An Ecological Study of the Sand-Hills of

the Western Part of Harvey County, Kansas

by

Jacob Homer Doell

A. B. Oberlin College
Oberlin, Ohio
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Doctor of Philosophy

W. H. Horr
Instructor in Charge

A. J. Mix
Head of Department

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Yucca glauca, "A sentinel of the desert"

ACKNOWLEDGMENT

This work would not be complete without grateful acknowledgment to Dr. W. H. Horr, of Kansas University, for his valuable suggestions, and for coming out to look the field over, and checking the species of plants mentioned.

I also wish to thank Professor Aldous of Kansas State College for identifying several grasses in the collection.

J. H. D.

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CHAPTER I

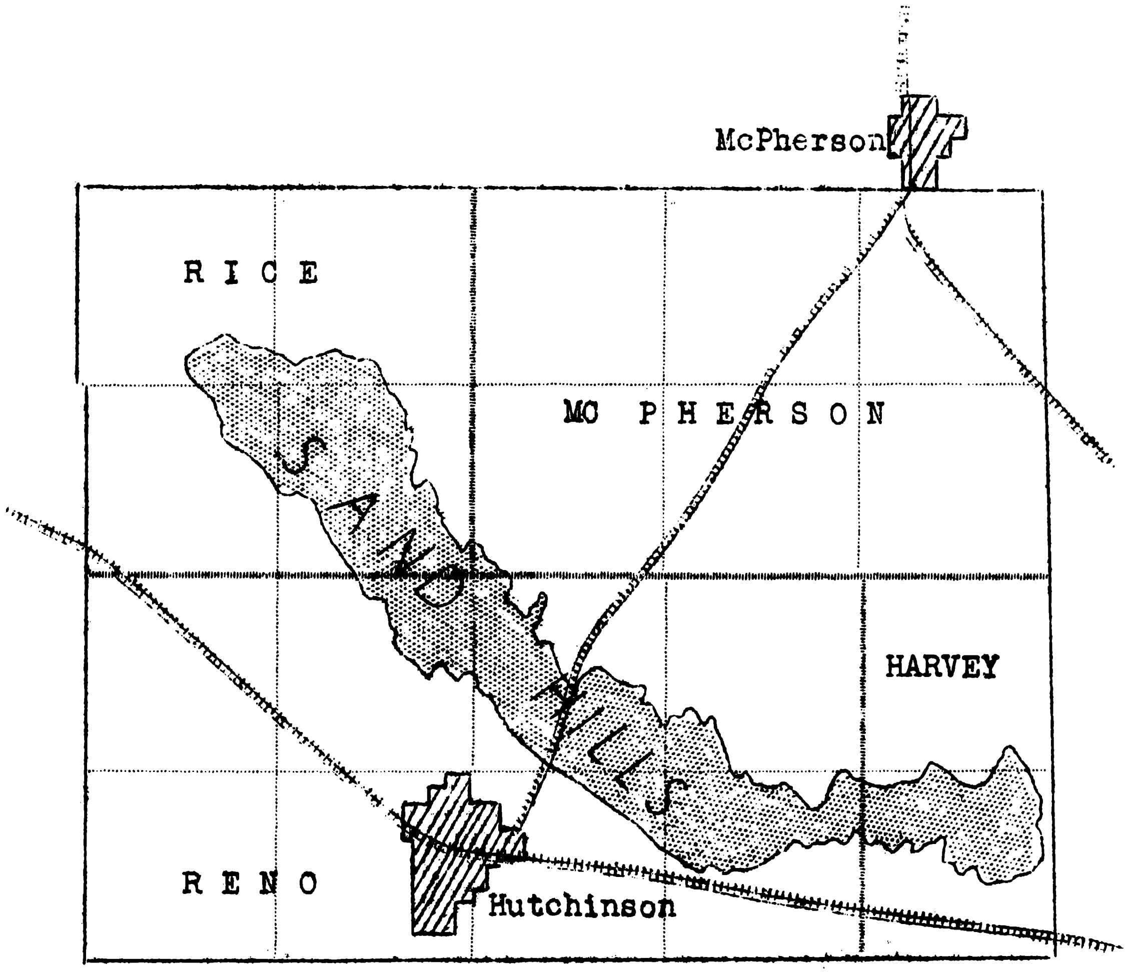
INTRODUCTION

In a cursory survey of the plants of Harvey County, the sand-hills area offered such a striking difference in appearance from the surrounding territory, that it was deemed worthwhile to make a closer study as to the causes for this wide difference in the vegetation obvious even to the casual observer. A search of the literature on this subject matter showed that the sand-hill flora had not received the deserved attention in this state. Other phases of plant life having attracted much wider attention; and this same problem having been subject to much intensive study in other parts of the country. The study by Hitchcock (VIII) in his Ecological Plant Geography of Kansas is all that is directly related to the problem.

The epoch making work by Cowles (V) on the Ecology of plants of the sand dunes of Indiana and Michigan; and the works of Pond and Clements (XI) and that by Rydberg (XIII) on the vegetation of the sand-hill regions in Nebraska and finally, that by Gleason (VII) on the Vegetation of the Inland Sand Deposits of Illinois, were further inducements to undertake a more intensive study of the ecological relationship of the plants of this section. The study was undertaken in the spring of 1932.

The results are the observations primarily of the seasons 1932, 1933 and 1934.

A map of this area is shown herewith.



Taken from
THE STATE GEOLOGICAL SURVEY OF KANSAS

CHAPTER II

ORIGIN

The soil was identified as belonging to the Tertiary Equus beds by the Kansas University Geological Survey of 1896 (IX). The sand is a surface residue due to erosion of this area. There are other and much more extensive sand-covered areas west and especially southwest, along the south side of the Arkansas River, otherwise the sand would appear to have been carried by prevailing south winds from the bed of the Arkansas River

CHAPTER III

PHYSIOGRAPHY

The topography of the region is extremely level, with no elevations of any consideration, and is gradually rising in the westerly direction with an elevation of 1,454 feet at Newton and 1,535 feet at Hutchinson, about forty miles west. The section of most intensive study is about halfway between the two points and some 1,492 feet in elevation above sea level.

CHAPTER IV

CLIMATE

The climate is characterized by great extremes in wet and drought; heat and cold; and, due to the level unbroken surface, by prevalence of periodic storms of considerable duration.

The average amount of annual precipitation and the distribution of the same as shown by the graph (Fig. 1) is such that late summer plants are discouraged during the blossoming and fruiting season. The graph shows further that the last two years of study and collecting of specimens of species were abnormally dry even for this region

