Plant-Soil-Microsite Relationships on a Saltgrass Meadow

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Highlight: *At least one million acres of potentially productive meadows in the central great plains are dominated by low value saltgrass. Soil chemical and physical factors have been measured to establish a microsite classification of vegetation-soil relations. The microsites are "slickspot," "level," "mound," and "swale." The mound microsite is dominated by alkali sacaton and produces the highest basal area ground cover. The slickspots were dominated by saltgrass, but average basal area was less than 10%. The level sites produced a mixture of saltgrass, blue grama, and alkali sacaton. The swales contained a mixture of saltgrass, western wheatgrass, and threadleaf sedge. The greatest hindrance to the conversion of these meadows to high quality pasture is that they are on a solonetz soil. The A horizon was a favorable habitat for plant growth; it was neither saline nor alkaline. The B horizon was a serious problem to plant growth because it is hard when dry and impermeable when wet. The C horizon is saline, but it remains moist or wet throughout the growing season.*

Saltgrass (*Distichlis stricta* (Torr.) Rydb.) meadows that cover an estimated one million acres in Colorado and Wyoming, are of little value for livestock production. Extensive saltgrass acreages also occur in Kansas, Utah, Nevada, Oklahoma, North Dakota, South Dakota, Nebraska, and Canada. The saltgrass sites are usually saline or natric, drainage is usually poor, and high water tables are common.

Saltgrass meadows might become important forage resources if they could be seeded to more palatable and nutritious forage species. Before these meadow areas can be rehabilitated, the site characteristics must be better understood.

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The purpose of this study was to determine relationships between existing vegetation and soil characteristics within a saltgrass meadow. Then, revegetation could be more readily planned because soil characteristics that influence seeding success and forage production could be predicted by using vegetation as an indicator to lessen the need for extensive soil sampling. A knowledge of soil characteristics is also necessary when conducting seeding research on this site. Establishing improved forage species on this site has been extremely difficult and seeding failures have been frequent.

Methods and Procedures

Study Area

Saltgrass meadows studied were in the Eastman Creek drainage on the Central Plains Experimental Range (CPER), operated by the Agricultural Reserch Service, U.S. Department of Agriculture, 19 km (12 miles) north of Nunn, Colo. Elevation is 1,650 m (5,400 ft).

The mean annual precipitation is 31 cm (12 inches), 85% of which falls between May and September; mean temperature for these months is 15.5°C (60°F) with an average minimum temperature of 9°C (47°F) and an average maximum temperature of 25.5°C (78°F).

Soils within the saltgrass meadows had been identified as an alkali-saline complex but have not been named (Hyder et al., 1966). Soils adjacent to the meadows were sandy loams and loams of the Havre, Greeley, Terry, Vona, and Ascalon series; the adjacent native vegetation was shortgrass plains.

The meadows sloped 0 to 3% toward the Eastman Creek drainage channel that bisected the meadow. The study area sampled was 4 km (2-½ miles) long and 0.2–0.6 km (⅛–⅜ mile) wide, but Eastman Creek drains a broad area that extends upstream at least 9.6 km (6 miles) beyond the study area. The drainage channel does not have year-round surface water flow. There were seepage pools and excavated stock-water developments that have contained water during most summer months. These are fed by an apparently permanent subsurface flow. Thirteen holes were dug to depths of 4.5 m (15 ft) with a hand auger. Free water was measured in 8 of the 13 holes at depths of 2 to 4 m. Conductivity of the water averaged 1 mmho.

Procedures

The saltgrass meadow boundaries were delineated on the basis of presence or absence of saltgrass, and sampling of the soils and vegetation was confined to these areas.

Study sites within the salt meadow were chosen to represent different vegetational and microrelief types. Microrelief areas sometimes appeared to be relatively distinct, but plant associations were not readily definable in the field. Aerial photographs aided in locating the study sites prior to sampling and served as a guide to relocating the individual plots at a later date. Microrelief data were based on reference to the drainage channel and other microrelief aspects.

