Soil and Vegetation Relationships in a Central Plains Saltgrass Meadow

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Abstract

A field study was conducted in a saltgrass *(Distichlis stricta)* meadow at the Central Plains Experimental Range to investigate relationships between soil types, salinity, sodicity, fertility, and vegetation ground cover and species composition. Three line transects that included 48 soil cores and their adjacent vegetation cover were sampled. Soils data indicated relatively good homogeneity between transect 1 and 3 with transect 2 exhibiting the poorest soil physical characteristics because of shallow A horizon and high sodium. Species composition averaged across transects reflected in general the following magnitude of ground cover distribution over the 1979-1983 seasons: blue grama *(Bouteloua gracilis)* > alkali sacaton *(Sporobolus airoides)* > saltgrass > western wheatgrass *(Agropyron smithii)*. Species nutrient concentration data showed western wheatgrass with the highest concentration of N and K, alkali sacaton highest in P, Ca, Mg, and Na. Saltgrass was assimilating primary NaCl and alkali sacaton Na_2SO_4. Blue grama showed low Na and Cl concentrations, which suggested a superficial rooting pattern above the saline horizons. Plant-soil correlations for all transects are discussed.

Saltgrass meadows occupy over 200,000 ha of the Central Great Plains of Colorado and Wyoming. These soils are predominantly saline and sodic in nature. Saltgrass, the dominant species on these meadows, is unpalatable; therefore various studies have been undertaken to rehabilitate these areas with more palatable salt-tolerant forage species.

Saltgrass meadow rehabilitation has included evaluating the effects of fertilizers, calcium amendments, mulches, tillage techniques, and seeding depths upon germination and establishment of salt-tolerant, drought-tolerant species (McGinnies and Ludwig 1977, 1978; Toogood and Cairns 1978; Bowman and McGinnies 1981; Sommerfeldt and Rupp 1982). These techniques are used to increase the survival chances of the seeded species.

In order to better understand the ecology of a saltgrass meadow and to facilitate the use of some of these planting practices, we initiated a field study of the relationships among soil types, salinity, sodicity, soil N, soil sodium bicarbonate-extractable P, vegetation ground cover, nutrient content, and species composition. This study reports on soil-vegetation-nutrient concentration relationships.

Methods and Materials

Field Description

This study was carried out along Eastman Creek at the Central Plains Experimental Range (CPER), which is in the shortgrass prairie located 70 km NE of Fort Collins, Colo. Mean annual precipitation is 302 mm, the bulk of which occurs between May and September. Temperatures in the growing season range from an average low of 9°C to an average high of 26°C . The frost-free period averages 133 days per year. A field reconnaissance study has shown 4 dominant grass species: saltgrass, alkali sacaton, blue grama, and western wheatgrass (McGinnies et al. 1976).

The soils represent primarily fine montmorillonitic, mesic, typic Natrustolls, or fine loamy, mixed, mesic Ustollic Natrargids (Solonetz soils). Soil series is classified as an Avar sandy loam, and consists of deep, well-drained but slowly permeable soils in depressional areas and drainage ways. The soils were formed in calcareous loamy alluvium.

Sampling and Analysis

Forty-eight soil cores were taken along 3 east-west transects perpendicular to Eastman Creek, which provides the main drainage of the area. Core no. 1 was taken 30 cm from the edge of the creek bank. Subsequent cores were then taken along the first line transect every 10 m up to core no. 16. Cores no. 17 through 32 (second line transect) were taken about 300 m north of the first transect, and cores no. 33 through 48 (third line transect) were taken across the creek, directly east of the second transect (Fig. 1).

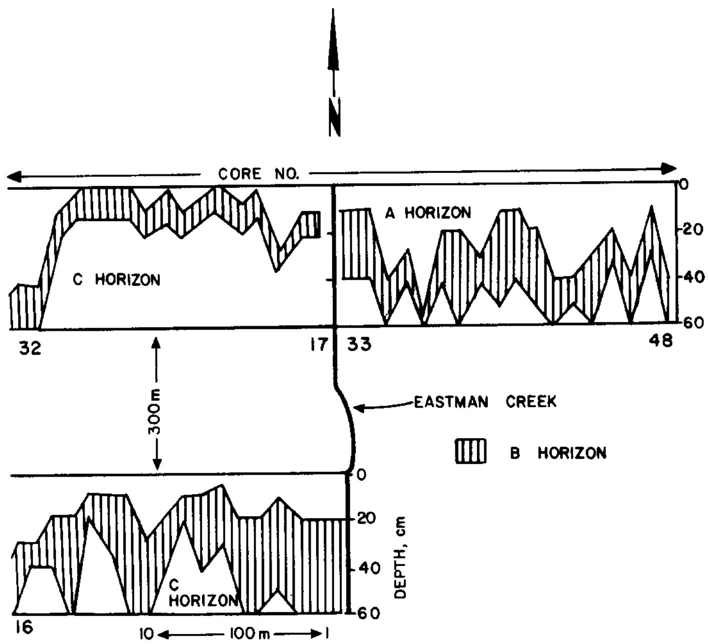

Fig. 1. *Soil horizon distribution to a depth of 60 cm at the 3 line transects along Eastman Creek.*

Cores were 7.5 cm in diameter and 60 cm deep. Diagnostic horizon depths were recorded and the cores were sectioned into six 10-cm consecutive increments for soil analyses across soil horizons. A 10-kg hammer operated by 2 persons was used to drive the core-borer into the ground, and a lever jack was used to remove it from the soil.

