tall dropseed. Other grasses contributing to the yield were tall dropseed, switchgrass, buffalo grass, and silver bluestem. Western ragweed was the dominant forb. The average forage yield for the three years was 2355.5 pounds per acre.

TABLE 17.—Forage yield and percentage composition by weight of vegetation on soil 5 of the blue shale-limy upland range site.

Species	Yield lbs./acre			Percentage composition by weight		
	1963	1964	1965	1963	1964	1965
Meadow tall dropseed.	1360.0	1162.0	1905.0	73.43	61.75	57.16
Western wheatgrass. .	95.0	155.0	347.5	5.04	8.23	10.42
Big bluestem.	87.5	135.0	360.0	4.72	7.17	10.80
Sideoats grama.	87.5	160.0	105.0	4.72	8.49	3.15
Tall dropseed.	150.0	100.0	212.5	8.09	5.31	6.37
Switchgrass.	72.5	65.0	45.0	3.91	3.45	1.35
Forbs.	. . . .	105.0	357.5	. . . .	5.57	10.72
	1852.0	1882.5	3332.5	99.91	99.97	99.97

Discussion

Many cracks ranging from ¼ to 1 inch were common within the profiles of soils 1, 2, and 5. The cracks were due to the swelling and shrinking characteristics of the clay minerals. The parent material, Blue Hill shale, contained montmorillonite (Hattin, 1962). It was assumed that these soils would contain appreciable amounts of this clay mineral since they developed from the Blue Hill shale. Since the permeability of these soils is slow, the cracks were advantageous in that they let water into the soil quite rapidly.

During periods of runoff, some of the surface materials washed into the cracks. Pieces of weathered organic matter (*i. e.*, grass stems) were often found along the old cracks. The soil material along the cracks was usually lighter colored and more calcareous, especially in soil 1, than the soil matrix.

Normally as the percentage of clay in a soil profile increases, the moisture percentages at 15 atmospheres tension increase. However, the moisture percentages of soil 3 decreased as the percentage of clay increased (Table 4). The lime content appeared to increase with depth of profile; when the textural analysis was taken, much of the lime was probably included with the clay fraction, thus giving a high clay percentage. The moisture percentages indicated that the percentage of clay may have been lower than that shown in Table 4.

The clay content of soil 3 was higher when the outwash material over shale was less than 2 feet in thickness; some clay from the shale was apparently mixed with the outwash material. Vegetative changes were common when the shale was within 2 feet of the surface. The percentage of big bluestem normally increased as the thickness of soil 3 over shale decreased. The soil probably received additional moisture from water following along the bedding planes of the shale.

The matrix of soil 1 did not effervesce when placed in contact with dilute hydrochloric acid. However, the soil pH indicated the soil was alkaline. The alkalinity was probably a result of the calcareous material along the cracks, or the soil may contain some sodium (U. S., 1954).

The alkaline soils were low in available P_2O_5. The phosphorus may have been in the form of tricalcium phosphate which would be unavailable to plants. In most alkaline soils, the activity of calcium is high and the result is the formation of insoluble forms of phosphates (Tisdale and Nelson, 1956). Soils containing a high percentage of clay minerals fix large amounts of phosphorus, thus making it unavailable to plants. Soil 4, which had neutral to medium acid horizons, had more available P_2O_5 than those soils with alkaline horizons.

Exposure seemed to be quite important in determining the vegetative composition and soil development on soils 1 and 2. According to Nichols (1961), evaporation is higher on a south exposure than on a north exposure. Due to less evaporation on the north exposure, a more mesic climate prevails which probably contributes to the vegetative differences and depth of soil development between soils 1 and 2. Soil 1, which occurs on a south exposure, supported a cover of western wheatgrass and sideoats grama while soil 2, which occurs on a north exposure, supports big bluestem as the dominant grass. Big bluestem probably occurs on soil 2 because of the more mesic climate.

Soil 2 shows more soil development by having a profile approximately 15 inches thicker than soil 1. Soil 2 also showed more development in the A1 horizon by being thicker and lighter textured. The increase in soil development on soil 2 is probably due to the better moisture conditions. However, soil 1 showed more weathering by having less free carbonates. Soil 1 did not effervesce when placed in contact with dilute hydrochloric acid while soil 2 effervesced strongly, which indicates free carbonates. Normally there is a reduction in free carbonates as a soil becomes more developed. There is no explanation why soil 2 has more free carbonates since it occurs in a more favorable climatic position for soil development.

Of the shale soils, excluding the north facing exposure, big bluestem appeared to prefer soils similar to soil 4. Big bluestem, which was one of the dominant grasses on soil 4, also occurred as nearly pure stands on the inclusions of soil 4 within soil 1. The preference of big bluestem to soils similar to soil 4 may be because the soil is more open. The soil remains open because there are many partially weathered shale fragments in the soil matrix.

Summary

Soils

The blue shale-limy upland range site is comprised of five soils, with three soils being developed from Blue Hill shale, one soil being developed from colluvial-alluvial sediments, and one soil being developed from calcareous outwash materials. The soils occurred intermixed in such small areas; therefore, for practical aspects of management, they were grouped into a soil complex.

