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RELATIONSHIPS BETWEEN VEGETATION, SOILS, AND POCKET GOPHERS IN THE NEBRASKA SAND HILLS*

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A study was conducted at three locations in the Nebraska Sand Hills to determine if selected soil factors attracted or limited the local distribution of plains pocket gophers (*Geomys bursarius*). The study was also designed to determine the extent of range recovery for the first 3 yr following control of plains pocket gophers. Soil samples were collected from gopher-disturbed and undisturbed areas. Analyses showed that differences in organic matter content, pH, nitrate–nitrogen, phosphorus, and particle size were not great enough to influence distribution of pocket gophers within the research areas. Changes in vegetation were analyzed for 3 yr following elimination of pocket gophers from disturbed areas. Comparison of areas disturbed by pocket gophers with undisturbed areas showed that gopher-disturbed areas had a greater percentage of bare soil with less litter and vegetation. Following control of pocket gophers, vegetation in the disturbed areas rapidly increased with corresponding decreases in the amount of bare ground. Species of perennial grasses began to replace annual species. Secondary plant succession was rapid when there was no grazing, but it was delayed by moderate to heavy grazing during the periods of active plant growth.

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INTRODUCTION

Plains pocket gophers (*Geomys bursarius*) inhabit vast areas of rangeland in the Nebraska Sand Hills. Burrowing and eating habits of gophers affect rangeland vegetation in several ways. Pocket gophers consume vegetation and reduce plant vigor. They also deposit soil on the surface which buries vegetation and provides space for invading plant species (Stubbendieck et al., 1979).

Soil type has been considered a major factor determining the distribution of plains pocket gophers (Downhower and Hall, 1966). Gophers occurred only in soils with a low clay content, less than 30%, and high sand content, greater than 40%. The silt fraction did not seem to affect the distribution of gophers. Beck and Hansen (1966) determined that plains pocket gophers were twice as frequent in sandy loam soils as compared to dune sand types.

Work by Bond (1945) showed that pocket gophers delayed natural plant succession on rangeland by disturbing the soil. Foster and Stubbendieck (1980) found that gopher infestation of rangeland was followed by an increased abundance of forbs because competition from grasses was reduced. Foster (1977) characterized gopher-infested rangeland in western Nebraska as having: (1) decreased forage production, (2) increased percentage of bare soil, (3) decreased percentage of basal cover of vegetation, and (4) delayed plant succession. A reduction in ground cover and the exposure of bare ground subjected the rangeland to accelerated wind and water erosion.

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Some believe that soil factors influence the local distribution of plains pocket gophers. It has been suggested that some soil factor attracts pocket gophers to a particular area. On the other hand, it has been suggested by others that local movement of the pocket gopher is dependent upon availability of suitable vegetation. One objective of this research was to determine if any of the selected soil factors in the three research locations in the Nebraska Sand Hills affected the distribution of the plains pocket gopher.

Soil disturbances and eating habits of the plains pocket gopher have been previously shown to initiate vegetation change. Preliminary data collected in 1977 indicated that differences in ground cover and vegetational composition existed between areas where pocket gophers had been active opposed to areas free of pocket gophers. The rate of secondary plant succession following control of pocket gophers was unknown. The second objective of the research was to determine the extent of range recovery for the first 3 yr following control of the plains pocket gopher.

METHODS AND MATERIALS

Study Sites

Investigations were conducted in Dawes, McPherson, and Sioux counties in the Nebraska Sand Hills. The Sioux County site, a hay meadow that was mowed annually in the summer and grazed in the winter on the Davis Ranch, was approximately 56 km north of Scottsbluff. This area was classified as a sandy range site. Areas without evidence of pocket gophers were in low-excellent (81%) range condition. Where pocket gophers were active, range condition was high-fair (48%). Otero soils (Ustic Torriorthent) were predominant on this study site. Otero soils were formed in wind-modified alluvial sediments. The average annual precipitation for the area is 464 mm (Anonymous, 1973).

The Dawes County study area was established on the Pepper Creek Ranch, approximately 58 km southeast of Chadron. Precipitation averages 525 mm (Anonymous, 1973). The range site was sand, and soil types on the study area were Valent and Dwyer loamy fine sand (Ustic Torripsamment). These upland soils were formed in eolian sand. At the initiation of the study, range condition was high-good (72%) for areas without evidence of pocket gopher activity, while areas in which gophers had recently been active were in high-fair (40%) range condition. During the time of the study, the area was moderately-to-heavily grazed during the spring.