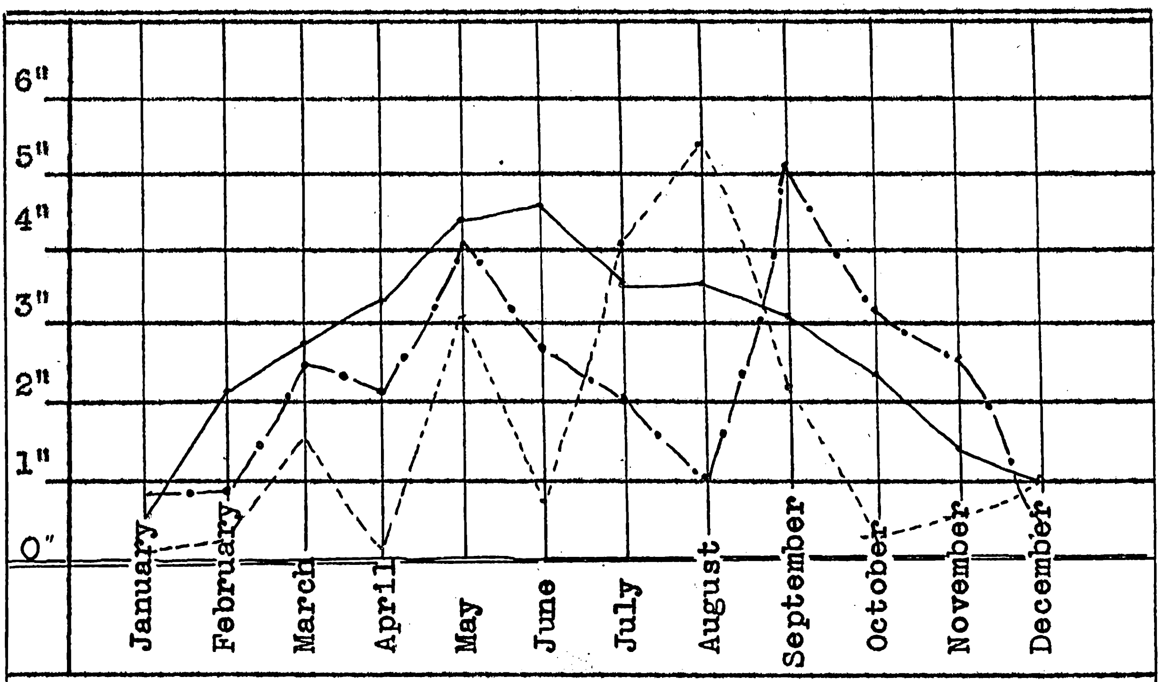


Fig. 1. Precipitation 1933, ------ 1934, —·—· .
Average Precipitation 1897-1933, ______ .

which may account for a possible lack in the number of species found.

The wind has an unbroken sweep, and in the spring months it prevails from the south and southwest to, or into summer.

The heat and cold accompanied by strong and dry wind are extreme and intense. Figure 2 shows the mean average temperature of Newton for the last thirty-seven years, and also the deviations of the years 1933 and 1934 from this average.

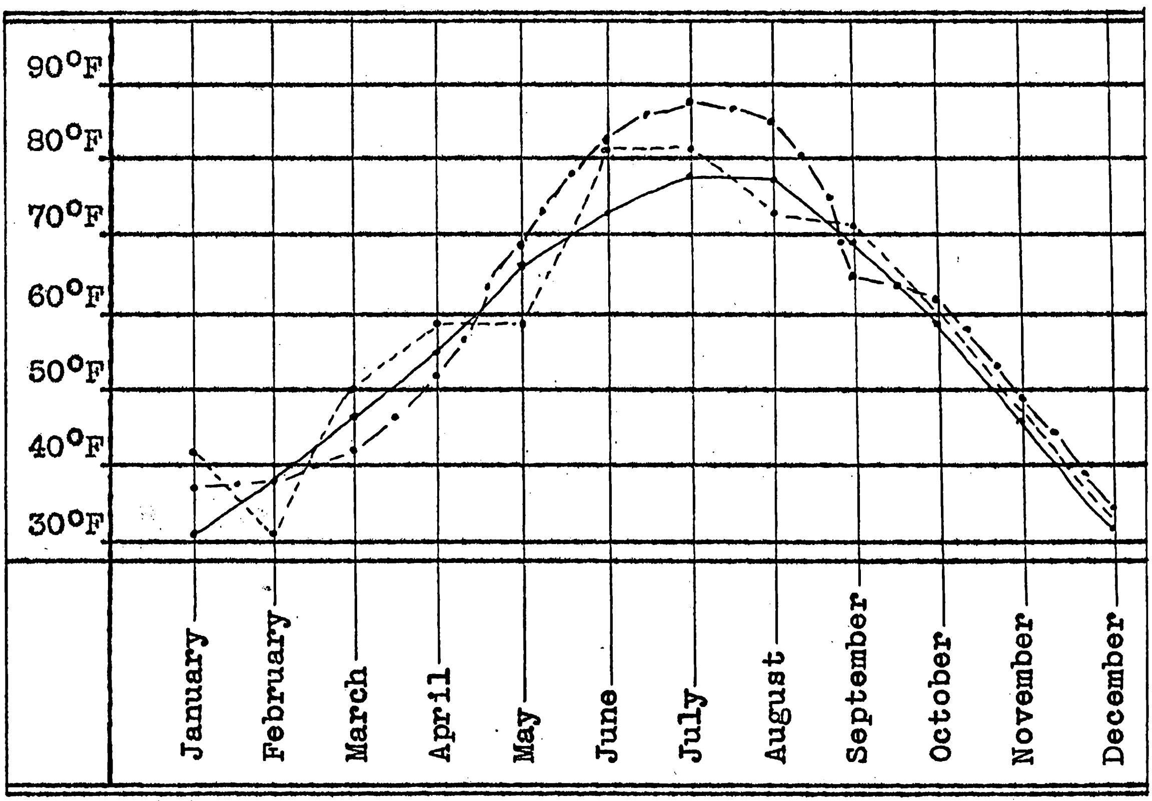


Fig. 2. Temperature 1933 -------, 1934 •—•——.
Average Temperature 1897-1933 ————.

CHAPTER V

EDAPHIC FACTORS

The sand deposit, or residue, is naturally the great and determining factor in the sand-hill floral formation, and, therefore, was studied in some detail.

It is somewhat difficult to place the boundaries of this sand-hill area at places, at other places there is a sharp demarcation of the boundary.

There has been considerable shifting of the dunes in the memory of settlers in this region. Some dunes that were on the south side of a surveyed section line have moved north due to prevailing southerly winds until they are now several hundred yards to the north of the former position and the section road has to detour these piles of sand.

The depth of this sand layer varies from the edge, where it may be only a thin covering or intermingled with the subsoil, to the highest dunes, which were not accurately measured in any one place, but estimated up to thirty-five to forty feet high.

There are other places at the bottom of blowouts throughout the complex where the sand has been swept away to the subsoil.

The sand is characterized by a very marked uniformity wherever samples were taken. Table No. 1 shows the results of sand observed for size of the particles.

TABLE 1

SIZE OF SAND PARTICLES AS DETERMINED BY STANDARD SOIL SIEVES

	Number of Screen					
	20	40	60	80	100	
Size of Mesh (In mm).	.900 x .900	.375 x .375	.185 x .185	.175 x .175	.160 x .160	
Size of Sand Particles	.900 and up	.375 to .900	.185 to .375	.175 to .185	.160 to .175	.160 and less
Per Cent of Soil Retained by Sieve	Trace	10	44.5	31.8	4.5	9.2

The No. 20 screen showed only a trace of particles too coarse to pass through the .9mm x .9mm mesh and only 9.2% that passed through the No. 100 screen.

The percolation test of the soil shows its relative permeability to water (Table No. 2). The brass cylinders used were 1 15/16" in diameter and the column of sand was 8.5" high.

The percolation test of the soil shows its relative permeability as being such that there is no surface water drained off in the heaviest rains but is retained by the sand where it falls, until it has time to seek a temporary water level.

This table (No. 2) also shows the rather impervious character of the subsoil that underlies most of the

TABLE 2

PERCOLATION TEST FOR THE SOILS

Kind of Soil	Time Percolation Starts	Water percolating in 15-minute periods (c.c.)			
		First Period	Second Period	Third Period	Average
Sandhills Sand	3 Min.	430	462	437	438
Garden Loam for Comparison	30 Min.	62.5	60	53.5	59
Sandhills Subsoil	4 hours 7.5 Min.	1.5	1.2	1.2	1.3

sand-hills. It is less than .3 of 1% as pervious to water as is sand and, therefore, prevents the water from seeping through it readily. The sand holds the water except where blowouts are too deep and it collects. These ponds are a very characteristic feature of the sand-hills in seasons of considerable rainfall.

