Vegetation-Soil Relationships in Flint Hills Bluestem Pastures[1]

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Change in species population may serve as a basis for evaluating the effects of grazing on range condition. However, it must also be recognized that vegetational composition varies from place to place independent of grazing influences and that populations on different soils may not respond alike to management treatments. Thus it becomes necessary to relate the vegetation to the site. In this study vegetational populations have been compared for different soils in the same climate. The experimental area was the Flint Hills bluestem pastures used in pasture utilization research at the Kansas Agricultural Experiment Station at Manhattan, Kansas. The purpose of the study was to associate vegetation with its environment as a basis for interpreting population changes and in segregating effects of grazing management practices from effects of site.

Bluestem grasslands such as these, when in climax or near-climax condition, are highly productive and are characterized by great stability under grazing. Shively and Weaver (1939) noted the long life span of the dominant species. Weaver (1940) pointed out that, after 90 or more years of settlement, large tracts remain practically uninvaded by weeds although surrounded by weedy fields and pastures. Phillips (1935) observed that climax is in dynamic equilibrium with the climate. In the Flint Hills bluestem pastures this equilibrium of the climax vegetation with climate is not easily disturbed except by long continued, abusive grazing or repeated burning over dry soil.

Under close grazing most of the climax dominants and certain minor species, including many forbs, decrease but other members of the climax increase to take their place. If grazing pressure continues, the latter also begin to decrease and invasion by weeds takes place. These responses were recognized in the mixed prairie of Oklahoma by Smith (1940) who stated that species were forced out in the order of their palatability or edibility. Weaver and Hansen (1941) described stages of pasture deterioration near Lincoln, Nebraska, from climax to depletion, employing a classification of certain true prairie species according to their response to grazing.

Dyksterhuis (1949) pointed out that departure from climax could be measured quantitatively by comparing the current relative coverage or production by species with that of the climax as determined by careful study of prairie relicts on the same kind of soil. Percentages of decreasers, increasers, and invaders were established as the basis for measuring degeneration. He recognized the influence of local site differences on the species population, even under total protection, and noted that there are many preclimax and postclimax sites differing in species composition but successionally in a state of equilibrium. Thus vegetation climax to a regional climate was not used as the maximum range condition for all sites. The climatic climax was expected to be represented only on the ordinary uplands, that is, on normal or zonal soils. Dyksterhuis showed that after sites had been classified on the basis of differences in undisturbed vegetation, degrees of grazing disturbance could be measured quantitatively because they were reflected in current plant populations.

The Flint Hills Grazing Region

The Flint Hills, an important livestock region supporting a year-round cattle population of some 500,000 head plus about 300,000 additional ones shipped there each summer to fatten, extends from the Nebraska line into northern Oklahoma between the 96th and 97th meridians. Its 4,000,000 acres constitute a major segment of the true prairie. Utilization of this

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region for grazing has been discussed by Anderson (1953).

Elevations of the Flint Hills region range from 1,550 feet in the central part to 850 feet at its southeastern extremity. Physiographically a strongly dissected plain, the terrain is rolling to hilly with relatively smooth, narrow divides bordered by rock outcrops and steep slopes. Breaks and escarpments occur adjacent to major stream valleys.

Rainfall of the region varies from 30 inches in the northern to 38 inches in the southern part, with seasonal distribution of precipitation and evaporation being relatively uniform over the area. About 75 percent of the moisture falls during the growing season, which ranges in length from an average to 170 days in the north to 190 days in the south.

As described by Fly (1949), the residual soils have developed from massive limestones, interbedded gray and yellow shales, and highly flinty or cherty limestones of the lower Permian formations. The divides have in places a thin mantle of loess. Under the native bluestem vegetation the soils throughout the Flint Hills have developed dark, well-granulated silt loam or silty clay loam surface horizons that are slightly acid in reaction. Fertility is moderate to high. Texture and consistency of subsoil, depth of soil, and degree of stoniness vary widely with the character of the parent material and the degree of slope. Broken rock and chert allow moisture and plant roots to penetrate deeply. However, wide variations exist in the ability of the soils to support the regional climax type of vegetation.