Forty-seven meter-square plots were permanently marked. Vegetation on each plot was sampled during July and August for percent basal area with twenty 0.05 m^2 quadrats marked into quarters. Ocular estimates were used to estimate the amount of basal cover of each species. Vegetation cover which approached that of a lawn was considered to be 100%. Growth potential data were based on average culm height of saltgrass because it was the only species that remained ungrazed during the period of the study, and it was also the only species present on all plots.

After completion of the vegetation sampling, a soil pit was dug in the center of each plot. From each pit two slices of soil, one from each side of the pit, were removed and soil horizons and horizon depths were determined. Depth of the pits depended upon depth to the C horizon, and ranged from 61 cm to 91 cm (24 inches to 36 inches) deep.

Because of the extreme variability within this meadow, and because of unsuccessful attempts to measure differences within the horizons, only three horizons were included in the data. In all sample pits the characteristic column tops in the B2 could be clearly seen and the change from B2 to C was relatively sharp. All material below the B2 was considered to be the C horizon. Because of the sharp demarcation at the top of the B2, everything above the B2 was classed as A horizon. Some profiles contained a distinct A2 horizon while others did not. It is believed that many of the profiles at one time contained an A2 horizon, but it may have been destroyed by erosion. Many A horizons also showed evidence of deposition and sometimes contained one or two buried strata.

Field observations on each horizon included depth, color, structure, consistency, and presence or absence of calcium carbonate.

Soil samples were composited by horizon from the two soil slices obtained from each soil pit. Samples were frozen in polyethylene bags until laboratory analyses could be made.

Soil samples were brought to saturation following the procedures of Richards (1954). pH values were determined with a pH meter on the soil paste. Pastes were then vacuum filtered to obtain a saturation extract. Electrical conductivity (EC) was determined on saturation extracts with a conductivity cell standardized with a 0.01 N KC1 solution.

Sodium was measured in the saturation extracts with a flame photometer. An atomic absorption spectrometer was used to determine the Ca and Mg in the soil extracts.

Sodium adsorption ratios (SAR) were calculated from Na, Ca, and Mg data as follows:

$$\text{SAR} = \frac{\text{Na (meq/liter)}}{\sqrt{\dfrac{\text{Ca(meq/liter)} + \text{Mg(meq/liter)}}{2}}}$$

The exchangeable sodium percentage increases as the SAR increases, and the larger the SAR, the greater the amount of the adsorbed sodium ion (Richards, 1954).

Mechanical analyses were made by the hydrometer method to determine percent of sand, silt, and clay (Day, 1965).

A total of 47 plots was analyzed for 32 soil and vegetation variables. The 47 plots were then separated into four microsite types (slickspots. level, mound, and swale) and data were analyzed for each microsite type. Means, variance, standard deviations, standard error of the means, and correlation coefficients (r) were computed for all plots together and for the individual microsites. Relationships for all possible combinations of individual soil and vegetation variables were determined from correlation coefficient matrices. Most vegetation relationships presented in this paper were based on the actual basal cover percentage.

Results

Saltgrass Meadow Vegetation

The dominant perennial species in descending order of their cover were saltgrass, alkali sacaton (*Sporobolus airoides* (Torr.) Torr.), blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.), threadleaf sedge (*Carex filifolia* Nutt.), and western wheatgrass (*Agropyron smithii* Rydb.). Average actual basal area for the dominants was 13.6, 8.4, 5.6, 3.6, and 2.3%, respectively. Average total cover for the 47 sample plots was 33.5%. Thirty-one other species were found on this area, mostly in trace amounts, but none was found in sufficient abundance to be used as an indicator plant of soil physical or chemical conditions. Forage production of all species was generally low because of below average precipitation in 1973, and the annual and perennial weeds were scarce in areas where they would normally be expected to occur.