The McPherson County study area was on the University of Nebraska Sandhills Agricultural Laboratory, approximately 18 km northeast of Tryon. The area was moderately grazed in mid-to-late summer each year. Areas were in high-good (70%) range condition where gophers had not been present and in high-fair (45%) condition where there was evidence of gopher activity. Soil of the research area was Valentine fine sand (Typic Ustipsamment), and the range site was classified as sand. These soils developed in windblown fine sand under a cover of mid and tall grasses. The average annual precipitation was 528 mm. The frost-free period ranges from 120 days in Sioux County to 136 days in McPherson County (Anonymous, 1973).

Locations for study were based on the presence or absence of pocket gophers. Those without evidence of gopher activity were termed "undisturbed," and those where pocket gophers were present were referred to as "disturbed" areas. Undisturbed areas and disturbed areas were the treatments in this study. Gophers in the disturbed areas were eliminated in the spring of 1978 by poisoning. Poisoning was repeated when necessary to avoid reoccupation of the tunnel systems. Eradication of the gophers from the disturbed areas allowed natural plant succession to occur. Research plots at each of the three locations and for each treatment consisted of four replications, each measuring 11 x 22 m.

Soils

Soil samples were collected from disturbed and undisturbed areas to determine if selected factors limited the local distribution of pocket gophers. Sampling was conducted randomly at 20 locations within each plot using a soil probe. Sampling was done at three depths: 0–15 cm, 15–30 cm, and 30–60 cm. Soils from the 20 locations were combined and analyzed for: (1) organic matter content, (2) pH, (3) nitrate-nitrogen, (4) phosphorus, and (5) particle size.

Organic matter content was determined by a colorimetric procedure (Jacobs et al., 1971). Soil pH was measured in a 1:1 dilution using a pH meter with a glass electrode (Anonymous, 1972). Nitrate-nitrogen was measured by a colorimetric procedure using the phenoldisulfonic acid technique (Bremner, 1965). Phosphorus content was determined colorimetrically using the Bray-1 soil test (Knudsen, 1975). Particle size analysis was determined by the pipet method (Anonymous, 1972).

Experimental design for the soils was a randomized complete block. Data for each location were analyzed separately and as a combined analysis by depth. Analysis of variance and F-tests (α=0.05) were computed for each variable.

Vegetation

Cover was measured by using a modified 10-point frame as described by Heady and Rader (1958). A series of six compass lines was randomly assigned in each replication of each undisturbed and disturbed treatment. The 10-point frame was systematically placed at 15 randomly assigned points along each compass line. Bare soil, litter, or basal cover of individual plant species was recorded where each pin contacted the surface. A total of 900 points was evaluated in each replication in August of each year. Vegetation data were collected

before pocket gopher control was initiated (1977), and for 3 yr following control (1978–1980).

Ground cover was analyzed using Chi-square contingency tables to test dependency on time. The Cramer's V-value, as described by Conover (1971), was used as a more specific test. Cramer's V-values can range from 0.0 to 1.0, where 1.0 is completely dependent. Percentages of bare soil, litter, and basal vegetation were compared for the undisturbed areas and disturbed areas at each location.

Vegetational cover was analyzed by multivariate analysis of variance (Stroup and Stubbendieck, 1983). Percentages of individual species were classified by life span, season of growth, and grazing response to determine whether any trend was significant over time. Vegetation was compared in the undisturbed areas and disturbed areas at each location. Wilks' Criterion was used as the test of significance (Morrison, 1976). F-tests were contucted (α=0.05).

RESULTS AND DISCUSSION

Soils

Organic matter. Organic matter varied little between gopher-disturbed and undisturbed areas at all research locations (Table I). Means were not significantly different ($p>0.05$). These results do not agree with those of Turner et al. (1973), who reported that gophers incorporate large quantities of organic matter into the soil. Organic matter was highest at the 0–15 cm depth corresponding with distribution of underground plant parts (Burzlaff, 1962).

pH. Soil pH was not different ($p>0.05$) between disturbed and undisturbed areas (Table I). The pH increased slightly with sampling depth, indicating that the surface soil is a zone of eluviation.