The native vegetation is classified as true prairie. Pastures are currently dominated by mid grasses such as little bluestem (*Andropogon scoparius*), sideoats grama (*Bouteloua curtipendula*), and Kentucky bluegrass (*Poa pratensis*), together with tall grasses including big bluestem (*Andropogon furcatus*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Lesser amounts of short grasses occur and are dominant only on droughty preclimax sites or on overgrazed areas. Forbs often are conspicuous at the time of flowering but seldom constitute a major percentage of the climax vegetation.

Procedure

Vegetational analyses were conducted during the growing seasons of 1947 to 1950 by the line interception method of Canfield (1941) as adapted to true prairie vegetation by Anderson (1942). This method gives estimates by species in terms of both percentage basal area or ground cover and percentage of total population. Sampling was initiated one year prior to subdivision of the experimental area and two years before grazing treatments were effected. Thus differential effects due to grazing intensity were lacking.

In order to obtain estimates that would significantly reflect the variety of responses of the vegetation to grazing and to reduce the likelihood of faulty generalization concerning population change, it appeared desirable to classify the samples according to site conditions. This would permit associating any such change with the site as well as with the treatment. Thus the location of each transect sample was recorded on an aerial photograph and the conditions of slope, soil, and exposure were noted. With the completion of a soil survey and soil map in 1950, it was possible to group vegetation samples according to various land characteristics and to compare the groupings statistically.

Fifteen mapping units, including two gullied ones in which the vegetation was not sampled, were delineated in a soil conservation survey. Table 1 summarizes this survey, describes the mapping units, and identifies each by use of the national standard symbols for coding soil properties (Guide for Soil Conservation Surveys. 1951). During the mapping it became apparent that certain of the soils differences were not reflected in vegetational differences. Therefore, those mapping units obviously similar in both soils and plant populations were grouped together into 10 soil units, exclusive of the gullied ones, for a more detailed analysis of the vegetation. The grouping of the original mapping units into 10 soil units is indicated in Table 1 and the relative coverage by species on each of these units is shown in Table 2.

Similarities in the vegetational composition of certain of these 10 groups suggested the further combination into five major groups, termed range sites. This grouping is indicated in Table 1 and shown in Table 2 together with average of vegetational composition for each group. The term range site, as employed in this study, refers to the combination of climatic and soil conditions of a given area as they affect species composition and forage production. Dyksterhuis (1949) pointed out that site separation is justified if (1) there is a measurable difference in species composition between two sites when development of natural vegetation and soil development are in equilibrium on each, or (2) with similar climax vegetation, there is a measurable difference in foliage production.

Although gullied lowlands and eroded clays occur in these pastures, the vegetation on them was not sampled because they are so highly variable in both soil and vegetational characteristics as to make sampling of little value and, in addition, they occupy only a small portion of the area under study.

Results

Table 2 compares percentage population of major increasing and decreasing grasses by soil units in the five major groups. The data reveal that the six soil units of the first two groups (ordinary uplands and limestone breaks range sites) supported far more vegetation of the regional climax than did the others. Little bluestem and big

Table 1. Range site classification and description of major soil units.

Unit grouping	Survey mapping symbol[1]	Soil unit description
		Ordinary upland
1	2F3U / 6-1	Gently sloping, deep, silty clay loam colluvial soils with little or no erosion.
1	2F3U / 10-1	Similar to first soil unit but on steeper slopes and with more chert fragments in subsoil.
2	3gF4C / 20-1	Strongly sloping, moderately deep, cherty silty clay loam soils with little or no erosion.
3	3gF4CL / 20-1	Similar to the above soils but with limestone fragments in soil and on surface.
4	3Fr4C / 5 or 8-1	Gently sloping, moderately deep, cherty silty clay loam soils with little or no erosion.
		Limestone breaks
5	4rF4C / 35-1	Steep, shallow, very cherty silty clay loam soils with little or no erosion.
6	4rF4C / 45-1	Similar to above but very steep.
5	4vF4CL / 35-1	Similar to 4rF4C / 35-1 but with limestone ledges and numerous limestone rocks exposed.
6	4vF4CL / 45-1	Similar to above but very steep.
		Clay upland
7	3F21E / 6-1	Gently sloping, moderately deep silty clay loam soils with tight clay subsoils over shale, with slight erosion.
8	3rF3(1)C / 5-1	Gently sloping, very cherty clay loam soils with tight clay subsoils and slight to moderate erosion.
		Very shallow
9	5vML / 6-2	Gently sloping, very shallow stony soils over massive limestone.
		Claypan
10	2M1DEa1 / 4-1	Gently sloping, thin loam over very dense clay, with numerous small "slick" spots.
		Dense clay
	3H21E / 6-2 (7)	Gently sloping moderately deep, tight silty clay soils over shale, with serious sheet and gully erosion. (Vegetation not sampled.)
		Lowland
	XUX / Du-8V	Mixed alluvial, colluvial and limestone shale soils on broken, irregular slopes along narrow upland drainages with severe gullying and bank cutting. (Vegetation not sampled.)