Some of these ponds have water so much of the time that hydrophytic species are not uncommon in this otherwise typically arid region.

With the pervious condition of the sand and its low water-holding capacity, due to the size of the sand particles, and largely to its lack of organic matter, the test for capillarity was applied (Table No. 3). This shows that the sand can readily supply its vegetation with sufficient water from the supply above the subsoil, only after the plants are well rooted.

TABLE 3

TEST FOR RISE OF CAPILLARY WATER IN THE SOILS
(In Centimeters)

Length of Test	Kinds of Soil		
	Sandhills sand	Garden Loam for Comparison	Sandhills subsoil
5 Minutes	$6\frac{1}{4}$	2	$1\frac{1}{3}$
15 Minutes	$9\frac{1}{2}$	$3\frac{1}{4}$	$2\frac{1}{2}$
30 Minutes	$11\frac{1}{4}$	$4\frac{1}{2}$	$3\frac{1}{2}$
45 Minutes	12	5	$4\frac{1}{3}$
1 Hour	$12\frac{1}{2}$	$5\frac{3}{4}$	$5\frac{1}{4}$
2 Hours	$13\frac{1}{2}$	$7\frac{3}{4}$	$6\frac{1}{3}$
1 Day	$14\frac{1}{3}$	$13\frac{1}{2}$	$17\frac{1}{2}$
2 Days	$14\frac{3}{4}$	$14\frac{3}{4}$	$22\frac{3}{4}$
3 Days	$14\frac{3}{4}$	$15\frac{1}{3}$	26
4 Days	$14\frac{3}{4}$	16	28
5 Days	15	$16\frac{1}{4}$	30

The sand is so fine and has so little binding chemical substance in it that it forms a loose sand mulch over its surface whenever it dries. This helps to conserve the soil water against evaporation, and keeps the sand moist to within six inches of the surface in the driest season, in places where dry sand is not deposited by the wind. This one characteristic makes for considerable luxuriance of vegetation in the sand when the plants in the surrounding territory are drying up during a hot dry spell.

4. Humus

The organic matter content of the sand, after thorough drying averages only .51%. The method used for determination of organic matter was that given by Braun-Blanquet

(II) for soils with no lime and little clay: A sample of the sand was dried in a drying oven for three hours at 110°C and then heated to white heat in a platinum crucible for one hour. The loss resulting from igniting the sand was used for the determination of the amount of organic matter.

5. Water Content

The water content of sand kept in the laboratory until thoroughly air dried averages only.1%.

6. Water-holding capacity of sand

The amount of water the sand is able to hold was determined by weighing and measuring the amount of laboratory dried sand in a cylinder and soaking the cylinder by immersing it in water for an hour, and draining off the water until no more would drip from the cylinder and reweighing. The amount of water thus held by the sand was 27% of the weight of the sand. It was 38.5% of the volume of the sand.

7. Soil Acidity

The sand and the subsoil tested according to methods mentioned by Braun-Blanquet (II), using the Baily (I) Hydrogen electrode. All showed a slight acid reaction.

CHAPTER VI

VEGETATION

The western part of Harvey county is in the region of change from the bluestem prairie, or the tall-grass, to the short-grass, or the buffalo-grass region.

This change is not entirely abrupt and is best seen in the original, or unbroken, prairie that has been fenced and pastured. Severe pasturing seems to be one of the causes to bring about the change from bluestem to buffalo-grass pastures; for the prairie that was not broken and has been used for hay meadows is still of the tall-grass type, while the pastures next to the tall-grass meadow are largely of the short-grass type except where the soil is loose, due to its sandy character. Here few of the main-short-grass species are found. The short-grass pastures are characterized by Buchloe dactyloides (Nutt.) Engelm., Bouteloua oligostachya (Nutt.) Torr, and Bouteloua hirsuta Lag. The first was never found in the sandy soil, and the latter two species only where the soil is clayey enough so as to pack quite hard.

There is little, if any, of the original, undisturbed prairie left in this section of the state. Close pasturing has changed most of the original prairie extant, to such an extent that, if left to itself without pasturing for awhile, it has little resemblance to that which has been preserved for prairie hay meadows. A large number of weeds are the dominant vegetation of which the following are the most numerous and most common: Allium mutabile Michx., Rumex crispus L., Amaranthus retroflexus L., Baptisia bracteata (Muhl) Ell., Euphorbia marginata Pursh., Callirhoe digitata Nutt., Opuntia rafinesquii Engelm., Oenothera biennis L., Apocynum cannabinum L., Verbena bracteosa Michx., V. stricta Vent., Solanum rostratum Dunal., Plantago major L., Vernonia fasiculata Michx., Ambrosia psilostachya Gray, Xanthium commune Britton., Achillea millefolium L., Cirsium lanceolatum (L) Hill., Helianthus annuus L., and Taraxacum officinale Weber.

Even the unbroken hay meadows, through cropping, have changed so that the tall prairie grasses are hardly dominant at certain times of the year. Psoralea digitata (Nutt.) and Amorpha canescens Pursch often obscure the grasses completely from a distant view. Nevertheless, this is the true prairie province, with no natural timber and brush except along the water courses, and the tall grass association is the climax formation, to use Cowles' term. Therefore, we shall consider any approach to this climax condition as an indication that the sand hill vegetation is becoming stabilized.

A considerable portion of the sand-hills marginal ground is under cultivation. Crops generally have to be planted late due to the shifting of the sand with the spring winds. Drifting sand often fills lister furrows and covers up corn into early July. These border fields, however, produce excellent watermelons which are planted late. Sweet potatoes also are often a safe crop.

The region of most intensive study in this problem was seventeen miles west and one to two miles north of Newton, because a main road passing through the sand-hills here makes it quite accessable, and, primarily because of the shifting dunes, a space had been left unfenced to the side of the road, at places as much as a quarter of a mile in width. This area was not pastured, and, therefore, the vegetation was as nearly original as could be found. It contains some high dunes, blowouts, and level regions.

The specimens of plants were taken from this undisturbed area whenever possible.

One of the striking features is the number of species, and the abundance of some that are seen on the way to the sand-hills, but could only rarely be found in the sand area, and many of them not at all.

The surrounding pastures are generally full of Vernonia fasciculata, Euphorbia marginata, and Poa pratensis L., but in the sand-hills this species of Euphorbia was never observed and the Vernonia and Poa pratensis only in one instance. Cultivated fields are generally marked by Helianthus annuus, but this species was not found in the sand-hills, while cultivated fields in the sand-hills were found covered with Helianthus petiolaris Nutt. (Plate I, Fig. 1).

The whole prairie region of this part of the state is marked by the absence of trees, except along the water courses, and those that have been planted. Also, there are no shrubs, except those that have found refuge under planted trees, or which have been planted there. The sand-hills, however, are dotted with cotton-woods, Populus sargentii Dode, and Salix nigra Marsh. and large areas of plum brush. An occasional Catalpa and Morus rubra L. complete the list of trees. The sand-hill plum, Prunus angustifolia Marsh. covers areas to the exclusion of all other vegetation, and may cover as much as 10% of the area of a pasture. Cephalanthus occidentalis L. is next in abundance, and is found in single shrubs and from a small clump to thickets of more than fifteen square rods, forming the densest cover of all vegetation. Cephalanthus is described in Trees in Kansas (XVI) as "a swamp-type species and is found growing only in swampy locations or along the margin of streams where an abundance of soil moisture is available." But here, in this arid region, among typical xerophytic surroundings it thrives on top of sand-dunes twenty feet high. Typically, however, it is found along gullies in low places and its presence on the very top of the dunes can be explained only in one way: that it kept up with the formation of the dune as that buried the shrub, as observed elsewhere, at the rate of several feet some years.