There were no significant correlations between basal area percentages of any of the dominant species (Table 1). The percentage composition of saltgrass to the total basal area was negatively correlated to each of the other dominant species. Because of its low palatability and its ability to use moisture from greater soil depths, saltgrass probably fills the voids grazing and drought create in the other species and it gradually occupies the area at the expense of these other species.

Table 1. Correlation coefficients (r) for species relationships based on basal area and on percent composition on 47 plots in a saltgrass meadow at Central Plains Experimental Range.

	Dominant vegetation species			
	Alkali sacaton	Western wheatgrass	Blue grama	Threadleaf sedge
Basal area				
Saltgrass	−.20	−.22	−.13	−.27
Alkali sacaton		−.24	−.15	−.04
Western wheatgrass			−.09	.20
Blue grama				.05
Percent composition				
Saltgrass	−0.44**[1]	−0.36*	−0.40*	−0.42**
Alkali sacaton		−0.25	−0.22	−0.18
Western wheatgrass			−0.12	0.19
Blue grama				−0.01

[1] * = $P < .05$; ** = $P < .01$.

Saltgrass Meadow Soils

Soil in the saltgrass meadow at CPER was similar to the Beckton soil described by Larson and Brown (1971) in Arapahoe County, Colo. The Beckton soil is of alluvial origin and is classified in the Suborder, Typic natrustolls; Family, fine montmorillonitic, mesic. Slickspots, or barren areas, are common. Under the old classification, this soil was in the Great Group of Solonetz. However, some solodization had occurred. Soil development appeared to have followed the classic solonetz pattern described by Kellogg (1934). No salinization stage was found, nor was soil without a columnar B horizon found within the meadow. The Eastman Creek soils were derived largely from alluvial materials, and contained some strata of sand and waterworn gravel within the soil profle. The sand and gravel layers were most noticeable in the C horizon and were mostly found 2 m (6.6 ft) or more below the surface.

Based on the average of all 47 plots (including seven plots on slickspots), thickness of the A, B2, and depth to C horizon were 15.2 cm (6 inches), 22.7 cm (8.9 inches), and 37.9 cm (14.9 inches), respectively. Average texture of the A horizon was a loam, and texture of the B2 and C horizons was a sandy clay loam. Percolation was usually very slow because the B2 horizon was nearly impermeable when wet.

The pH averaged 7.0 in the A, 8.2 in the B2, and 8.8 in the C horizons. Effervescence, when treated with HC1, ranged from none to violent in the A and B2 horizons, and from moderate to violent in the C horizon.

Electrical conductivity measurements indicated that salt increased in the soil profile from top to bottom. Most of the B2 and all of the C horizons had salt concentrations high enough (electrical conductivity exceeding 4 mmho/cm) to require special management practices (Richards, 1954). Salt content was below 1 mmho/cm in the A horizons of most of the sample plots, and salinity effects were negligible.

Microsites

Correlation coefficients were computed to determine the relationship between several soil factors and basal area of five species, and also between the soil factors and total basal area (Table 2). Although a number of these coefficients were significant and meaningful, most of the coefficients were lower than expected.

The saltgrass meadow was extremely variable from plot to plot in both vegetation and soil, and it appeared that the variability produced the low correlation values. The microrelief on the meadow was similar to that shown by Kellogg (1934) in his drawing of a cross section "through an eroded spot on the solonetz-complex."

Hanson and Whitman (1938) and Redmann (1972) reported that vegetation-microsite criteria were significant enough to stratify study areas based on similar criteria. Because the microrelief appeared to cause much of the variability and because there appeared to be four distinct microsites, each plot was classified into one of four microsites. The microsites were "slickspot," "level," "mound," and "swale."

The slickspots were characterized by shallow, somewhat circular depressions 1 to 4 m in diameter and by the absence of an A horizon which had probably been lost through wind erosion. Vegetation on the slickspots was usually sparse and sometimes absent in the center.