Soil 1 and 2 were dark colored regosolic soils which developed from Blue Hill shale and occurred on south and north exposures, respectively. Soil 3 was a dark colored regosolic soil which developed from outwash material while soil 4 was a dark colored lithosolic soil which developed from Blue Hill shale. Soil 5 was a dark colored soil which developed from colluvial-alluvial sediments from the shale and outwash material.

Profile descriptions were written for each soil and compared with respect to depth, color, texture, and structure.

Particle size distribution, percent organic matter, available P_2O_5, exchangeable K_2O, and reaction were determined on three profiles of soils 1, 2, 3, and 5 and two profiles of soil 4. The moisture percentage at 15 atmospheres tension was determined on most horizons. The particles size distribution was determined by the hydrometer method.

The texture of soils 1, 2, 4, and 5 was clay throughout the profile except the A1 horizon of soil 2 ranged from silty clay to clay. Soil 3 ranged from loam in the A1 horizon to clay loam in the C1 horizon.

The percentages of soil moisture for soils 1, 2, 4, and 5 ranged from 20.2 to 27 percent and normally increased with an increase in the percent clay. Soil 3 had lower soil moisture percentages than the clayey soils.

The percentage organic matter was low in soils 1, 4, and 5. In soils 2 and 3, the percentage organic matter was high in the A1 and AC horizons.

Available P_2O_5 was very low in soils 1, 2, and 3. In soils 4 and 5, the available P_2O_5 was low but ranged from 16 to 40 pounds per acre.

Exchangeable K_2O was high in all soils except soil 3.

Soils 1, 2, 3, and 5 were mildly to moderately alkaline with values of pH ranging from 7.6 to 8.0 in the first two horizons. The soil pH of soil 4 was neutral to medium acid with value ranges from 5.9 to 6.8.

Vegetation

Basal cover and percentage composition were determined by a point frame and at least 5,000 points were taken on each soil.

Forage yields were determined by a micro-unit forage inventory method and at least 20 plots were clipped on each soil. After allowing the forage to air dry, the forage was weighted in grams and recorded in pounds per acre by multiplying the gram weight by 50. Yields were taken from 1963 to 1965, inclusive.

On soil 1, the basal cover was approximately 6 percent. The dominant grasses were sideoats grama and western wheatgrass and together they comprised over 75 percent of the composition. Big bluestem and buffalo grass comprised approximately 13 percent of the composition. The forage yield ranged from about 750 to 1200 pounds per acre with an average of 1304.9 pounds for the three years. Sideoats grama and western wheatgrass together produced over 50 percent of the yield; however, western wheatgrass only contributed 2.44 percent of the yield in 1963. Other important grasses contributing to the yield were big bluestem and buffalo grass. The principal forb contributing to the yield was western ragweed.

On soil 2, the basal cover was approximately 8.50 percent and big bluestem made up over 75 percent of the composition. Other important grasses were little bluestem and sideoats grama. The forage yields ranged from 1005 pounds to 2972.5 pounds per acre with an average of 1849.3 pounds for the three years. Big bluestem produced from 58 to 72 percent of the yield while sideoats grama and little bluestem together produced 14 to 17 percent of the yield.

On soil 3, the basal cover was 10 to 11 percent. Sideoats grama and blue grama comprised over 55 percent of the composition while big bluestem and buffalo grass made up about 25 percent of the composition. The forage yield ranged from 1180 to 3243.5 pounds per acre with an average of 1890.8 pounds for the three years. Sideoats grama and big bluestem contributed from 48 to 53 percent of the yield, and blue grama and little bluestem comprised 24 to 27 percent of the yield. Leadplant and other forbs, especially western ragweed, also contributed to the yield.

On soil 4, the basal cover was 6.38 and the dominant grasses were big bluestem and sideoats grama which made up 46.37 and 32.27 of the composition, respectively. The forage yield ranged from 753.4 to 1890.4 pounds per acre with an average of 1218.3 pounds for the three years. Big bluestem produced from 36 to 44 percent of the yield. Sideoats grama and little bluestem together produced 30 to 34 percent of the forage yield. Forbs, especially western ragweed, and leadplant also contributed to the yield.

On soil 5, the basal cover was 9.38 and meadow tall dropseed comprised 75.26 percent of the composition. Western wheatgrass, big bluestem, and sideoats grama comprised 8.95, 6.39, and 5.97 percent of the composition, respectively. Forage yields ranged from 1852 to 3332.5 pounds per acre with an average of 2355.5 pounds for the three years. Meadow tall dropseed produced from 57 to 73 percent while western wheatgrass and big bluestem together produced 10 to 20 percent of the yield. Western ragweed also contributed to the yield.

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Appendix A

Chemical Determinations[5]

Organic Matter

Organic matter was determined by a wet oxidation procedure in which 1 gram of soil was placed in a 250 ml. flask and 10 ml. of 1N nitrogen potassium dichromate was added. Then 20 ml. of concentrated sulfuric acid was added. Heat of dilution was utilized to carry the reaction along. After a reaction time of 30 minutes, 100 ml. of distilled water was added. Samples were allowed to cool and then filtered; the organic matter was determined colorimetrically by using a model 6-A Coleman Jr. spectrophotometer. Color development was due to the reduction of red-orange chromic ion to the green chromus ion.