Nitrate-nitrogen. Soil nitrate-nitrogen content was not different ($p>0.05$) at the Dawes or McPherson county locations (Table I). Nitrate-nitrogen at the Sioux County location was lower ($p<0.05$) in the undisturbed area as compared to the disturbed area at the 30–60 cm sampling depth. This difference may be attributed to the highly mobile nature of nitrate-nitrogen, as it is readily leached and evaporated. Microorganisms may immobilize soil nitrate-nitrogen (Smith, 1977). Effects of gophers on soil organisms that influence fertility have not been investigated. Pocket gophers may increase soil fertility by the addition of excrement and the decay of food caches (Grinnell, 1923).

Phosphorus. Soil phosphorus was lower ($p<0.05$) in the gopher-disturbed area only at the Dawes County location (Table I). Organic matter and soil pH are closely related to phosphorus availability. However, these factors were not different ($p>0.05$) between disturbed and undisturbed areas and therefore were discounted as limiting phosphorus content. Phosphorus levels in the disturbed area may have been lower due to the large quantity of forbs utilizing phosphorus.

TABLE I. Mean percentages of soil organic matter (%), pH, nitrate-nitrogen (ppm), and phosphorus (ppm) on undisturbed rangeland compared to rangeland disturbed by plains pocket gophers before gopher control (1977). Mean values for undisturbed vs. disturbed areas at each location and at each depth in the same column followed by an asterisk (*) are significantly different (α=0.05).

Research Location	Sampling Depth (cm)	Sampling Area	Soil Factors			
			OM (%)	pH	NNO_3^- (ppm)	P (ppm)
Sioux County	0–15	Undisturbed	1.63	7.2	1.1	12.0
		Disturbed	1.46	7.3	1.4	13.0
	15–30	Undisturbed	0.79	7.4	1.0	
		Disturbed	0.82	7.4	1.0	
	30–60	Undisturbed	0.59	7.5	0.6*	
		Disturbed	0.59	7.4	1.3*	
Dawes County	0–15	Undisturbed	0.60	7.1	1.2	15.0*
		Disturbed	0.79	7.1	1.3	12.0*
	15–30	Undisturbed	0.45	7.3	1.0	
		Disturbed	0.46	7.2	1.1	
	30–60	Undisturbed	0.22	7.3	0.8	
		Disturbed	0.29	7.3	1.0	
McPherson County	0–15	Undisturbed	1.30	6.5	1.2	3.0
		Disturbed	1.35	6.5	1.1	3.3
	15–30	Undisturbed	0.81	6.7	1.0	
		Disturbed	0.83	6.7	1.1	
	30–60	Undisturbed	0.50	6.9	0.8	
		Disturbed	0.50	6.8	0.8	

Particle size. Mean percentages of particle-size analysis did not differ significantly at the Dawes and McPherson county locations (Table II). At the Sioux County location, percentages of silt in the 0–15 cm and 15–30 cm sampling depths were significantly different between disturbed and undisturbed areas. The percentage of silt was higher in the surface layer in the undisturbed area and decreased with depth, while in the disturbed area silt was more abundant in the 15–30 cm sampling depth than in the 0–15 cm sampling depth. The percentage of clay in the 15–30 and 30–60 cm depths was higher in the undisturbed area as compared to the disturbed area. Total sand percentages were not different ($p>0.05$) between areas.

Turner et al. (1973) found that continual burrowing and pushing of soil by pocket gophers promoted vertical cycling and mixing of soil constituents. Cycling and mixing of the soil

TABLE II. Particle-size analysis for undisturbed rangeland compared to rangeland disturbed by plains pocket gophers before gopher control (1977). Mean values for undisturbed vs. disturbed areas at each location and at each depth in the same column followed by an asterisk (*) are significantly different (α=0.05).

Research Location	Sampling Depth (cm)	Sampling Area	Percentage		
			Sand	Silt	Clay
Sioux County	0–15	Undisturbed	72.1	21.4*	4.1
		Disturbed	76.7	19.3*	4.0
	15–30	Undisturbed	79.8	16.5*	3.7*
		Disturbed	76.9	20.3*	2.9*
	30–60	Undisturbed	77.7	17.8	4.6*
		Disturbed	81.1	16.0	3.0*
Dawes County	0–15	Undisturbed	89.5	7.4	3.1
		Disturbed	90.0	7.4	2.6
	15–30	Undisturbed	91.1	6.6	2.3
		Disturbed	90.5	6.9	2.6
	30–60	Undisturbed	92.8	5.3	1.9
		Disturbed	91.6	5.8	2.6
McPherson County	0–15	Undisturbed	86.6	7.4	6.0
		Disturbed	87.0	6.8	6.0
	15–30	Undisturbed	87.8	6.0	6.3
		Disturbed	87.8	5.8	6.5
	30–60	Undisturbed	90.8	3.4	5.8
		Disturbed	89.8	4.3	6.0

may account for these small differences. The majority of gopher burrowing is done 8–16 cm below the soil surface; therefore, soils from this depth will be brought to the surface and continually cycled.

