Vegetational Changes on a 25 Year Subsere in the Loess Hill Region of Central Nebraska

JOHN W. VOIGT

Assistant Professor of Botany, Department of Botany, Southern Illinois University, Carbondale, Illinois

INTRODUCTION

SUBSERES exist where an established natural vegetation has been destroyed or modified. Man's cultivation of marginal and submarginal lands and his improper use and management of grazing lands are the chief causes of subseres in grassland areas. In regions where the balance between climate and vegetation is in delicate adjustment and where the soils are vulnerable to erosion, subseres are both common and severe.

In this study, the subsere is the Sheen pasture located 4.5 miles west of the city of Kearney, Nebraska, and $\frac{1}{2}$ mile north of the Kearney canal. The pasture is 160 acres in size, consisting of two tracts of 80 acres each which were fenced together as one, but separated by a valley or canyon running north and south. A portion of the west 80 acres on the nearly level upland and slopes had been broken for a short period and abandoned because of severe erosion. This subsere from cultivation of a native pasture was 23 years old at the time the study was undertaken in 1946.

These eroded loess hill lands reverting to native pasture have suffered a loss of fertility and successional changes are very slow, especially when such an area occurs within the fenced limits of land used as pasture, and the grazing animals have access to the recovering vegetation. Even where grazing animals are removed completely the return to excellent range condition may take several decades. The slopes of the subsere range from 5 to 20

percent and are eroded so severely that upon entrance to the pasture, and viewed from a distance of a quarter of a mile, the tawny colored bunches of annual three awn grass $(Aristida \ oligantha)^1$ and red three awn grass (Aristida purpurea) were so abundant on the slopes that they blended together to give the impression of bare loess soil. Other important grasses on these slopes were buffalo grass (Buchloe dactyloides), blue grama (Bouteloua gracilis), western wheatgrass (Agropyron smithii) and smaller amounts of tumblegrass (Schedonnardus panniculatus), weedy bromes (Bromus spp.) and sand dropseed (Sporobolus cryptandrus). Buffalo grass occurred as small circular patches 5 to 25 feet in diameter, and had a more open appearance than the dense covered areas of good range condition found in the less disturbed east 80 acres. The circular areas of buffalo grass were nearly always surrounded by three awn grasses. Many spots were found where forbs and other grasses among the buffalo grass had been entirely excluded and other places where only weakened and dying stems of vervain (Verbena stricta), dotted button-snakeroot (Lacinaria punctata), and other forbs were found (Fig. 1A). Dying bunches of three awn grass in the buffalo grass sod with only 3 to 5 living shoots protruding from a decaying crown also indicated

¹ Nomenclature of grasses follows Hitchcock's "Manual of the Grasses of the United States," that of other species is according to Britton and Brown's "Illustrated Flora," unless other authority is given. that buffalo grass was once more becoming established, though slowly.

Wheatgrass where it occurred was patchy and the patches often ran together to form large ones. Blue grama existed on the slopes as isolated knobs which were frequently found on pedestals of soil five inches high (Fig. 1B). Nearly bare soil inhabitated mainly by three awn grasses surrounded these. Some blue grama was found on "cat-steps," where the soil had softened and slipped several inches to a foot. These areas were mostly small and irregular. hairy chess (*Bromus commutatus*) occurred as an understory in the wheatgrass and made weak mixtures with buffalo grass when the latter was weakened and had an open cover. This vegetation after more than two decades still lacked the characteristics of good or excellent range condition. There was a poorly developed understory except for weedy species. There was a fair mulch in the buffalo grass type, but a poor one in the wheatgrass type and practically none in the three awn grass type. Most species were dwarfed due to low soil fertility, and they



FIG. 1. Vegetation on eroded loess hill lands. July 1948

A. Typical patch of buffalo grass surrounded by red three awn grass. Western wheatgrass in darker area in background. B. A hummock of relict blue grama on pedestal of soil about 5 inches high. The bunch grass is annual three awn.

On the nearly level upland the vegetation had made greater advances. Buffalo grass still prevailed in discontinuous patches though mostly larger than those of the slopes. Wheatgrass and buffalo grass inter-fingered in streaks or narrow bands. Fewer bunches of three awn grass were found, but where they occurred in the wheatgrass sod the bunches were weakened and dwarfed. Sand dropseed in 1946 was the most abundant grass, but a series of good years for growth followed and resulted in a decrease of this invading species and an increase of higher types such as buffalo grass. Small amounts of little barley (Hordeum pusillum) and

also had a poor color. Weeds were numerous in many cases.