In contrast to the slickspot, the mound microsite was a very slightly to moderately raised, round to elongated area that was one to several meters across. Vegetation on the mounds was usually dense and vigorous. The A horizon was usually very deep and appeared to contain the soil the wind had eroded from the adjacent level and slickspot sites.

The level site was intermediate between the slickspot and the mound microsites. The A horizon was always present but was frequently thin. Vegetation was usually relatively dense but it lacked the vigor of that on the mounds.

The swale microsite consisted of the sometimes indistinct and discontinuous drainageways that carried runoff across the relatively level meadows to the channel that bisected the meadow. The swale is characterized by finer-textured surface soils and a dense, characteristic vegetation containing a high percentage of western wheatgrass and threadleaf sedge. The slickspot, level and mound microsites tended to form a continuum, but the swale seemed to be a distinct microsite that cut across the other three microsites.

When viewed on aerial photograhs, the meadow had the appearance of "patterned ground" or "mima-type" microrelief as described by Arkley and Brown (1954) and McGinnies (1960).

Microsite-Vegetation-Soil Relations

After the individual plots had been assigned to a microsite, all possible correlations between vegetation and soil factors were calculated. The correlation coefficients for microsite vegeta-

Table 2. Correlation coefficients showing the vegetation-soil realtionships within the saltgrass meadow located at Central Plains Experimental Range, Nunn, Colo.

Soil factor	Horizon	Saltgrass[1]	Alkali sacaton	Western wheatgrass	Blue grama	Threadleaf sedge	Total cover[2]
Thickness	A	−.16	.63**	−.12	−.06	.00	.52**
Thickness	B2	.34*[3]	.07	.13	.12	.26	.53**
Depth to	C	.18	.54**	−.01	.11	.22	.75**
pH	A	−.13	.47**	−.01	.01	−.07	.38*
	B2	.18	.54**	.30*	.09	−.23	.33*
	C	.26	.57**	.32*	−.13	−.20	.39*
Electrical conductivity	A	.06	.09	−.10	−.37*	−.14	−.30*
	B2	−.10	.14	−.32*	−.37**	−.31*	−.42**
	C	.02	−.02	−.26	−.30*	−.16	−.35*
Sodium adsorption ratio	A	.15	−.04	−.24	−.31*	−.24	−.39**
	B2	−.02	.20	−.33*	−.36**	−.26	−.29*
	C	.19	.32*	−.22	−.28*	−.17	−.09
Sand	A	.20	−.22	−.21	.15	−.11	−.06
	B2	.14	.23	−.30*	.29*	−.05	.38**
	C	.15	−.15	−.09	.12	−.28*	−.08
Silt	A	−.10	.19	.09	−.07	.22	.20
	B2	.03	−.38**	.08	.02	.05	−.30*
	C	.01	.14	−.16	.04	.05	−.08
Clay	A	−.28*	.17	.31*	−.22	.04	−.10
	B2	−.26	−.02	.31*	−.33*	.02	−.29*
	C	−.20	.08	.24	−.19	.32*	.03

[1] Species data used in correlations was basal area.
[2] Total cover is percent of ground occupied by basal area of all species.
[3] $* = P < .05$; $** = P < .01$.

Table 3. **Average percent basal area and average species composition for four microsites on a saltgrass meadow.**

Species	Average basal area (%)				Average species composition (%)			
	Slick-spot	Level	Mound	Swale	Slick-spot	Level	Mound	Swale
Saltgrass	5.7	16.8	13.6	12.0	82	51	32	31
Alkali sacaton	0.7	6.9	23.9	2.3	7	20	50	7
Western wheatgrass	2.8	0.2	1.6	7.6	11	1	3	25
Blue grama	0.0	8.1	3.2	6.1	0	23	7	14
Threadleaf sedge	0.0	1.5	4.0	10.7	0	5	8	23
Total	9.2	33.5	46.3	38.7	100	100	100	100

tion-soil relationships were generally higher than when these relationships were examined on the meadow as a whole. The most meaningful and important vegetation-soil relationships within each microsite are reported below. All correlation coefficients shown are significant at the 5% level or better.