[1]National standard symbols for coding soil properties, U. S. Dept. of Agric. Soil Conserv. Service. Guide for Soil Conservation Surveys. 1951.

bluestem together made up 47.0 and 51.8 percent of the vegetation of these two groups but only 32.1, 29.7, and 16.6 percent in the clay uplands, very shallow, and claypan groupings, respectively. Indiangrass made up 9.9 and 10.1 percent of the population in the first two groups but only 4.3, 3.9, and 1.8 percent in the others. When major increasing and decreasing perennial grasses were compared, soil units in the first two groups were found to support 57.9 and 62.8 percent decreasers, respectively, and only 26.6 and 23.5 percent increasers. Corresponding values in the other three groups of soil units were 38.0, 35.1, and 19.9 percent for decreasers and 44.6, 49.4, and 54.7 percent for increasers.

To test the validity of these groupings, the populations of decreasing and increasing perennial grasses of the 10 soil units were compared, on the basis of absolute basal intercept as measured in the line-transect samples, in a series of analyses of variance applied to the 10 groups for each of the four years. In each case highly significant differences were noted among units for both increasing and decreasing species, thus supporting the hypothesis that population differences as influenced by site do actually exist.

The six soil units of the ordinary upland and limestone breaks groups were then subjected to the same type of analysis to test the assumption of homogeneity. In these tests neither total increasers nor total decreasers gave F values high enough to indicate significance at the .05 level in any of the four years, tending thus to substantiate the hypothesis that these six soil units produced similar vegetation. However, examination of the relative coverage by individual species revealed the fact that the two limestone breaks units contained a significantly greater percentage of sideoats grama and the ordinary upland units a significantly greater percentage of Kentucky bluegrass. Unit 2 varied from this in that its population of sideoats grama resembled that of the limestone breaks units.

Analysis of the data for the clay upland group, units 7 and 8, showed that these two were essentially alike but differed significantly from the other groups. Their vegetation is preclimax in nature.

Units 9 and 10 support vegetation even more unlike the regional climax than that of units 7 and 8. Unit 9, designated as the very shallow range site, is characterized by very shallow soils along ledges of massive limestone, while unit 10, the claypan site, has a very shallow surface soil over dense clay subsoil.

The gullied lowlands are in reality a complex of many sites too small to delineate individually. They were not sampled but were delineated to complete the map, making a total of six range sites. These gullied lowlands support a plant cover distinctly different from that of the five groups described above. It is highly variable due to the presence of bare areas and actively eroding banks, as well as seeps and springs. Stands composed almost entirely of cordgrass (*Spartina pectinata*) or coarse sedges are found in wet places, while typical lowland prairie occurs in the more mesic ones between areas bared by active erosion. Accurate and representative sampling of the vegetation in this site is not possible.

Characteristics of the five upland and the single lowland range sites and their respective vegetation may be summarized as follows:

OU—*Ordinary Upland Site.* Lands having sufficient depth of soil with medium or loamy texture and hence with suitable soil-plant moisture relations to support the type of vegetation that is climax on the zonal soils of the regional climate.

LB—*Limestone Breaks Site.* Lands similar to the above but occurring on steeper slopes and therefore subject to somewhat greater loss of moisture by runoff and with less development. The vegetation,

Table 2. Special composition as percent of total plant population by soil units and range sites. Summary of 1947-1950 line-transect samples for six bluestem pastures.