Available Phosphorus (P_2O_5)

Available phosphorus was extracted at a ratio of 1 part soil to 10 parts extractant. The extractant used was .025N HC1 and .03N NH_4F, and the total extraction time was one minute. The solution was filtered and then 5 drops of a HC1-Ammonium molybdate solution were added. The color was developed by addition of sulfonic acid. The available phosphorus was determined colorimetrically after standing for 15 minutes and the model 6-A Coleman Jr. Spectrophotometer was used to determine the color intensity.

Exchangeable potassium (K_2O)

Exchangeable potassium was extracted with 1 part soil to 5 parts neutral normal ammonium acetate. The extraction time was 10 minutes. The exchangeable potassium was determined by a Perkin-Elmer flame photometer.

pH

The pH was determined from a mixture of 1 part soil to 1 part water with a Beckman Zeromatic pH meter. The standard saturated KC1 calomel electrode and general purpose glass electrode were used.

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5. Chemical determinations were made at the soil testing laboratory, extension crops and soils, Kansas State University, Manhattan, Kansas. Procedures were taken from a letter by George W. Wright, extension specialist, soil testing, Kansas State University, Manhattan, Kansas.

Appendix B

Forbs

The following list of important forbs is ranked in order of relative abundance for each soil.

Soil 1

Common Name	*Scientific Name*
Western ragweed	Ambrosia psilostachya Gray
Bigroot pricklypear	Opuntia macrorhiza Engelm.
Illinois bundleflower	Desmanthus illinoensis (Michx.) MacMill.
Carrotleaf lomatium	Lomatium daucifolium Coult. and Rose.
Purple prairieclover	Petalostemum purpureus (Vent.) Rydb.
Fendler aster	Aster fendleri A. Gray
Narrowleaf four-o'clock	Allionia linearis Pursh

Soil 2

Leadplant	Amorpha canescens Pursh
Silverleaf scurfpea	Psoralea argophylla Pursh
Western ragweed	Ambrosia psilostachya Gray
Stenosiphon	Stenosiphon linifolius (Nutt.) Britton
Falseboneset	Kuhnia suaveolens Fresen.
Smallflower gaura	Gaura parviflora Dougl.
Lemon beebalm	Monarda citriodora Coult.

Soil 3

Leadplant	Amorpha canescens Pursh
Small soapweed	Yucca glauca Nutt.
Western ragweed	Ambrosia psilostachya Gray
Slimflower scurfpea	Psoralea tenuiflora Pursh.
Bigroot pricklypear	Opuntia macrorhiza Engelm.
Blacksamson echinacea	Echinacea angustifolia DC.
Dotted gayfeather	Liatris punctata Hook.
Purple prairieclover	Petalostemum purpureus (Vent.) Rydb.
Upright prairieconeflower	Ratibida columnifera Woot. and Standl.
Broom snakeweed	Gutierrezia sarothrae (Pursh) Britton and Rusby
White polygala	Polygala alba Nutt.
Scarlet globemallow	Sphaeralcea coccinea (Nutt.) Rydb.
Ironplant	Sideranthus spinulosus (Pursh) Sweet
Wavyleaf thistle	Cirsium undulatum (Nutt.) Spreng.
Fendler aster	Aster fendleri A. Gray
Milkweed	Asclepias pumila (A. Gray) Vail
Nineanther dalea	Dalea enneandra (Nutt.) Britton
Common breadroot scurfpea	Psoralea esculenta Pursh

Common Name	*Scientific Name*
Tallbread scurfpea	Psoralea cuspidata Pursh
Lemon beebalm	Monarda citriodora Coult.
Stickleaf mentzelia	Mentzelia oligosperma Nutt.

Soil 4

Leadplant	Amorpha canescens Pursh
Western ragweed	Ambrosia psilostachya Gray
Carrotleaf lomatium	Lomatium daucifolium Coult. and Rose.
Illinois bundleflower	Desmanthus illinoensis (Michx.) MacMill.
Dotted gayfeather	Liatris punctata Hook
Slimflower scurfpea	Psoralea tenuiflora Pursh
Purple prairieclover	Petalostemum purpureus (Vent.) Rydb.
Blacksamson echinacea	Echinacea angustifolia DC.
Small soapweed	Yucca glauca Nutt.
Bigroot pricklypear	Opuntia macrorhiza Engelm.
Lemon beebalm	Monarda citriodora Coult.
Fendler aster	Aster fendleri A. Gray
Smoothseed wildbean	Strophostyles leiosperma (T. and G.) Piper

Soil 5

Western ragweed	Ambrosia psilostachya Gray
Silverleaf scurfpea	Psoralea argopylla Pursh
Illinois bundleflower	Desmanthus illinoensis (Michx.) MacMill.
Narrowleaf four-o'clock	Allionia linearis Pursh

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