Vegetation sampling consisted of determining the ground cover on four 30 × 30-cm plots at each core location. Vegetation sampling was done in June of 1979, 1982, and 1983. Percent composition was calculated from the ground cover data. Plant analyses were made only on the 1979 samples. A rating of 10 was used for full ground cover and 0 for no cover. Species were rated as percent of total cover, with 100 being only species in the cover, 50 the species accounting for half the cover, and 0 the species being absent from the cover. Vegetation from selected grids was harvested, dried

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at 70° C for 2 days, ground to pass through a 40-mesh screen, and wet-digested for total elemental analyses. Total nitrogen (N) and phosphorus (P) were determined colorimetrically by Technicon-Autoanalyzer, and potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) by atomic absorption spectrophotometry. Chloride and nitrate were determined on separate samples by selective ion electrodes and inorganic sulfate by turbidimetry (Bardsley and Lancaster 1965).

Soil analyses included pH, electrical conductivity (EC), and sodium adsorption ratio (SAR) (Richards 1954), and total N (Bremner 1965), $NaHCO_3$-extractable P (Olsen et al. 1954), and texture (Day 1965). Correlation analyses were used to compare plant and soil parameters. An analysis of variance was determined to evaluate significance by years, transects and transects by years interactions on total cover, actual species cover, and on species composition.

Results and Discussion

Soils Data

Figure 1 shows the various horizon depths for the 3 transect lines. A-horizon depth varied from absent to 45 cm. Average A horizon depth was about 30 cm, with a definite trend towards a deeper A from east to west (creek to hill) in the first transect. Transect no. 2 (core nos. 17 to 30) showed very shallow or absent A horizons. This area had the poorest physical characteristics. The rest of transect 2 and all of transect 3 were fairly similar to transect 1. The B horizon in many instances extended as far as the sampling depth (60 cm). The shallowest B horizon was found in core no. 21, which had about 15 cm of B with the A horizon absent. These B horizons were typically columnar in structure, and largely impermeable to water. Many cores at sampling were moist (near or exceeding 0.033 MPa suction) in the A horizons and showed a distinct and abrupt lack of moisture at the A-B interface. The moisture of the A evaporates or runs off laterally along a sandy A-B horizon interface before any appreciable penetration into the B is achieved. The C horizon was much lighter in color than the 2 other horizons because of insignificant amounts of organic matter. Many of the C horizons were moist because of capillary fringe moisture from the shallow water table below.

The A horizon contained 25 to 35% clay and was classified as sandy loam to loam; the B horizon (30 to 40% clay) as sandy loam to sandy clay loam; and the C horizon (25 to 35% clay) as sandy loam to loam.

Figure 2 shows soil reactions (pH), electrical conductivities (EC), and sodium adsorption ratios (SAR) of the top 20-cm depth. The pH of the 0-20 cm depth varied from acid (5.2) to alkaline (8.2), but the majority of the cores were around 7.0 to 7.5. The 20- to 40-cm layers (Figure not shown) showed a decrease in acidity in most instances (pH 6.2 to 9.6), with most layers between pH 7.0 and 8.0. This increase in alkalinity was due primarily to the increase in sodium (Na^+) in the B and C horizons. This same trend was noted with the 40–60 cm layers (pH 6.5 to 9.8).

Electrical conductivity in the 0–20 cm zone (Fig. 2) varied from 0.8 to 20.0 dS/m. The high salt areas were those with the shallow A and B horizons in transect 2. In the 20 to 40 cm layers EC increased significantly in areas where the depth to the C horizon decreased. The same trend was observed with the 40 to 60 cm layers.