Species	RANGE SITES												
	Ordinary Upland					Limestone Breaks			Clay Upland			Very Shallow	Claypan
	SOIL UNITS												
	1	2	3	4	ave.	5	6	ave.	7	8	ave.	9	10
	%	%	%	%	%	%	%	%	%	%	%	%	%
Perennial grasses													
Decreasers													
Big bluestem	16.5	21.4	20.1	19.8	*19.0*	19.0	20.5	*20.1*	16.4	15.3	*15.6*	13.2	10.2
Little bluestem	28.6	26.5	30.9	32.2	*28.0*	29.4	32.8	*31.7*	18.8	15.9	*16.5*	16.5	6.4
Indiangrass	11.0	8.8	9.7	4.5	*9.9*	9.1	10.5	*10.1*	5.3	4.0	*4.3*	3.9	1.8
Switchgrass	0.5	0.4	0.5	0.5	*0.5*	0.6	0.4	*0.4*	0.7	0.4	*0.4*	0.1	0.3
Prairie junegrass	0.3	0.3	0.4	0.9	*0.3*	0.3	0.3	*0.3*	0.4	1.1	*0.9*	1.2	0.6
Prairie dropseed	0.2	0.2	0.3	0.4	*0.2*	0.2	0.2	*0.2*	0.2	0.3	*0.3*	0.2	0.6
Total	57.1	57.6	61.9	58.3	*57.9*	58.6	64.7	*62.8*	41.8	37.0	*38.0*	35.1	19.9
Increasers													
Sideoats grama	5.3	9.1	5.1	5.5	*6.9*	10.5	11.6	*11.3*	8.0	7.6	*7.7*	9.1	4.3
Buffalograss	2.1	1.9	0.5	0.9	*1.8*	1.1	1.0	*1.0*	6.1	10.0	*9.1*	3.1	17.9
Kentucky bluegrass	14.8	7.8	7.9	8.4	*11.1*	3.1	3.1	*3.1*	11.0	8.3	*8.9*	2.0	12.9
Blue grama	0.4	0.5	tr.	0.7	*0.4*	3.3	1.7	*2.2*	1.8	7.3	*6.1*	20.9	9.5
Hairy grama	0.6	1.6	0.5	0.2	*1.0*	3.6	2.6	*2.9*	1.3	4.8	*4.0*	10.4	2.4
Tumblegrass	0.4	0.5	0.4	0.5	*0.4*	0.4	0.3	*0.4*	1.2	1.5	*1.4*	1.0	1.6
Sand dropseed	0.5	0.7	1.8	3.8	*0.7*	0.5	0.2	*0.3*	3.4	5.3	*4.8*	1.5	3.0
Purple lovegrass	2.1	1.0	2.0	4.8	*1.7*	0.4	1.3	*1.0*	0.5	0.4	*0.4*	0.6	0.3
Scribner panic	1.6	1.0	1.4	0.9	*1.3*	0.7	0.6	*0.6*	1.6	0.6	*0.9*	0.3	0.7
Sand paspalum	0.1	0.2	0.2	0.0	*0.2*	0.1	0.1	*0.1*	0.2	0.2	*0.2*	0.2	0.1.
Tall dropseed	1.1	1.0	1.2	0.4	*1.1*	0.8	0.5	*0.6*	1.5	1.0	*1.1*	0.3	2.0
Total	29.0	25.3	21.0	26.1	*26.6*	24.5	23.0	*23.5*	36.6	47.0	*44.6*	49.4	54.7
Other perennial grasses	0.5	0.6	0.7	0.0	*0.5*	0.1	0.3	*0.2*	1.6	0.6	*0.8*	0.9	2.4
Total perennial grasses	86.6	83.5	83.6	84.4	*85.0*	83.2	87.9	*86.5*	80.0	84.6	*83.4*	85.4	77.0
Annual grasses	0.6	0.3	1.6	3.1	*0.6*	1.2	0.3	*0.6*	3.9	2.7	*3.0*	0.5	11.5
Sedges and rushes	5.8	7.6	7.6	3.4	*6.6*	6.9	4.2	*4.9*	7.3	5.1	*5.6*	3.4	5.2
Perennial forbs	5.0	5.9	4.9	6.2	*5.4*	5.6	5.1	*5.3*	5.7	5.1	*5.3*	5.9	4.8
Annual forbs	1.6	2.3	2.2	0.8	*2.0*	2.7	2.0	*2.2*	2.8	2.4	*2.5*	4.4	1.5
Shrubs	0.3	0.4	0.1	2.1	*0.4*	0.4	0.5	*0.5*	0.3	0.1	*0.2*	0.4	tr.
Number of samples	119	119	29	5	272	48	116	164	42	136	178	19	21

however, is like that of the above site in its major features and may be considered climax in nature.