Better conditions prevailed over most of the eastern half of this 160 acre pasture. Grazing had been general and there was good cover. The vegetation was mostly of buffalo grass and smaller patches of blue grama. Sand dropseed and bluegrass occurred in the ravines where grazing was heaviest. Small patches of wheatgrass occurred on the uplands. Side-oats grama (*Bouteloua curtipendula*) occupied the mid-slopes of the hill sides. Few weeds were in evidence but forbs of the mixed prairie climax were well represented on the upland. There was a good mulch in this part of the pasture and practically no paths existed except near the gate.

NATIVE VEGETATION

The native vegetation of this region is mixed prairie, consisting of mid grasses and short grasses. The short grasses are found over the entire area, particularly upon the drier portions of upland. Blue grama is the most common short grass. Buffalo grass occurs in lesser amounts. tically the same (80.6) in 1949. Sand dropseed in 1946, which increased greatly during the drought of the early thirties, and buffalo grass constituted over 80 percent of the vegetation. In 1946 sand dropseed had decreased from 41.3 percent to 23.0 percent in 1948. Buffalo grass, one of the climax grasses of this region, increased 8.9 percent in 1948 and a further increase of 12.3 percent in 1949 to make up a total of 63.2 percent. Sand dropseed decreased to 10 percent in 1949. A study

TABLE 1

Foliage cover, composition, and frequency of dominance in fifteen 100 square foot quadrats on nearly level upland.

Year Foliage cover (%)		1946 66.6		1948 81.6		1949 80.6
SPECIES	FREQDOM.	COMPOSITION	FREQDOM.	COMPOSITION	FREQDOM.	COMPOSITION
Sand dropseed	8	41.3	4	23.0	2	10.0
Buffalo grass	6	42.0	10	50.9	: 10	63.2
Wheatgrass	0		0	5.9	3	11.0
Three awn grass	0	7.9	0	8.6	0	11.2
Tumblegrass	0	4.8	0	0.6	0	1.0
Hairy chess	1	4.0	0	4.0	0	3.4
Blue grama	0		1	7.0	0	
Scribner's panic	0		0.		. 0	0.2
1	15	100.0	15	100.0	15	100.0

The lower and mid-slopes support most of the mid grasses, but alternate with the short grasses on the uplands or have short grasses among them as an understory (Weaver and Bruner, 1948).

VEGETATION CHANGES

In 1946, 30 permanent 100 square foot quadrats were laid out on the nearly level upland. Fifteen of these were rechecked in 1948 and 1949. The same 15 quadrats are reported on for each of the years 1946, 1948, and 1949 (Table 1). The greatest change in the vegetation during these periods was in composition. Foliage cover increased from 66.6 percent in 1946 to 81.6 percent in 1948 and remained pracof wheatgrass and three awn grasses shows that both increased until in 1949 they made up 11.0 and 11.2 percent respectively. The subsere grasses, tumblegrass and hairy chess, steadily decreased.

The 15 quadrats on the upland in 1946 were dominated by sand dropseed and buffalo grass with a frequency of dominance of 8 and 6 quadrats respectively. In 1948 sand dropseed dominated only 4 quadrats while buffalo grass dominated 10. In 1949 sand dropseed dominated in only 2, buffalo grass dominated 10, and western wheatgrass dominated 3. The picture afforded by changes in composition is that some gains have been made in a return to climax conditions on the nearly level upland, but it seems apparent that complete return to climax conditions will involve many years.

On the severely eroded slopes in 1948, buffalo grass made up 33.9 percent of the vegetation and dominated 7 quadrats. Three awn grasses made up 28.7 percent of the composition and dominated 6 of the quadrats. Foliage cover was only 67.8 percent.

SOIL FERTILITY AND VIGOR OF PLANTS

Samples of soil from the first four inches beneath the vegetation on the slopes of the subsere and from the first four inches in the part of the pasture which had never been broken were taken. The samples were analyzed for total percent organic matter, nitrogen level, and the level of soluble phosphorus. Soil samples were taken in duplicate.

Two wash tubs of soil in the subsere were taken from the first four inches after the vegetation had been removed. The same was done in the unbroken part of the pasture. Two contiguous sods, 16 x 8 x 3 inches were taken from the subsere. The soil from each site was sieved to remove roots, and the two sods were cloned and planted in boxes filled with soil from the top four inches of the subsere and two sods were planted in boxes filled with soil from the top four inches of the unbroken pasture. The sods were immersed in water before planting. The boxes used had the same specifications as those used by Weaver and Darland (1949) in measuring the vigor of range grasses. Water was added as needed and in equal amounts to each set of sods. After six weeks of growth the removable sides of the boxes were unfastened and the soil washed from the roots with a watering hose and flaring rose nozzle.