Salix tristis Ait., a dwarf willow, not exceeding

PLATE I

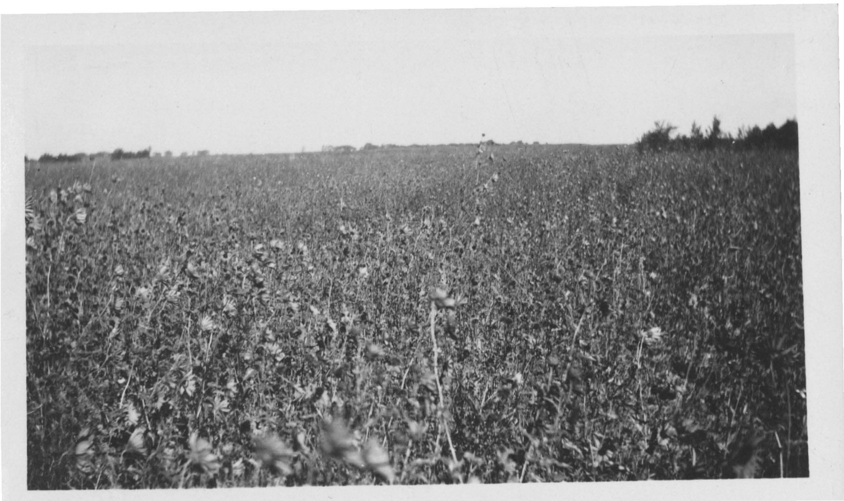


Fig. 1. Helianthus petiolaris in a cultivated field.

Fig. 2. Cephalanthus occidentalis, July, 1932

the medium grasses in height is quite common. And an occasionally unidentified species of Rubus (Tourn.) L., Rosa setigera Michx., Amorpha fragrans Sweet., and A. canescens complete the list of shrubs commonly found in these sand-hills.

A considerable portion of the sand-hills area is always bare of vegetation, composed of the bare shifting sand, which is blown back and forth as the wind shifts from the south to the north and back again to the south. The newly formed dunes thus generally cover all the plants which try to get established in the open spaces.

Therefore, it may be assumed that most of the sand dunes now covered by plants were at one time of this bare character. This makes the succession of plants the most interesting ecological problem in the whole study. To answer this to any great degree of accuracy though, the observer should have accurate data of a large number of years. The closest approach to this seems the constant study of various blowouts over a few seasons, and a comparison of the various parts with similar parts of the older and more stabilized blowouts.

These blowouts are numerous throughout the sand-hills and are found in all stages of their formation from the merest inception to the stabilized condition of the blowouts. They occur throughout the sand-hills wherever the layer of sand is deep enough so that the wind can undermine the roots of the existing vegetation, and in all stages of stability of the sand surface. A blowout may be started in a sand dune or on the more level sand that is well sodded over. In the latter case it may start along a cow path or any place where the sod is broken due to over-pasturing or some similar cause. It generally starts by wind blowing the sand away from the roots of the existing plants. These topple over, die off, and the sand is blown away by the wind, and deposited to the leeward and buries plants there. When once started it generally keeps on growing till it reaches a stage where the leeward dune breaks the wind too much for further growth, or until the rehabilitation plants conquer the sand again and thus stop its growth.

The accompanying illustration, Figure 3, from Gleason (VII), shows well the condition of the ordinary blowout.

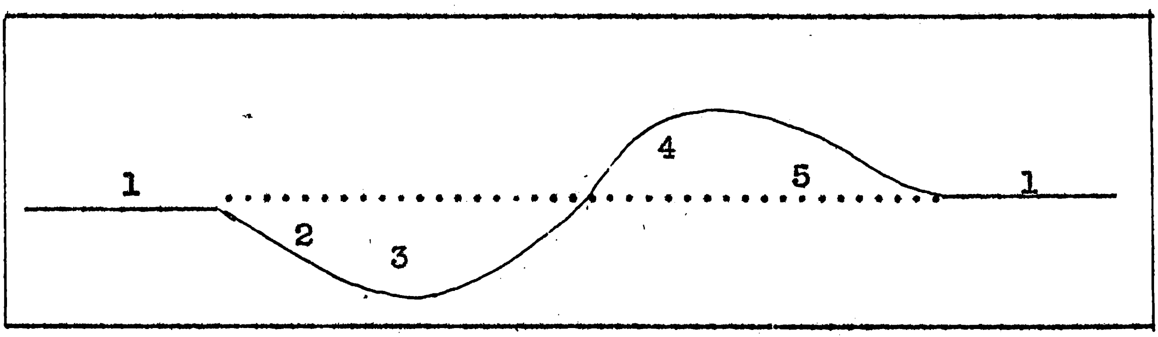


Fig. 3. Diagrammatic longitudinal section of a typical blowout: 1. Original level of sand. 2. Windward slope. 3. Basin. 4. Lee slope. 5. Deposit. (Gleason)

The spring winds are more destructive than the summer winds for the spring is the windiest season. Furthermore, the soil is more bare because the annuals are mostly late and the perennial plants have not yet started their growth, so the soil is barest of plants in the spring months. The summer storms are less severe and summer moisture and warmth soon clothe much of the sand with vegetation. These winds are primarily from the south. Therefore, the blowouts are mostly north and south with the windward slope at the south end. There are, however, occasional blowouts that reverse in the fall and winter when the north winds are severe.

Plate I, Fig. 2, page 16, and Plate II, Figs. 1 and 2 show the south end of a blowout whose lee slope has a trough cut through it and the north winds are leaving their deposit at the south end. Plate I, Fig. 2 shows the deposit in July, 1932, with a thicket of Cephalanthus about four feet high. Plate II, Fig. 1 shows the same deposit from a little different angle in March of 1933 after the snowless winter winds. The Cephalanthus is buried with a three foot deposit of new sand so that only the tips stick out about one foot. Plate II, Fig. 2 shows the same spot again from the same angle a few months later in May, 1933. The new growth again covering the sand and about two feet high. The average active blowout has the windward slope to the south, with a steep gradient and little vegetation; and this largely of the sort that is sliding down from the more or less level sod in front of it, which is under-cut by wind, while the loose sand is constantly removed from its base. A few summer annuals may find a foothold on this slope. There is, however, little chance for seed to lodge there and become covered to a depth to insure their germination.

The bottom of the active blowout is a little more favorable for starting new plants, but these are mostly late summer annuals. The seed is carried in and covered by the less violent winds as summer progresses. The moisture conditions here are also more favorable; but tender herbs are lacerated by the surface-rolling sand, so that these species are generally only few, consisting of Cenchrus tribuloides L., Diodia teres Walt., one of the harshest and best protected plants, due to coarse hairs that cover the whole plant; Cristatella jamesii T. & G., which, due to its glandular, sticky hairs, generally has a coat of sand sticking to these hairs and serving as a protection. The sides of the trough are generally the steepest part of the advanced blowout. Here the wind-driven sand cuts the banks severest, and the roots of plants on the level surface serve somewhat as a protection against sliding sand. The sides, therefore, are often under-cut since most of the plants which can succeed in the sand-hills develop an enormous root system which penetrates the loose sand to great depths. Surface plants slide down the steep banks and thus serve as almost the only vegetation of the sides. (Plate

PLATE II

Fig. 1. The same as Plate I, Fig. 2, in March, 1933.