Slickspot Microsite

The slickspot microsite was the most unfavorable for plant growth within the saltgrass meadow; this was indicated by the sparse total basal cover (Table 3) and the low plant height of the saltgrass (Table 4).

Saltgrass dominated the slickspot microsite (Table 3). The surface of many slickspots were barren of vegetation except near the edges. Saltgrass rhizomes grew under these bare spots in a layer between the B2 and the C horizons but did not penetrate upward through the B2 horizon. In a few cases, these rhizomes actually formed a dense network under the barren surface (B2) horizon. When these rhizomes reached the opposite boundary of the slickspot, where the profile contained an A horizon, the rhizomes tillered upward normally. Average plant height (9.3 cm) indicated that this microsite type had the poorest growth potential of any of the four microsites studied.

Table 4. **Summary of soil factor means stratified by horizon for the four microsite types located on a salt meadow at Central Plains Experimental Range, Nunn, Colo.**

Soil factor	Horizon	Microsite			
		Slick-spot	Level	Mound	Swale
Horizon thickness (cm)	A	–[1]	13.3	39.7	7.2
Horizon thickness (cm)	B2	10.7	23.0	24.7	29.6
Depth to (cm)	C	10.7	36.2	64.3	36.8
Saltgrass height (cm)	–	9.3	13.8	19.4	14.8
pH	A	–[1]	6.8	7.4	7.1
	B2	7.7	8.3	8.7	8.0
	C	8.4	8.8	9.2	8.8
Electrical conductivity (mmho/cm)	A	–[1]	0.6	0.6	0.7
	B2	4.5	3.1	4.0	2.1
	C	11.8	9.4	10.3	8.5
Sodium adsorption ratio	A	–[1]	5.0	1.8	3.0
	B2	31.7	26.9	35.8	16.7
	C	54.3	80.8	106.5	73.5
Sand (%)	A	–[1]	66.7	64.2	57.5
	B2	56.9	62.2	67.3	54.4
	C	55.9	55.1	43.6	44.6
Silt (%)	A	–[1]	18.0	18.1	24.1
	B2	14.4	13.8	6.3	15.5
	C	13.1	18.4	18.0	16.6
Clay (%)	A	–[1]	14.6	17.7	19.9
	B2	28.7	24.8	26.4	30.2
	C	31.0	26.5	38.4	38.8

[1] The A horizon was absent on the slickspots.

Soils on the slickspots lacked an A horizon and had columnar B2 horizon with the domed column tops visible at the soil surface. The C horizon was massive.

Electrical conductivity values were the highest of any of the microsites, but the SAR values of the C horizon were lower than for the other microsite types (Table 4). Both electrical conductivity and SAR increased as depth or thickness decreased. There was a high correlation between EC and SAR of the B2 horizon (r = .94).

Total basal area was adversely affected by the amount of salt (EC) in the C horizon ($r = -.89$;; $P < .01$). Saltgrass was the only species present on all slickspots, and its basal area increased with pH at the C horizon (r = .88).

Level Microsite

The dominant species on the level microsite was saltgrass, but blue grama and alkali sacaton were important subdominants (Table 3). Total basal area was intermediate between the slickspot and mound microsites. The relative amounts saltgrass and alkali sacaton showed a negative relationship ($r = -.47$) which indicated that as alkali sacaton decreased, saltgrass increased. Saltgrass was reported by Sampson (1924), Aldous and Shantz (1924), and Shantz and Piemeisel (1940) to be resistant to damage by grazing livestock, but alkali sacaton was reported to be less resistant to heavy grazing (Klipple and Costello, 1960). Past grazing could have influenced the present species composition because alkali sacaton is much more palatable to livestock than is saltgrass.