Blue grama grown on the soil from the pasture had 16 times as many flower stalks as there were on the sod from the subsere, flower stalks were over 2 times as long, the average weight of the tops was over 2 times as great, roots averaged 2 inches longer, and the root weight was greater. Buffalo grass grown on soil from the pasture had 4 times as many stolons as there were on the sod growing on subsere soil, and the stolons were almost 2 times as long (Fig. 2). The average weight of the foliage of buffalo grass on pasture soil was 3 times as great as that on the subsere soil, root weight was exactly 2 times as much for buffalo grass on pasture soil and root depth was 2 inches greater than when grown on the subsere soil.

The greatest differences in the soils occurred in the 0 to 4 inch level where all measurements made showed better conditions in the unbroken pasture. The 4 to 12 inch level showed less difference. Organic matter ranged from 2.92 percent in the 0 to 4 inch level of the unbroken pasture (under buffalo grass) to 1.49 percent in the subsere under the same grass. In the unbroken pasture the nitrogen level was 0.11 to 0.20 parts per million in the 0 to 4 inch level while for the same level in the subsere it was only 0.10 to 0.11. Phosphorus was low in all soils at both the 0 to 4 inch and the 4 to 12 inch levels (Table 2).

STABILITY OF SOIL

A comparison of the stability of lumps of soil from the eroded subsere, taken from the top 12 inches (lower part) and from the lower part of the A horizon of the uneroded pasture was made by dropping equal sized lumps of soil from each site into tumblers half-filled with water and timing their disintegration with a watch. In sixty seconds the light colored loessal soil from the eroded subsere had crumbled into a pile at the bottom of the tumbler. The lump of soil from the A horizon of the uneroded pasture contained



FIG. 2. Buffalo grass sods from a clone taken from the subsere; planted in soil from top 4 inches of pasture soil (left), and in soil from top 4 inches of subsere (right). Growth period, 6 weeks. July 1948.

TABLE 2

Chemical analysis of soils from the 0-4, and 4-12 inch depths in both the pasture and the subsere.*

SPECIES	DEPTH, IN.	% ORGANIC MATTER	NITROGEN	SOLUBLE PHOSPHORUS
		Pasture	e	
Buffalo	0-4	2.92	0.11-0.20	very low
grass	4 - 12	1.88	0.05-0.07	very low
Blue grama	0-4	2.94	0.14-0.18	very low
	4 - 12	3.11	-	very low
37		Subser	e	
Buffalo	0-4	1.49	0.10-0.11	very low
grass	4-12	1.44	0.05-0.07	very low
Blue grama	0-4	0.96	0.10-0.11	very low
	4 - 12	0.31		very low

* Sampling was made under both buffalo grass and blue grama grass from level upland. Samples were made in duplicate. The level of nitrogen is given in parts per million.

more total organic matter (Table 2). The organic matter served to cement the crumbs together so effectively that the lump from the pasture remained an entity for a period in excess of two minutes (Fig. 3). This erosiveness of the soil in the subsere has kept the fertility level low and the only successful species on it are three awns, sand dropseed, buffalo grass, blue grama, western wheatgrass and several annuals.

ROOT BEHAVIOR IN THE SUBSERE

The steepness of slopes which were cultivated in the west 80 acres has resulted in rather severe erosion of the topsoil. Most of the A horizon has been removed and not infrequently much of the B horizon over most of the subsere. "There was a very thin, poorly developed new A_1 horizon only two to three inches deep. The soil is of loessal parent material, rich in lime throughout which is often in concretions, and with a pH of 8. The same light color prevailed from the soil surface to four feet in depth. The lime layer began at a depth of 5.5 to 7.5 inches and was still present at four feet." (Weaver and Darland, 1949.)