CU—*Upland Site.* Lands having sufficient depth of soil but with somewhat less infiltration, slower permeability, and a smaller percentage of water available to plants than ordinary uplands, hence supporting at best a somewhat preclimax vegetation.

Cp—*Claypan Site.* Lands having sufficient depth of soil, but with even more restrictive water relations than the clay upland sites, thus supporting a preclimax vegetation.

VS—*Very Shallow Site.* Lands having insufficient depth of soil for normal water storage, hence supporting under proper grazing a vegetation distinctly preclimax.

Ld—*Lowland Site* (gullied). Lands receiving more water than normal and having, because of position and soil depth, such moisture relations as to support a postclimax vegetation under proper grazing (with gullies controlled).

Having grouped certain soil units into range sites on the basis of the foregoing evidence, the validity of these groupings was subjected to further analysis. Each group mean was compared separately with each of the others for both decreasers and increasers for each of the four years by means of *t*-tests. These tests revealed consistent, highly significant differences between the two range sites, ordinary uplands and limestone breaks (considered together here as representing the regional climax), and the others, except in 1947 when the *t*-value for the comparison of the means of these two sites with that of the very shallow site was too low for significance at the .05 level.

Values of *t* for the other comparisons are not consistent, failing in many instances to approach the .05 level of significance. Comparison of the means of the clay upland site with those of the very shallow and the claypan sites gave fairly high *t*-values, exceeding the .01 level in some cases, notably in 1949 and 1950. The very shallow and claypan sites failed in all cases but one to show differences significant at the .05 level. The claypan site, however, differed markedly from the very shallow site in percentage of several important species. The former was high in buffalograss (*Buchloe dactyloides*) and Kentucky bluegrass, but very low in little bluestem, while the latter was high in blue grama (*Bouteloua gracilis*) and hairy grama (*B. hirsuta*).

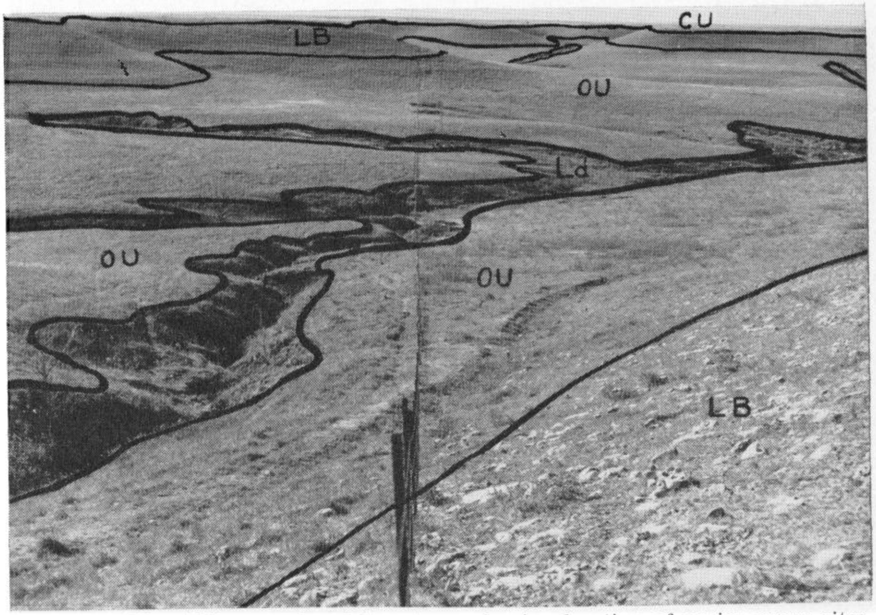

FIGURE 1. Flint Hills experimental pastures showing location of major range sites. **OU**—ordinary uplands; **LB**—limestone breaks; **CU**—clay uplands; **Ld**—lowland (gullied) site.