Plant height of saltgrass and total basal area indicated that this site was intermediate in productivity when compared to the slickspots and the mounds.

The A horizon of the level microsites varied from fine granular to massive. The B2 horizon was columnar, and the C was massive. Soil texture was sand to sandy clay loam for A, sandy loam to sandy clay for the B2, and loam to clay for the C horizons. An A2 horizon was present between the A1 and B2 soil horizons in approximately half of the soil pits dug in this microsite.

There was a correlation (r = .66) between thickness of the B horizon and saltgrass basal area; this correlation indicates that other species have difficulty competing with saltgrass where there is a thick B horizon. The correlation between thickness of the A and cover of alkali sacaton was positive (r = .59).

Alkali sacaton was correlated with pH in all horizons (r = .52 to .67), whereas western wheatgrass was negatively correlated (r = .46 to $-.63$).

Blue grama had relatively large basal area and composition percentages (Table 3). Blue grama basal area was greatest in those plots in which the EC and SAR values were low. In no case did blue grama occur where the EC was greater than 2 mmho/cm in the A horizon. Total cover also increased as EC and SAR values in the lower horizons of the soil profile decreased. Hanson and Whitman (1938) suggest that, in time, rejuvenation may allow blue grama to become the dominant species for areas such as these. Because blue grama is a shallow rooted species, it grows well in the well-leached A horizon.

Mound Microsite

The mound microsites contrasted sharply with the slickspots. The mounds produced the densest vegetation cover of the four microsite types (Table 3). Similar types of microrelief have been referred to in the literature as mounds, patterned ground, hummocks, and mima-relief (Hanson and Whitman, 1938; Arkley and Brown, 1954).

Origin of these particular mounds is uncertain. One possibility is that the soil was blown in from what had been the A horizon on the slickspots or from upland sources outside of the meadow, and this windblown material was trapped by the existing alkali sacaton tussocks. The bigger the mounds grew, the more soil they trapped (Shantz and Piemeisel, 1940). Arkley and Brown (1954) reported that the digging of fossorial rodents created mounds where there was a claypan, a hard B2 horizon, or a high water table that restricted the rodents' digging activities. Rodent activity was not observed in any of the mound microsite study plots, but pocket gopher (*Thomomys talpoides*) mounds were common on the meadow. It was also suggested that the mounds may have been formed by an upwelling of the ground water table which pushed the soils upward (Gardner, H. R., Personal communication, 1973). However, if this was the force that formed the mounds, it would be expected that the B2 horizon would also have been moved upward to undulate with the micro-relief, or that gaps in the B2 horizon would occur at the upwellings. No gaps in the B2 horizon were found, and the B2 horizon remained relatively level from the slickspots to under the thick A horizon that made up the mound.

Species on the mound microsites in order of decreasing importance were alkali sacaton, saltgrass, threadleaf sedge, blue grama, and western wheatgrass (Table 3).

Correlation analysis indicated a negative association between saltgrass and alkali sacaton ($r = -.90$). This was a displacement effect, because where alkali sacaton was able to persist on mounds, saltgrass did not invade. Alkali sacaton commonly occurred in large clumps (some over 152 cm (60 inches) in diameter) near the edges of the mounds, and many of the clumps had dead centers. The alkali sacaton plants on the mounds were coarser and more robust than those on the level site.

Total basal area was greater on mound microsites than any of the other microsites (Table 3). The very large soil volume of the A horizon allowed for greater water storage capacity above the impermeable B2 horizon and, therefore, apparently favored more plant growth. SAR and EC values were low in this A horizon (Table 4). The amount of alkali sacaton was positively correlated with the more clayey textures in all three horizons. Saltgrass favored the sandier soils.

Mound microsites had a very deep A horizon in comparison with the other soil profiles studied (Table 4), but the B2 horizon was comparable in thickness to that of the B2 found in the level and swale microsites. Texture for the profile was sandy loam to clay, but the mound microsite soils tended to contain more clay than the level microsite in all horizons.