Using the monolith method of Weaver and Darland (1949), and the modified monolith method of Weaver and Voigt (1950), the root systems of the annual three awn and the red three awn grasses were taken from an 11 percent slope (Fig. 4). Most of the roots (95 percent) of the red three awn grass were in the first six inches, and weighed 28.14 grams (Table 3). In the second six inches were 0.620 grams or 2.09 percent of the roots. The roots in the 1–2 foot and the 2–3

on the Great Plains of Colorado as well as this region of Nebraska reports that in Colorado the root system of this plant varied from 2.5 to 3.5 feet in vertical penetration, with most of the direction of penetration being vertical. In compact soils it was about the same, but slightly more shallow. In Colorado in coarse sand which was firmly compacted the spread was 3 to 4 feet from the crown and the depth of penetration hardly below 2 feet. This variation of the root system



FIG. 3. Lump of soil from the A horizon of the pasture (left) remaining as a discreet lump after 2 minutes in water. Center, a lump of soil of the same size as above from the subsere as it appeared immediately upon being placed in water. Right, a lump of the same subsere soil 60 seconds later, showing its instability and erosive nature. May 1950.

foot levels decreased to 0.525 and 0.418 grams respectively. Only 1.74 percent of the roots were in the 1–2 foot level and only 1.41 percent in the last foot. The unusually large percentage of the root weight of this species in the first six inches of soil is due in part to the fact that stem bases were included because of the difficulty involved in their removal. They are also important in their effect upon the soil and function in this regard as do roots and rhizomes (Weaver and Darland, 1949).

Weaver (1920), who has made an examination of this species in several sites to the soil environment is probably a large factor in its success in development on eroded soils (Weaver and Darland, 1949). It was because of this apparent adaptability of the three awn grasses to such poor soils that their root systems were studied.

A monolith $2\frac{1}{2}$ feet wide and 3 feet deep was taken of the annual three awn grass. The monolith was taken to reveal the root distribution of this annual species. The interspace between bunches in this species is, on the average, about 6 to 10 inches. Root competition in the upper foot of soil under the annual three awn is severe as the space between bunches is very well occupied by overlapping, laterally extended roots of crowns close together. The root system was mounted for photographing after the mass (Table 3). The 6 to 12 inch layer contained 1.92 grams or 14.2 percent. The 12 to 24 inch layer contained 1.95 grams or 14.5 percent and the 24 to 36



FIG. 4. Roots of three awn grass in the subsere

A. A three-foot deep and one-foot wide monolith of red three awn grass. Most of the roots were in the first 6 inches of soil, only 5 percent were in the last $2\frac{1}{2}$ feet. Aug. 1948. (Courtesy J E. Weaver.) B. A monolith $2\frac{1}{2}$ feet wide and 3 feet deep of annual three awn grass. The first 6 inches contains 65 percent of the total root mass. August 1949.

soil had been washed free (Fig. 4B). The root system was sectioned for rootweight distribution by depth. In the 0 to 6 inch layer the roots weighed 8.80 grams or 65 percent of the total root inch layer contained 0.82 grams or 6.1 percent.

The root distribution of the annual three awn grass decreased a little morc gradually than that of the red three awn as they penetrated in depth, although by far the greater portion was still in the first 6 inches. This abrupt change at the 6 inch layer in these grasses give them a "dual purpose" root system. The upper portion of the root system of these grasses being thick and widely spreading may utilize the precipitation not penetrating deeply. The thinner and more deeply penetrating portion of the root system may serve to utilize the moisture at deeper levels, down to about four feet. Although this thinner and deeper portion of the root system of the three awns make

TABLE 3

Oven dry weight of roots and percentage of dry weight at several soil depths

DEPTH (INCHES)	ANNUAL 1	THREE AWN	RED THREE AWN		
	WТ., gm.	Wt., percent	Wt., gm.	Wt., percent	
0-6	8.800	65.2	28.140	94.76	
6-12.	1.920	14.2	0.620	2.09	
12 - 24	1.950	14.5	0.525	1.74	
24 - 36	0.818	6.1	0.418	1.41	
 Fotal	13.488	100.0	29.703	100.00	

up only a small percentage of the total root mass, it is probably absorbing out of proportion to its weight. Big bluestem (Andropogon furcatus), near Lincoln, Nebraska had only 2.8 percent of the root mass in the lower half of a penetration to 6 feet, but because of these deeper roots this species remained alive and recovered rapidly following the drought of the early thirties. For this reason its root system at the deeper level is thought to have been absorbing out of proportion to its weight (Weaver and Voigt, 1950).

DISCUSSION

Under present conditions it seems likely that succession will continue very slowly though there have been some good gains toward a climax on upland. Many weedy

annual and perennial grasses still dominate even after 25 years. Three awn grasses especially on the eroded slopes of the subsere seem certain of remaining as a successional stage for a long period. Booth (1941), working in Oklahoma has reported subseres in three awn grasses for a long period of time. Until organic matter accumulates and the fertility is partially restored by reaction of grasses and forbs, there seems little chance of better native grasses and forbs becoming established. Nature's way in improving or building a new soil is painfully slow, and is brought about by a slow progression from weeds to annual grasses and then perennial grasses which slow the wind movement and add organic matter so that the support and continuance of the climax species is possible.