The extent to which the range site classification reported here might apply to the broad area was explored by comparisons of the physical characteristics of the experimental pastures with those of the Flint Hills generally. The comparative data given in Table 3 reveal a striking similarity in the range sites and in the percentage of each site present. It is evident that the experimental pastures are representative of the Flint Hills grassland, and that conclusions drawn from their study should have direct application to the approximately 2,800,000 acres of this region remaining in native grass.

Discussion

The stability of prairie vegetation precludes rapid change in population of climax species except under extremes of treatment. Local environmental differences, however, influence the composition and density in the stabilized state. It is necessary to relate population samples to these environmental or site differences in order to obtain data suitable for the evaluation of trends that result from management practices.

Numerous subdivisions can be delineated on the basis of soil differences by those trained in soil classification methods. In this study statistical analyses of the populations of major forage species in 10 such subdivisions have indicated that certain soils are sufficiently alike to support like plant populations and, therefore, sufficiently alike to be classed as a single range site. Analyses of the species composition in relation to soil conditions indicated that six groups of these soil units should be recognized as range sites in the bluestem pastures of this study area.

Ordinary uplands and limestone breaks range sites exhibited greater percentages of the mid and tall grass dominants of the climax prairie than did the other range sites. The ordinary uplands repre-

FIGURE 2. Detail of limestone breaks range site (steep slope at left) and very shallow range site above limestone outcrop.

sent that portion of the prairie on which the climax may attain full expression, while the limestone breaks, a site with an environment nearly as favorable, may also be capable of exhibiting the climax vegetation. The other units sampled may be considered preclimax because soil depth and water relations are less favorable to plant growth. Big bluestem, little bluestem, and indiangrass together made up 55 to 60 percent of the vegetation of the two climax sites and only 16 to 36 percent of the other three. Short grass species such as buffalograss and blue grama, on the other hand, were relatively more abundant in sites having less favorable water relations.

The lowland site was not sampled but appeared from field observation to represent a postclimax because of the additional water received from slopes and the greater depth of permeable soils. Much of this site is gullied with raw exposures of soil and parent rock. The vegetation, in the portions not seriously eroded, is of a postclimax nature.

It is evident from these data that a close relationship still exists between site conditions and species composition even after some degree of degeneration has resulted from grazing. This is emphasized by the fact that the most favored sites still contain the greatest amounts of decreasing species. Recognizing these relationships, any future trends in species composition must be considered in light of potential development of vegetation for the site.

The grouping of the natural soil units into categories based on obvious differences in vegetation and soils will facilitate sampling the plant populations and the interpretation of data. It is proposed that this method of grouping serve as a basis for classification of range sites in Flint Hills range pastures both for purposes of conservation and land use and for further research.

Comparison of the range sites delineated on the basis of species composition with those based on the physical characteristics of the land shows striking similarity in that the same general kinds of sites were selected. Ranged in order from postclimax to lowest producing preclimax, these would be lowlands, ordinary uplands, limestone breaks, clay uplands, claypan, and very shallow uplands. Some differences exist, however, within these physical groupings. The limestone breaks with very steep slopes (35 to 60 percent) resemble the ordinary uplands in percentage of major grass species but were separated from them partly because it appeared that erosion losses might be excessive if they were closely grazed. Had the data on composition alone been considered, these steep slopes might have been grouped with the ordinary upland site. Soil depth and water relations are favorable despite the presence of much stone and chert. Brief utilization checks in 1950 and 1951 showed that these steep slopes received about the same degree of use as the moderate to gentle ones.

Clay uplands might have been included with the ordinary uplands if depth and texture of surface soil alone had been mapped. Their species composition is, however, sufficiently different to set them apart as a distinct range site. The claypan and very shallow range sites differ from all the others in both plant composition and soil condi-

Table 3. Comparison of range site composition of the Flint Hills grassland (exclusive of cultivated land) with that of the experimental pastures in percent of total area.