Swale Microsites

The swale areas were slight depressions that had a drainage slope of 0–1% toward the main drainage channel, but the swales themselves did not form a definite drainage channel.

Soils in the swale microsite areas were sandy loam to clay in texture. Structure was granular in the A horizon, columnar in the B2 horizon, and massive in the C horizon. These soils had the highest amounts of clay in the A, B2, and C horizons of any of the microsite types observed (Table 4). The high amount of clay in the A horizon was the most distinctive soil characteristic of this microsite. Because of the high moisture holding capacity of the clays, the collection of runoff, and the shallower depth to the water table, the swales were more moist than other microsites.

The dominant species in the swale microsites in order of decreasing dominance were saltgrass, western wheatgrass, threadleaf sedge, blue grama, and alkali sacaton (Table 3), and total cover averaged 38.7%. Together, threadleaf sedge and western wheatgrass made up almost 50% of the average total basal area. The abundance of one or both of these species was one of the most pronounced and consistent indicators of the swale microsite. Basal area of saltgrass was associated (but not significantly correlated) with alkali sacaton, but both were negatively correlated to western wheatgrass ($r = -.63$). Western wheatgrass and threadleaf sedge seemed to grow well on these high clay content soils.

Alkali sacaton was associated with high salt concentrations ($r = .64$ to $.85$), while saltgrass was associated with high pH ($r = .68$ to $.86$). The other three species occupied the less saline, less alkaine swales. For example, whenever there was a high percentage of threadleaf sedge, the pH of the A horizon was less than 7.0 and was usually between pH 5.5 and pH 6.0.

Discussion and Conclusions

The presence of at least some saltgrass was the most consistent vegetation characteristic of these solonetzic soils throughout the saltgrass meadow. At the saltgrass meadow margins where the presence of saltgrass stopped abruptly, these soils also stopped abruptly, almost exactly where the saltgrass stopped. Outside the meadow boundary the soils were the typical soils of the local uplands. Some saltgrass was found outside the saltgrass meadows primarily on undeveloped alluvial soils or around "buffalo-wallows" on the uplands, but the saltgrass was generally restricted to small areas or patches and was a minor component of the vegetation. Plants from these upland patches of saltgrass did not appear to be a different ecotype than plants from the meadow soils when plants from uplands and various microsites were all grown under uniform greenhouse conditions.

Blue grama was highly sensitive to salt. Basal area and relative abundance of blue grama increased with a decrease of salt in the A and B2 horizons. Blue grama was not an indicator of soil conditions below the B2 horizon because the shallow rooting depth of blue grama made its survival relatively independent of the sodium and salt content of the C horizon.

Total basal area and plant height increased markedly when the thickness of the A horizon and the depth to the C horizon increased. The A horizon was considerably deeper on the mound microsites than on the other three microsites. Because of low salt and a greater soil volume for water retention above the inhospitable C horizon, more optimum growing conditions existed within the deeper A horizons. On individual plots within the level microsite where the A horizon was deep, alkali sacaton constituted the greatest portion of the total cover. Where the basal area of alkali sacaton was high, the pH was also higher than average. The increase of pH in the mounds was believed to be in part caused by the presence of calcium carbonate contained in relatively recent deposits of windblown materials that were trapped by the stemmy alkali sacaton. Thus, a high total cover, a mound microrelief, or a deep A horizon generally indicated that the A horizon had lower salt, higher calcium carbonate, and lower sodium contents. An abundance of western wheatgrass generally indicated a more clayey site, and western wheatgrass and threadleaf sedge usually indicated lower pH vaues in the B2 and C horizons.