Fig. 2, The same as Plate I, Fig. 2. in May, 1933.

III, Fig. 1)

The lee slope of the blowout is less steep than either the windward slope or the sides of the trough and may be cut in the first stages of the formation but it soon becomes inactive. This slope serves as a highway for the sand in its transportation from the trough to the deposit. It, therefore, is a poor place for young plants to get started and so remains bare until summer when the windy season is over. Then the seeds that have been covered to a favorable depth germinate and the slope becomes sparsely covered by plants. A few perennial grasses may start and live through the following seasons, but the bulk of the vegetation is composed of summer annuals. This slope generally forms an unbroken line with the front of the deposit of sand and, therefore, the vegetation is similar in the two formations.

There may be deep rooted plants of the previous cover surface of the lee slope, and there may also be plants on the face of the deposit slope that have been partially buried each spring and that come through the sand the following summer. In this way some slopes have perennial plants as a residue from a previous occupation. Plate III, Fig. 2 shows an early summer condition (July 4), while Plate IV, Fig. 1 shows the same place later, on September 16. Aside from the few perennial grasses the plants are almost exclusively <u>Heliotropium convolvulaceum</u> Nutt.

PLATE III

Fig. 1. The steep bank of a blowout.

Fig. 2. The lee slope in early summer condition, July 4.

PLATE IV

Fig. 1. The same place as Plate III, Fig. 2 on September 16.

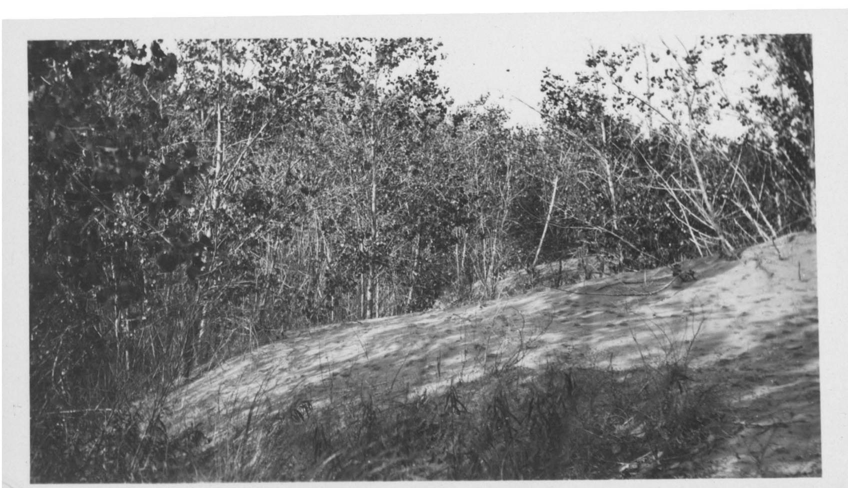


Fig. 2. The lee slope of the deposit.

This plant is a summer annual. The seed generally germinates in June, and as Plate III, Fig. 2 shows the seedlings are only about two to three inches high in early July. They generally have to start under adverse conditions, for if a strong wind carries the dry sand over the surface with any great velocity the young plants are cut severely by it; and the intense light and heat on this southern slope are a severe test for a young seedling.

Temperature readings on June 8, 1933, at 2:30 P.M. showed as follows: on the south slope the surface sand was 142°F; at five inches down it was 95°F; and at ten inches the sand was 86°F. At the same time the north slope of the deposit was as follows: surface sand, 126°F; at five inches down, 95°F; and at ten inches down, 86°F.

The Heliotropium seedlings were just getting a start and were mostly not over an inch high, with their lower leaves next to this hot sand, in fact many of the leaves were in contact with the sand. The plant is almost white due to the coarse appressed hairs, which serve as a protection against the loose sand that is almost constantly running over the sandy surface.

No attempt was made to measure this strength of the light, but with the reflection from the light buff color of the sand the light is intense. Camera exposures had to be cut down to one-half normal to prevent over-exposures.

The lee slope of the blowout and deposit generally has a greater variety of plants than shown in Plate IV, Fig. 1. Species in the order of frequency could be arranged somewhat as follows: Heliotropium convolvulaceum, Diodia teres, Cenchrus tribuloides, Cristatella jamesii, Froelichia floridana (Nutt.) Moq., Eragrostis pectinacea (Michx.) Steud., Calamovilfa gigantea (Nutt.) Scribn. & Merr., Ambrosia philostachya.

The north side of the deposit in a blowout that is caused by a south wind is the region of the greatest plant growth. Here the vegetation is protected somewhat against the south wind and the heat and drought due to it. The only adverse condition here is that the deposit may receive so much sand in a given time that the plants will be buried faster than they can stand. If this deposit reaches Populus, Salix or Cephalanthus which can stand being covered up from the bottom, and keep pace in their growth with the dune, the dune reaches a considerable height. Plate IV, Fig. 2 and Plate V, Fig. 1 show this condition in which cotton-woods are the main growth. A few annuals but especially the perennial grasses make a luxuriant growth at the foot of this slope.

If the deposit reaches a considerable height and the trough is deepened in proportion it reaches a stage where the blowout is checked by its own development, because the wind is checked and the sand cannot be carried over the deposit any longer. Thus the blowout has reached its natural limits and so becomes inactive and in the course of time is stabilized by the succession of plants that always bring about the perennial grass cover of all loose sand areas.

This simple form of blowout, however, is not the commonest form; for blowouts are constantly reaching into each other and this complicates their analysis.

There is a general tendency to form series of sand ridges from north to south. Many of these are from fifty to two hundred yards wide, and from a quarter of a mile to a mile in length. This is a complex of blowouts that defies all analysis, yet they do not contain anything that is not analogous to a part of a simple blowout.

CHAPTER VII

RECOVERY

We assumed that the tall-grass, or blue-stem prairie association is the climax plant formation of all this region of the State of Kansas, outside of the sand-hills, and if any part would be left undisturbed by cultivation, cropping or grazing it would finally revert back to the original condition and that, therefore, any near approach to this condition could be considered as stabilization in the sánd-hill vegetation.

The greater abundance of trees and bush or shrub in the sand-hills is due primarily to the fact that bare sand dunes serve, and have in the past served, as barriers against prairie fires. Even today the sand-hill pastures are burned over occasionally and poplars of forty feet in height have been burned bare to near the top, while the smaller trees and bushes that had grown since the last fire were again scorched and killed to the ground.

The recovery of the loose, bare-sand areas by the tall, perennial grasses constitutes a series of changes and successions of plant formations.

1. The Basin Association

The floor or basin of the blowout is generally destitute of plants in a well established stage of its formation and generally remains very sparsely settled until the blowout has reached its natural limits. As stated above, there may be a few remnants of plants that have been carried in from the surrounding banks or even some that have weathered excavation, but generally it is bare of plants. (Plate V, Fig. 2)

Plate VI, Fig. 1 shows a stage in recovery in which Diodia, Cristatella, a few sedges, and some grasses, including Eragrostis pectinacea and Cenchrus tribuloides form a very sparse covering.

In Plate VI, Fig. 2 and Plate VII, Fig. 1 we have a stage in which young poplars growing from the roots of Populus sargentii are the main plants. These young shoots come from roots of small trees on the sides of the blowout and often run seventy-five feet or more just under the surface of the sand. A root may give off many shoots as it crosses the basin.