That this depleted condition will be improved by nature only through the passage of time (several decades) means a stand of low value and loss of potential income to the owner. Even light or no use of the recovering vegetation by animals means a long wait if native range is desired. Reseeding with native species would probably be unsuccessful with such low fertility conditions. Many introductions, both grasses and forbs, are available and it has been demonstrated that some of these can be established more easily and in a short time give good grazing service. Crested wheatgrass (Agropyron cristatum) is one of the most promising grasses and has been grown in soils varying from heavy clays to raw subsoil and under relatively dry climatic conditions. Other possibilities are smooth brome grass (Bromus inermis), and yellow sweet clover (Melilotus officinalis) according to Short (1943).

Successful reseeding with either native or introduced species in dry climates must take into consideration the selection of the proper species, the balance between themselves and the fertility level of the soil, and the soil moisture conditions. It is not a simple task to choose grasses that in a year or two will provide good cover, compete with and suppress weeds, be palatable for grazing, and be established easily.

SUMMARY

Subseres are caused mostly by biological activity. A common cause of subseres in grasslands is plowing for cultivation, subsequent erosion and abandonment. The subsere under consideration is 160 acres, located in the loess hill region of central Nebraska. This subsere from cultivation and abandonment has been recovering for 25 years, although subjected to light grazing.

The sere part of this pasture is still dominated mostly by three awn grasses and with smaller amounts of buffalo grass and blue grama.

Foliage cover increased from 66.6 percent in 1946 to 80.6 in 1949. The greatest changes were in the composition of the grasses. In 1946 sand dropseed and buffalo grass made up over 80 percent of the vegetation. Sand dropseed decreased from 41.3 percent in 1946 to 10 percent in 1949. Buffalo grass during this period increased from 42 percent to 63.2 percent. Wheatgrass and three awn grasses by 1949 were 11 and 11.2 percent, respectively.

From 15 quadrats on upland in 1946, sand dropseed dominated 8 and buffalo grass 6. In 1949, sand dropseed dominated 2, buffalo grass 10, and wheatgrass 3.

Comparative development of clones of blue grama and buffalo grass from the subsere was made on the soils from the first 4 inches of depth from the subsere and from the pasture. Both species were of greater stature, had more flower stalks, more roots, and greater root weight when grown on the soil taken from the pasture.

Organic matter ranged from 2.92 percent in the first 4 inch level of the pasture to 1.49 percent in the subsere. The nitrogen level in the pasture soil to 4 inches depth was 0.11 to 0.20 parts per million, while in the subsere it was 0.10 to 0.11. Phosphorus was low in both soils at both the 0 to 4 and 4 to 12 inch levels.

Equal sized lumps of soil from the lower part of the first 12 inches depth of the subsere and pasture were dropped into tumblers of water and their rate of decomposition recorded. The subsere soil decomposed in 60 seconds while the soil from the pasture remained a single entire lump for over 2 minutes.

Red three awn grass roots were 95 percent in the first 6 inches, 2.09 percent in the second 6 inches, 1.74 and 1.41 percent in the 1 to 2 and 2 to 3 foot levels, respectively.

Annual three awn roots were 65 percent in the first 6 inches, 14.2 percent in the second 6 inches, 14.5 and 6.1 percent in the 1 to 2 and 2 to 3 foot levels respectively. The occupance of the upper soil so thoroughly, and their adaptability to poor soils are reasons for the success of these species in the subsere.

Under present conditions, with a light stocking rate it seems likely that succession will continue very slowly. Many weedy annual grasses, and weeds still dominate after 25 years. Reseeding with introductions that will establish on eroded soils seems to offer the best solution for managing these lands profitably.

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SCIENTIFIC AND TECHNICAL WRITING

The ideal of scientific writing was expressed very early in the modern scientific movement in Thomas Sprat's History of the Royal Society (1667). The members of the Society, he said, tried

"to return back to the primitive purity, and shortness, when men delivered so many things, almost in an equal number of words. They have exacted from all their members a close, naked, natural way of speaking; positive expressions; clear senses; a native easiness: bringing all things as near the mathematical plainness as they can; and preferring the language of artizans, countrymen, and merchants, before that of wits or scholars."

> Porter G. Perrin in An Index to English 1939