The saltgrass meadow was highly variable, not only among microsites, but also between individual plots within microsites. The soils on the Eastman Creek saltgrass meadow are not entirely similar to other soils reported in the literature. They lack the high magnesium of the solonetzic soils in North Dakota (Hanson and Whitman, 1938), and have higher sodium and less silt than the solonetzic soils in Canada (Toogood and Cairns, 1973). Eastman Creek soils appeared to be similar to the Beckton series in Arapahoe County, Colo., (Lawson and Brown, 1971), but the Eastman Creek soils were more saline.

In past attempts to revegetate these meadows with improved forage species, stand establishment has been extremely variable. Much of this variability appears to be related to the intermixed pattern of the microsites. It will be impractical to treat each microsite separately in a pasture seeding because of the smallness of the individual patches in each microsite. Based on the results reported by Toogood and Cairns (1973) there is little reason to hope for more uniform stands if one attempts to eliminate the microsites by land leveling. Our own limited experience indicated that plowing may even increase variability, particularly if it brings the C horizon to the surface. Even when the seeded stand is established on all the microsites, extreme variability in yields is to be anticipated.

Our preliminary studies indicated that the quantity and quality of underground water were quite good and that there was an apparently permanent water table within 2 to 4 m (6 to 13 ft) of the soil surface. If this water could be used for irrigation, it might be possible to leach the salt and sodium out of the profile. However, legal restrictions prevent the development of new irrigation wells and no other source of water is available. The utilization of any underground water will have to be by plants that can penetrate the saline soil layers with their root systems to reach the water table.

Literature Cited

Aldous, A. E., and H. L. Shantz. 1924. Types of vegetation in the semiarid portion of the United States and their economic significance. J. Agr. Res. 28:99-127.

Arkley, R. J., and Herrick C. Brown. 1954. The origin of Mimamound (Hogwallow) microrelief in the far eastern states. Proc. Soil Sci. Soc. Amer. 18:195-199.

Day, P. R. 1965. Particle fractionation and particle-size analysis. p. 545-567. *In:* C. A. Black, (Editor). Methods of soil analysis. Amer. Soc. Agron. Madison, Wisc.

Hanson, H. C., and W. Whitman. 1938. Characteristics of major grassland types in western North Dakota. Ecol. Monogr. 8:59-113.

Hyder, D. N., R. E. Bement, E. E. Remmenga, and C. Terwilliger, Jr. 1966. Vegetation-soils and vegetation-grazing relations from frequency data. J. Range Manage. 19:11-17.

Kellogg, C. E. 1934. Morphology and genesis of the solonetz soils of western North Dakota. Soil Sci. 38:483-501.

Klipple, G. E., and D. F. Costello. 1960. Vegetation and cattle responses to different intensities of grazing on short-grass ranges on the Central Great Plains. U.S. Dep. Agr. Tech. Bull. 1216. 80 p.

Larson, L. S., and J. B. Brown. 1971. Soil survey of Arapahoe County, Colorado. Soil Conserv. Serv., U.S. Dep. Agr. U.S. Government Printing Office. 78 p.

McGinnies, W. J. 1960. Effect of Mima-type microrelief on herbage production of five seeded grasses in western Colorado. J. Range Manage. 13:231-234.

Redmann, R. E. 1972. Plant communities and soils of an eastern North Dakota prairie. Bull. Torrey Bot. Club. 99:65-76.

Richards, L. A., Ed. 1954. Diagnosis and improvement of saline and alkaline soils. U.S. Dep. Agr. Handbook 60. 160 p.

Sampson, A. W. 1924. Native American forage plants. John Wiley and Sons, Inc. New York, N.Y. 435 p.

Shantz, H. L., and R. L. Piemeisel. 1940. Types of vegetation in Escalante Valley, Utah, as indicators of soil conditions. U.S. Dep. Agr. Tech. Bull. 713. 46 p.

Toogood, J. A., and R. R. Cairns. 1973. Solonetzic soils technology and management. Dep. of Ext., Univ. of Alberta, Edmonton, Canada. 92 p.