It is interesting to note that Cowles (V) makes the observation that this does not happen in the Lake Michigan region with Populus monilifera Ait. and P. balsamifera Du Roi.

There are sometimes young cotton-woods in these situations that come up from seed; however, for this to happen the blowout must be deep and close to the clay subsoil so that the basin will hold water long enough for these seedlings to penetrate the sand to perpetual moisture.

PLATE V

Fig. 1. The lee slope of the deposit.

Fig. 2. The basin almost bare of plants.

PLATE VI

Fig. 1. The basin in a more advanced stage of recovery.

Fig. 2. The basin with Populus sargentii starting.

PLATE VII

Fig. 1. The basin with Populus sargentii from roots.

Fig. 2. The basin well wooded

This condition, however, is not very common in these sand-hills.

If there is no great excess of moisture the basin may become well wooded. (Plate VII, Fig. 2) However, in a prolonged wet spell the basin is apt to fill with water and drown out the young trees; or the grasses and weeds become thick enough that the next fire that sweeps through the dry vegetation will kill most of the young trees and in that case the grasses that are not hurt by the fire become the dominant cover. The roots of these grasses will sod the soil and the dead leaves and stems add to the humus cover of the sand until we have a tall-grass prairie.

2. The Lee Slope Association

The loose sand of the lee slope and the whole sand deposit is a much more difficult place for most plants to gain a foothold.

The best sand binder of all plants in these sand-hills undoubtedly is <u>Calamovilfa gigantea</u>. This grass produces enormous root stocks that grow many feet in length in the loose sand, and produce stems at intervals. These stems readily grow from six to seven feet in height and a quarter of an inch or more in diameter, with twelve to fifteen leaves, eighteen to thirty inches long, on the stem, besides a bunch of basal leaves. The root system is exceedingly well developed and reaches far into the wet sand of the deeper strata so that the grass grows well in the dryest, hottest weather. The stem and leaves of *Calamovilfa* are so hard that they stand the sand blasts, and will not decay in a year thus holding the sand in which they grow and constantly collecting the surface-blown sand. (Plate VIII, Fig. 1 and Fig. 2)

The success of *Calamovilfa gigantea* in coping with this loose drifting sand depends largely upon the fast rate of growth of its underground rootstocks, its ability to recover from being buried by sand, its enormous root system, which supplies it with sufficient moisture in the dryest seasons, and its copious growth of hardy leaves and stems above the ground. This latter growth soon produces a cover over the sand and other plants can get a start and help to hold the sand from further blowing.

Calamovilfa is confined to this loose-sand area entirely, and as the interstitial plants become numerous and the sand well settled it invariably loses out.

Next to *Calamovilfa*, *Panicum virgatum* L. ranks as a sand binder though it is not a pioneer in the loose sand. Once started it is more efficient in sodding the sand than *Calamovilfa* for it produces a denser root system, and will stay past the loose-sand stage and grow in well sodded prairie. It produces a much denser growth than *Calamovilfa* though it does not reach the height and coarseness of the former. (Plate IX, Figs. 1 and 2)

PLATE VIII

Fig. 1. Calamovilfa gigantea as sand binder.

Fig. 2. Calamovilfa gigantea as sand binder.

PLATE IX

Fig. 1. *Panicum virgatum.*

Fig. 2. *Panicum virgatum.*

What can be called lee slope in the complex dunes composes a large part of the loose-sand area; and the plants found there depend largely upon the age or stability of the sand deposit. Besides the species mentioned there are a large number of other plants in this formation, of which the following species are the most characteristic: Pasplum ciliatifolium Michx., Panicum virgatum, P. scribnerianum Nash., P. lanuginosum Ell., P. praecocium Hitchc. & Chase, Setaria imberbis R. & S., Cyperus bushii Britton, C. schweinizii Torr., C. filiculmis Coult., Cristatella jamesii, Cassia chamaecrista L., Tephrosia virginiana (L.) Pers., Lespedeza capitata Michx., Lechea villosa Ell., L. tenufolia Michx., L. Intermedia Leggett., Physalis virginiana Mill., Plantago purshii R. & S., P. virginica L., Diodia teres, Ambrosia psilostachya, Xanthium commune and Helianthus petiolaris Nutt.

3. The Deposit Association

In the simple blowout the deposit generally takes a fanlike form, due partly to the less intensity of the wind here, and partly due to the veering of the wind off the straight course. In the complex dunes the deposit is a rather irregular loose-sand area, receiving fresh sand with every wind that carries the fine sand. Even the side winds, that may partly fill the trough again, spread the deposit sand over considerable area. Therefore, the limits between deposit and sodded areas are poorly marked in most places.

Aside from the regular plant formation characteristic of the deposits, this is the region of ruderal species. Here many vagrant weed seeds, blown in from the outside, may get a start even if conditions are not favorable for fruiting and the establishment of the species. However, many common weeds surrounding the sand-hills have never been observed even in this area. It is in this region of the sand deposit where this is not excessive, that the greatest variation in plants is found. The permanent grasses are encroaching from all sides and sodding over the loose sand, and if the blowout loses its activity the whole area will become covered with the vegetation of the settled sand-hill prairie.

The most common weed species are: Croton glandulosus L., Cycloloma atriplicifolia (Spreng.) Coult., Mollugo verticillata L., Helianthus petiolaris, Froelicha gracilis Moq., F. floridiana Coult. & Nels., Oxybaphus hirsutis Sweet. (G)., Apocynum cannabinum L., Verbena bracteosa, Solanum rostratum, Diodia teres, Ambrosia trifida L., A. psilostachya, Euphorbia geyeri Engelm., Sideranthus annuus Rydb, Salsola kali L., Cristatella jamesii, Lepidium apetelum Willd., L. ruderale L., Physalis virginiana, Chenopodium album L., Amaranthus graecizans L., A. blitoides Wats., A. retroflexus, Lactuca scariola L., and Solidago leptocephala

T. & G.

Of the annual grasses the following are the most common: Digitaria sanguinalis (L.) Scop., Festuca octoflora Walt., Hordeum pusillum Nutt., Bromus racemosus L., Cenchrus tribuloides, and Seteria imberbis.

The permanent grasses are getting more plentiful and are characterized by the following species: Calamovilfa gigantia, Eragrostic secundiflora Pres., E. Trichoides (Nutt.) Nash., Elymus striatus Willd., E. virginicus L., Paspalum ciliatifolium, Panicum praecocius, Chloris verticillata Nutt., Triplasis purpurea (Walt.) Chapm., Aristida purpurascens Poir., Sporobolus canovirens Nash., Agrostis hyemalis (Walt) B. S. P.

4. The Prairie Association

The ultimate prairie association of the sand-hills never reaches the climax prairie formation of the surrounding country due to the characteristics of the sand that constitutes the sand-hills. The sand is too loose to form the short-grass prairie of many of the surrounding pastures; while many of the grasses of the tall-grass prairie have not been found in the sand-hills. Among these may be mentioned: Boutelous curtipendula (Michx.) Torr., Agropyron smithii Rydb., A. repens (L.) Beauv., Schedonnardus paniculatus (Nutt.) Trelease., Elymus virginicus L. and Tridens flavus (L.) Hitchc.

The low, wet places of the sand-hills are characterized by the following grasses: _Tripsacum dactyloides_ L., _Andropogon virginicus_ L., (Plate X, Fig. 1) _Echinochloa crusgalli_ (L.) Beauv., _Alopecurus geniculatus_ L., _Sporobolus cryptandrus_ (Torr.) Gray., and _Spartina michauxiana_ Hitchc.