Ground cover. Bare, or uncovered, soil was more abundant in areas disturbed by pocket gophers compared to undisturbed areas (Table III). Following control of the plains pocket gophers in early spring of 1978, ground cover of vegetation rapidly increased. This caused an increase in litter cover, therefore greatly reducing the bare soil component. Changes were highly significant over time at all three research locations. Cramer's V-values indicated percentages of bare soil, litter, and vegetation were more dependent on time in the disturbed area than in the undisturbed area. Ground cover in the disturbed area became similar to the undisturbed area over time. From 1978 to 1980, vegetation decreased slightly in both disturbed and undisturbed areas at all research locations (Table III). Possibly, this was a response to below average precipitation.

Vegetation Classified by Grazing Response

Plant species were classified according to their response to grazing. The classification of plants as decreasers, increasers, or invaders was defined by Nichols et al. (1978). Decreasers are the most desirable plants, while invaders are the least desirable to grazing animals. Vegetation response following pocket gopher control varied among research locations. Multivariate analysis indicated that undisturbed and disturbed areas

TABLE III. Ground cover (%) on undisturbed rangeland compared to rangeland disturbed by plains pocket gophers prior to gopher control (1977) and for 3 yr (1978–80) following gopher control.

Research Location	Cover	Undisturbed				Disturbed			
		1977	1978	1979	1980	1977	1978	1979	1980
		%							
Sioux County	Bare soil	25	17	9	11	44	21	17	14
	Litter	61	59	75	76	48	62	70	75
	Vegetation	14	24	16	13	8	17	13	11
			Cramer's V = 0.127				Cramer's V = 0.206		
Dawes County	Bare soil	39	22	29	27	41	26	33	31
	Litter	52	58	61	63	53	62	59	63
	Vegetation	9	20	10	10	6	12	8	6
			Cramer's V = 0.129				Cramer's V = 0.173		
McPherson County	Bare soil	29	16	17	18	36	23	24	16
	Litter	58	61	67	70	55	58	63	72
	Vegetation	13	23	16	12	9	19	13	12
			Cramer's V = 0.118				Cramer's V = 0.141		

differed in the incidence of plant groups over time at all locations.

Pocket gopher activity at the Sioux County location affected vegetation more than in Dawes or McPherson counties. Precipitation was lower in Sioux County. Therefore, vegetation was more sparce, and the feeding of gophers destroyed a higher percentage of the vegetation. In addition, recovery was slowed by the lower precipitation. Preliminary data in 1977 revealed a larger number of increaser species in the undisturbed area than in the disturbed area (Fig. 1). Pocket gophers affected the increasers most severely by reducing the quantity. Important grass species reduced in the increaser group included *Stipa comata* Trin. & Rupr. (needleandthread), *Agropyron smithii* Rydb. (western wheatgrass), and *Bouteloua gracilis* (H.B.K.) Lag. *ex* Steud. (blue grama).

The density of invaders, or weedy species, was considerably higher in the disturbed area (Fig. 1). *Bromus tectorum* L. (downy brome) was the most abundant invader. Following gopher control, the density of invaders greatly decreased.