	Range Sites				
	Ordinary upland and limestone breaks[1]	Clay upland	Very shallow	Claypan	Lowland
	%	%	%	%	%
Flint Hills grasslands[2]	63.3	26.6	1.8	5.4	2.9
Experimental pastures	59.7	25.0	2.4	3.4	9.5

[1]Sites supporting the regional climax grouped together for this comparison.
[2]Data from Reconnaissance Soil Conservation Surveys, Kansas. Published by the U. S. Dept. of Agric. Soil Conservation Service and Kansas State College, by counties, 1945-51.

tions. It is apparent that because of complex interactions between numerous physical factors resident in soils, the final classification of landscape into range sites must be based on differences reflected in the natural vegetation. Certain factors such as erodibility may necessitate a further breakdown for application of specific conservation or land use measures if uses other than range grazing are contemplated.

Summary and Conclusions

To facilitate studies of vegetation in experimental bluestem pastures and to aid in the evaluation of species populations and trends that result from management treatments, soils of the experimental bluestem pastures of the Kansas Agricultural Experiment Station were mapped, delineating 13 upland soil mapping units on the basis of slope, degree of erosion and soil conditions. This number was reduced to 10 by combining certain similar ones.

Sampling of the plant populations by means of randomized line-transect samples revealed that the number of distinctive vegetational units was smaller than the number of soil units mapped. Statistical analyses of the populations of major forage species, together with major site differences, have been the basis for recognizing six range sites, one of which was not sampled in these studies.

Future sampling and population trend studies will be based on deviations from the populations originally found on these range sites. Thus, the groundwork has been laid for accurate and reliable evaluation of population responses to management treatments.

Comparison of the study area with the Flint Hills grasslands as a whole reveals that it is representative of the region and conclusions drawn from the study should have widespread application. A groundwork has been laid for classification of Flint Hills range lands for purposes of conservation and land use and for research.

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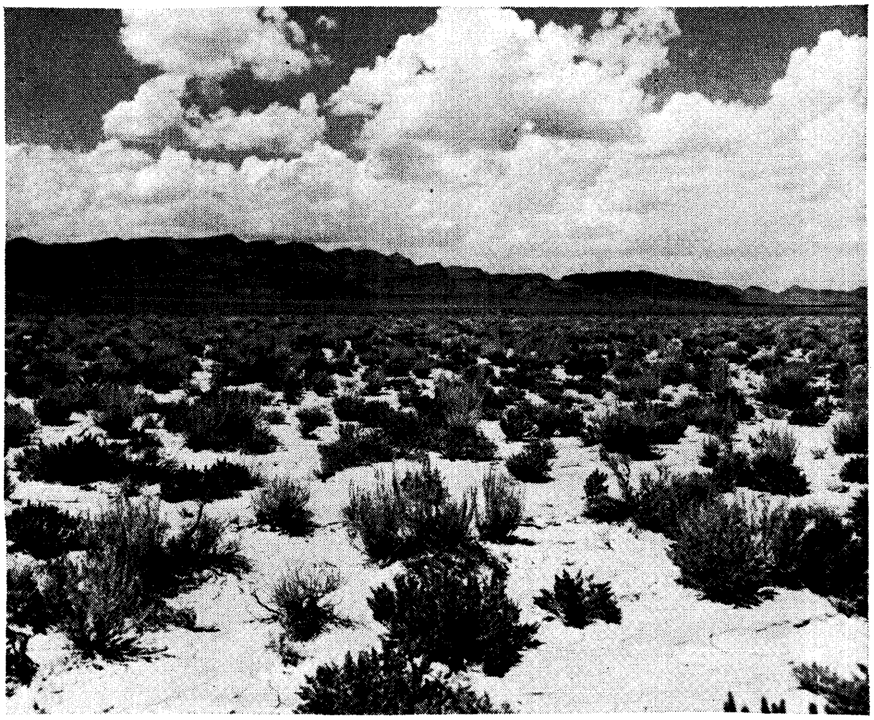

Shadscale-whitesage type in Delamar Valley, Nevada. Photograph by Royale K. Pierson, Bureau of Land Management, Washington, D. C. First Place, Range Types, Photograph Contest at San Jose, California annual meeting.