PLATE X

Fig. 1. *Andropogon virginicus* in a low spot.

Fig. 2. *Yucca glauca* acting as wind break.

CHAPTER VIII

SAND BINDERS

The sand binders are of prime importance in the stabilization of loose-sand drifts, for the duty of holding the sand involves upon them until the subsequent species can get started and cover the sand surface, and thus prevent the wind from undermining some plants and burying others. The grasses readily hold the first place in this important work, as is shown by the observations in our locality and also in those of workers in other parts of the world.

Warming (XIV) names Psamma arenaria as the most important sand binder in the costal regions of Denmark. Secondary sand binders according to his observations in costal regions are three woody plants: Hippophae rhamnoides, Salix repens and Empetrum nigrum. In the inland dunes in Europe he names Elymus arenarius as the most important of sand binders.

Braun-Blanquet (II) ranks two grasses: Agropyrum and Calamagrostis as the most important sand binders for inland Europe. And Aristida pungous and Euphorbia gouyoniana as the chief sand binders in the North African deserts; while for the sea strand areas of Europe he places Elymus europaeus, Ammophila arenaria, and Cyperus capitatus in the order of importance.

Cowles (V) places Ammophila arundinacea first as dune former and also as a sand binder; of less importance he classes Agropyrum dasystachum, Elymus canadensis and Calamagrostis longifolia.

Hitchcock (IX) in his article on Reclaiming Sand Dunes ranks Ammophila arenaria as first in both Europe and America; and as a second he mentions Elymus arenaria as a sand binder along the sea coasts. For the interior dunes in Central Netherlands and Denmark he places Calluna vulgaris, a heath-forming shrub, as the chief plant in artificial sand binding.

Pond and Clements (X) give Redfielda flexuosa, as the chief plant that finally controls the blowouts in the Nebraska sand-hills by binding the loose sand in these blowouts. It is often associated with Muhlenbergia pungens as a secondary and aiding species.

Gleason (VII) ranks Rhus candensis as the most important sand binder and dune former in the inland sand deposits of Illinois, and Panicum virgatum as only slightly less efficient, and Tephrosia virginiana and Ceanothus ovatus as secondary in this respect.

From this paper of Gleason's one may judge that he has to deal with considerably less loose sand than is the case along the shore of Lake Michigan; and probably not the severe drought and storm that the Kansas sand-hills are subjected to.

As mentioned before Calamovilfa gigantia, and Panicum virgatum, and especially the first mentioned are the first to be established in our loose sand before any other plants can gain a foothold. Along with the last mentioned grasses there are: Cephalanthus, Prunus, Salix and Populus that serve as dune formers even if they have little power of binding the sand with their roots. To these last should be added Yucca glauca Nutt. which due to its clusters of evergreen leaves makes an excellent windbreak, (Plate X, Fig. 2, and Plate XI, Fig. 1) and due to its enormous storage root system (Plate XI, Fig. 2) acts to prevent the sand from blowing readily where the Yucca makes a dense growth.

PLATE XI

Fig. 1. Yucca glauca acting as windbreak.

Fig. 2. Storage root system of Yucca glauca

CHAPTER IX

SUMMARY AND CONCLUSIONS

1. The sand-hills of Harvey, Reno and Rice counties are similar to other sand-hills in Kansas, especially westward along the Arkansas River. They are characterized as typically inland sand deposits. They differ from lake and seastrand sand deposits in having no increase of sand supply washed up with every storm, but have just a given amount of sand which is carried back and forth by the winds. It is only prevailing winds from one direction that cause movement of the whole complex in a general direction.

2. The climate is characterized by extremes in temperature, wind, moisture and light.

3. The sand dunes, often bare of all vegetation, are one of the characteristics that mark the sand-hills area as peculiar to itself and distinguishes the area from the surrounding country.

4. The vegetation is characteristically xerophytic. The grasses are the predominant plant cover both as to number of species and as to stand. While many species found in the sand-hills are the same as in the surrounding territory, enough are so typical of the sand hills that they serve as another trait that characterizes the sand-hills.

5. The blowout is the result of a break in the sod or some other cause, and is a wind excavation in the loose sand with its consequent lee deposit. Many long ridges of loose sand are merely a complex of individual blowouts working into each other.

6. The individual blowout serves the best explanation of the existing differences in the plant formations in the sand hills.

An active blowout destroys vegetation by excavation and burial. The blowout is composed of the windward slope, the basin, the lee slope, and the deposit.

7. In recovery each of these goes through definite stages until they reach the prairie association and become stabilized.

8. The prairie association is the climax plant formation for the prairie.

9. Special sand binders are plants especially fitted to stop the loose sand from drifting and giving other plants a chance to cover the sand.

The sand-hills cannot be considered as waste land for they have considerable value as pasture land. Four to five acres will support a mature beef.

ANNOTATED LIST OF SPECIES

Pteridophyta
    Filicales
        Marsileaceae
            1. Marsilea vestita Hook. & Grev.

    Equisetales
        Equisetaceae
            1. Equisetum laevigatum A. Br.

Spermatophyta
    Najadales
        Alismaceae
            1. Sagittaria latifolia Willd.
            2. Sagittaria graminea Michx.

Graminales
    Gramineae
1. Tripsacum dactyloides L.
2. Andropogon scoparius Michx.
3. Andropogon virginicus L.
4. Andropogon furcatus Muhl.
5. Sorghastrum nutans (L.) Nash.
6. Digitaria sanguinalis (L.) Scop.
7. Leptoloma cognatum? (Schultes) Chase
8. Paspalum ciliatifolium Michx.
9. Panicum virgatum L.
10. Panicum huachucae Ashe
11. Panicum lanuginosum Ell.
12. Panicum praecocius Hitchc. & Chase.
13. Panicum scribnerianum Nash.
14. Echinochloa crusgalli (L.) Beauv.
15. Setaria imberbis R. & S.
16. Cenchrus tribuloides L.
17. Stipa spartea Trin.
18. Aristida intermedia Scribn. & Ball.
19. Aristida purpurascens Poir.
20. Alopecurus geniculatus L.
21. Sporobolus clandestinus (S. Prerg.) Hilche
22. Sporobolus asper (Michx.) Kunth
23. Sporobolus cryptandrus (Torr.) Gray.
24. Agrostis hyemalis (Walt.) B. S. P.
25. Calamovilfa gigantea (Nutt.) Scribn. & Merr.
26. Sphenopholis obtusata (Michx.) Scribn.
27. Koeleria cristata (L.) Pers.
28. Spartina michauxiana Hitchc.
29. Chloris Verticillata Nutt.

30. Bouteloua oligostachya (Nutt.) Torr.
31. Bouteloua hirsuta Lag.
32. Triplasis purpurea (Walt.) Chapm.
33. Agrastis hyemalis (Walt.) B. S. P.
34. Eragrostis Megastachya (Koeler) Link
35. Eragrostis trichoides (Nutt.) Nash
36. Eragrostis pectinacea (Michx.) Steud.
37. Eragrostis secundiflora Pres.
38. Poa pratensis L.
39. Festuca octoflora Walt.
40. Bromus racemosus L.
41. Hordeum jubatum L.
42. Hordeum pusillum Nutt.
43. Elymus virginicus L.
44. Elymus robustus Scribn. & J. G. Sm.
45. Elymus striatus Willd.