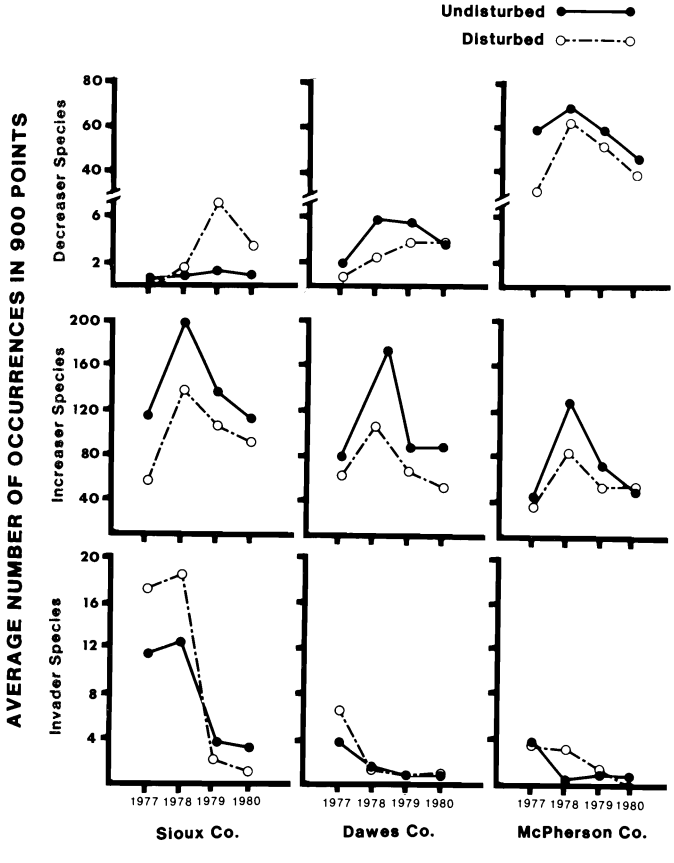

FIGURE 1. Relative composition (average number of occurrences) of decreaser, increaser, and invader species on undisturbed rangeland compared to rangeland disturbed by plains pocket gophers prior to control (1977) and for 3 yr (1978-1980) following control at three research locations in the Nebraska Sand Hills.

In 1977, there was no decreaser species in the disturbed areas at the Sioux County location (Fig. 1). Following gopher control, decreaser species grew in number to where they were more abundant than the more stable population of decreasers in the undisturbed area. *Oryzopsis hymenoides* (R. & S.) Ricker (Indian ricegrass) was the most significant decreaser species. *Oryzopsis hymenoides* is considered a pioneer species in successional vegetation changes on sandy soils. Natural replacement by species in higher successional stages would explain the decline of Indian ricegrass and other decreasers in 1980.

Grazing practices undoubtedly affected response of the vegetation following gopher control. Ungrazed plants at the Sioux County location recovered rapidly. Plants in moderately-to-heavily grazed areas in spring at the Dawes County location were stressed at a time when carbohydrate reserves were low (Moser, 1977). Therefore, rate of recovery was slow. Moderate grazing in mid-to-late summer allowed plants at the McPherson County location to build depleted carbohydrate reserves. Rate of recovery was more rapid at that location compared to the Dawes County location.

SUMMARY AND CONCLUSIONS

Soil characteristics did not attract or limit the occurrence of pocket gophers at the three study sites in the Nebraska Sand Hills. There was no difference in organic matter content or pH at any of the three research locations. At the Dawes County location, soil phosphorus was higher in the undisturbed area than in the gopher-disturbed area. Phosphorus level may have been depleted in the disturbed area due to a large quantity of forbs utilizing soil phosphorus.

Differences in particle size occurred between the disturbed and undisturbed areas at the Sioux and Dawes county research locations, although these differences were not great enough to affect pocket gopher burrowing activities. Variations in particle size and differences between mound and intermound soils indicated that pocket gophers mixed soil particles.

Two factors that influence the feasibility of pocket gopher control would be rate and extent of rangeland recovery. Responses of vegetation after gopher control varied among the three research locations. At the Sioux County location, preliminary data indicated that there were large differences in the vegetation between gopher-disturbed and undisturbed areas. After pocket gopher control, vegetation changed rapidly. There was an increase in the more desirable species.

Changes in vegetation were influenced by several factors. Climate, weather conditions, and grazing practices varied among research locations. Pocket gopher activity in Sioux County had a greater effect on the vegetation than in Dawes and McPherson counties. At the Sioux County location, precipitation was lower, and the activities of the pocket gopher severely affected composition of the vegetation. After gopher control, secondary plant succession was rapid and the vegetation composition approached that of the undisturbed area within 3 yr.

At the Dawes County location, natural plant succession was delayed by grazing practices. Time and intensity of grazing reduced the competitive ability of the plants generally associated with early colonization of the mound areas.

The McPherson County location was in a precipitation zone similar to that of the Dawes County location. Species composition was more stable, and the presence of the plains pocket gopher did not greatly affect the vegetation composition. Moderate grazing in mid-to-late summer allowed plants to build carbohydrate reserves, and the species that usually dominated the plant communities in the area quickly colonized the sites.

The extent of rangeland recovery following pocket gopher control was dependent on several factors. Precipitation greatly influenced plant growth and succession. In an area of low precipitation, vegetation changes caused by pocket gophers were much larger than in an area where precipitation was less limiting. Any factor, such as precipitation, grazing, or soil fertility that stresses growth of vegetation will in turn affect the extent and rate of rangeland recovery following pocket gopher control.

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