Cyperaceae

1. Cyperus Sp.
2. Cyperus inflexus Muhl.
3. Cyperus schweinitzii Torr.
4. Cyperus bushii Britton
5. Cyperus strigosus L.
6. Eleocharis palustrus (L.) R. & S.
7. Eleocharis acicularis (L.) R. & S.
8. Fimbristylis autumnalis (L.) R. & S.
9. Scirpus validus Vahl.
10. Scirpus lineatus Michx.
11. Hemicarpha micrantha (Vahl.) Britton
12. Carex pennsylvanica Lam.

Xyridales

Commelinaceae

1. Tradescantia reflexa Raf.
2. Commelina virginica L.

Liliales

Juncaceae

1. Juncus tenuis Willd.

Liliaceae

1. Allium mutabile Michx.
2. Yucca glauca Nutt.

Amaryllidaceae

1. Hypoxis hirsuta (L.) Coville.

Iridaceae

1. Sisyrinchium albidum Raf.

Orchidales

Orchidaceae

1. Ibidium Cernuum?

Salicales

Salicaceae

1. Salix nigra Marsh.
2. Salix tristis Ait.
3. Populus sargentii Dode.

Urticales

Urticaceae

1. Morus rubra L.

Polygonales

Polygonaceae

1. Eriogonum annuum
2. Rumex altissimus Wood.
3. Polygonum aviculare L.
4. Polygonum ramo ramosissimum Michx.
5. Polygonum muhlenbergii (Meisn.) Wats.
6. Polygonum pennsylvanicum L.
7. Polygonum persicaria L.
8. Polygonum hydropiperoides Michx.

Chenopodiales

Chenopodiaceae

1. Cycloloma atriplicifolium (Spreng.) Coult.
2. Chenopodium album L.
3. Corispermum hyssopifolium L.
4. Salsola Kali L.

Amaranthaceae

1. Amaranthus retroflexus L.
2. Amaranthus graecizans L.
3. Amaranthus blitoides Wats.
4. Froelichia floridana (Nutt.) Moq.
5. Froelichia gracilis Moq.

Nyctaginaceae

1. Oxybaphus hirsutus (Pursh.) Sweet.

Aizoaceae

1. Mollugo verticillata L.

Caryophyllales

Portulacaceae

1. Talinum rugospermum Holzinger.
2. Portulaca oleracea L.
3. Portulaca pilosa L.

Ranunculales

Ranunculaceae

1. Anemone caroliniana Walt.
2. Delphinium virescens

Papaverales

Papaveraceae

1. Argemone intermedia Sweet.

Cruciferae

1. Lepidium apetalum Willd.
2. Lepidium ruderale L.
3. Sisymbrium canescens Nutt.
4. Arabis virginica (L.) Trel.

Capparidaceae

1. Cristatella jamesii T. & G.

Rosales

Rosaceae

1. Rubus sp.
2. Rosa setigera Michx.
3. Prunus angustifolia Marsh.

Leguminosae

1. Schrankia uncinata Willd.
2. Cassia chamaecrista L.
3. Baptisia bracteata (Muhl.) Ell.
4. Baptisia australis (L.) R. Br.
5. Crotalaria sagittalis L.
6. Melilotus alba Desr.
7. Hosackia americana (Nutt.)
8. Psoralea tenuiflora Pursh.
9. Psoralea digitata Nutt.
10. Amorpha canescens Pursh.
11. Amorpha fragrans Sweet.
12. Petalostemum villosum Nutt.
13. Petalostemum candidum Michx.
14. Tephrosia virginiana (L.) Pers.
15. Desmodium illinoense Gray.
16. Lespedeza capitata Michx.
17. Strophostyles pauciflora (Benth.) Wats.

Geraniales

Linaceae

1. Linum floridanum (Planch.) Trel.

Oxalidaceae

1. Oxalis violacea L.
2. Oxalis stricta L.

Geraniaceae
1. Geranium carolinianum L.

Zygophyllaceae
1. Tribulus terrestris L.

Polygalaceae
1. Polygala sanguinea L.
2. Polygala verticillata L.

Euphorbiaceae
1. Croton glandulosus L.
2. Euphorbia geyeri Engelm.
3. Euphorbia marginata Pursh.

Malvales
Malvaceae
1. Callirhoe digitata Nutt.

Violales
Cistaceae
1. Crocanthemum majus (L.) Britt.
2. Lechea intermedia Leggett.
3. Lechea villosa Ell.
4. Lechea tenuifolia Michx.

Violaceae
1. Viola rafinesquii Greene.

Opuntiales
Cactaceae
1. Opuntia rafinesquii Engelm.

Myrtales
Lythraceae
1. Ammannia coccinea Rottb.
2. Lythrum alatum Pursh.

Onagraceae
1. Ludvigia alternifolia L.
2. Ludvigia palustris (L.) Ell.
3. Oenothera rhombipetala Nutt.
4. Oenothera humifusa Nutt.
5. Oenothera Laciniata Hill.
6. Oenothera serrulata Nutt.

Gentianales
Apocynaceae
1. Apocynum cannabinum L.

Asclepiadaceae
1. Asclepias tuberosa L.
2. Asclepias amplexicaulus Sm.
3. Asclepias verticillata L.
4. Acerates angustifolia (Nutt.) Dec.

Polemoniales
Boraginaceae
1. Heliotropium convolvulaceum Nutt.
2. Lithospermum gmelini (Michx.) Hitchc.
3. Lithospermum angustifolium Michx.

Verbenaceae
1. Verbena hastata L.
2. Verbena stricta Vent.
3. Verbena bracteosa Michx.

Labiatae
1. Salvia azurea Lam.
2. Salvia lanceaefolia Poir.
3. Hedeoma hispida Pursh.

Solanaceae
1. Solanum nigrum L.
2. Solanum rostratum Dunal.
3. Physalis heterophylla Nees.
4. Physalis virginiana Mill.
5. Datura tatula L.

Scrophulariaceae
1. Linaria canadensis (L.) Dumont.
2. Pentstemon buckleyi
3. Veronica peregrina L.
4. Gerardia pauporcula (Gray) Britton.

Acanthaceae
1. Ruellia ciliosa Pursh.

Plantaginales
Plantaginaceae
1. Plantago purshii R. & S.
2. Plantago virginica L.

Rubiales
Rubiaceae
1. Galium aparine L.
2. Diodia teres Walt.
3. Cephalanthus occidentalis L.

Campanulales

Cucurbitaceae

1. Cucurbita foetidissima H.B.K.

Compositae

1. Vernonia fasciculata Michx.
2. Liatris squarrosa? Willd.
3. Liatris punctata Hook.
4. Liatris spicata (L.) Willd.
5. Liatris kansana
6. Sideranthus annuus Rydb.
7. Solidago nemoralis Ait.
8. Solidago leptocephala T. & G.
9. Aster multiflorus Ait.
10. Erigeron annuus (L.) Pers.
11. Erigeron canadensis L.
12. Antennaria neodioica Greene.
13. Gnaphalium polycephalum Michx.
14. Ambrosia trifida L.
15. Ambrosia psilostachya Gray
16. Xanthium commune Britton.
17. Lepachys columnaris (Sims) T. & G.
18. Helianthus petiolaris Nutt.
19. Helianthus maximiliani Schrad.
20. Helianthus subrhomoideus
21. Coreopsis tinctoria Nutt.
22. Bidens involucrata (Nutt.) Britton
23. Gaillardia lutea Greene.
24. Achillea millefolium L.
25. Artemisia ludoviciana Nutt.
26. Cirsium lanceolatum (L.) Hill.
27. Lactuca scariola L.
28. Pyrrhopappus grandiflorus Nutt.

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THIS THESIS WAS TYPED

by

Bernhard Bargen
Buhler, Kansas