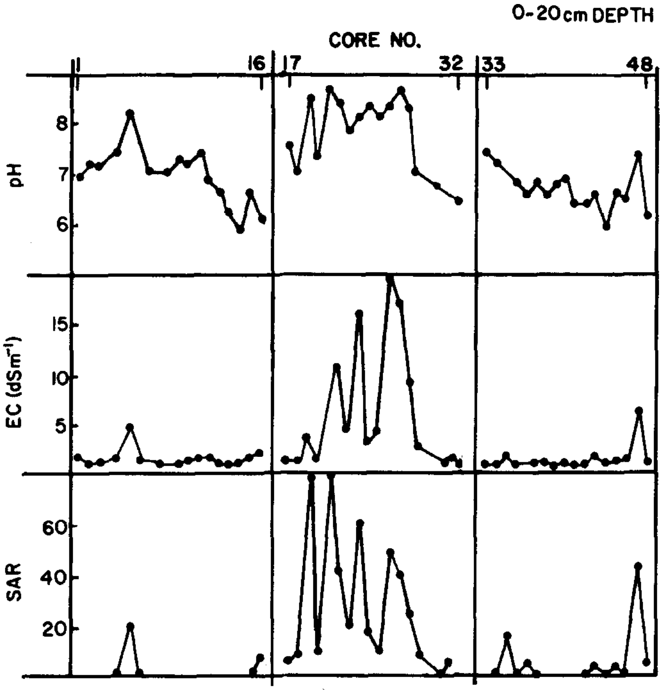

Fig. 2. *Soil pH, EC, and SAR at 0-20 cm depth for the 3 line transects.*

Table 1. Average total soil N and sodium bicarbonate extractable P at two depths in the tree transect lines.

Transect No.	Depth	Total N	$NaHCO_3$-P
	cm	µg/g	
1	0–20[1]	980[2]	13.9
	20–40	420	12.4
2	0–20	640[2]	8.5
	20–40	390	10.5
3	0–20	680[2]	9.3
	20–40	410	5.3

[1]Transect 1 at 0–20 cm was significantly higher ($\alpha = 0.05$) in N and P than transects 2 and 3 at 0–20 cm.
[2]Nitrogen was significantly higher ($\alpha = 0.05$) at the 0–20 cm depth than at the 20–40 cm depth in all transects.

Sodium adsorption ratios (SAR) (Fig. 2) generally reflected the same pattern as salinity. Values varied from less than 0.5 in the top 20 cm to over 60 in some samples below 30 cm. Samples that showed sodium problems were again those cores with the very shallow A and B horizons.

Table 2. Average percent total cover, actual species cover, and species composition in a saltgrass meadow.

Species	Ground cover or composition	Transect No.[1] 1	2	3	Years[1] 1979	1982	1983
		%					
Total	cover	69[c2]	46[a]	60[b]	46[a]	60[b]	68[c]
Blue grama	cover	31[b]	16[a]	33[b]	19[a]	31[b]	30[b]
	composition	45[ab]	35[a]	55[b]	39[a]	52[b]	44[a]
Saltgrass	cover	9[a]	18[b]	8[a]	8[a]	12[ab]	15[b]
	composition	13[a]	37[b]	13[a]	18[a]	20[a]	23[a]
Alkali sacaton	cover	12[a]	12[a]	15[a]	13[a]	14[a]	12[a]
	composition	18[a]	28[a]	26[a]	29[b]	24[ab]	19[a]

[1]Transect values represent average transect values for 3-year sampling, and years values represent 3 transect values for the same year.
[2]Values on a line with the same letter with transects or within years do not differ significantly ($\alpha = 0.05$) according to Duncan's multiple range tests.

Table 3. Average Nutrient concentration ($\bar{x}$) and standard deviation (SD) of the four saltgrass meadow species across all sites.

Plant Cover		N	P	K	Ca	Mg	Na	Cl
					%			
Western wheatgrass	$\bar{x}$	1.19	0.16	1.06	0.32	0.079	0.033	0.36
	SD	0.07	0.03	0.16	0.07	0.007	0.009	0.13
Blue grama	$\bar{x}$	1.02	0.19	0.70	0.33	0.090	0.057	0.20
	SD	0.05	0.03	0.12	0.05	0.010	0.020	0.02
Saltgrass	$\bar{x}$	0.87	0.16	0.64	0.29	0.095	0.160	0.55
	SD	0.19	0.03	0.18	0.07	0.016	0.110	0.33
Alkali sacaton	$\bar{x}$	1.02	0.22	0.94	0.37	0.110	0.260	0.51
	SD	0.13	0.03	0.09	0.05	0.022	0.080	0.16

Nitrogen and $NaHCO_3$-extractable P are shown in Table 1. With the exception of a few cores, N concentration was generally inversely related to the depth of the A horizon and was significantly higher ($\alpha = 0.05$) in the top 20 cm than at the other depths. As expected, the bulk of the organic matter and N was found in the 0–10 cm depth. Both N and P were significantly higher in the top 20 cm of transect 1 than in the top 20 cm of transects 2 and 3. Phosphorus concentration varied widely across the transects and with depth. In a few instances, values in excess of 20 μg P/g soil were found in the 40–60 cm depth. Since the corresponding N values were much lower at these depths than at the 0–10 cm depths, it appears that a highly soluble form of inorganic P is found in these localized areas (high N values would have indicated a buried horizon). The average values for both soil N and soil P did not differ significantly from other areas of the CPER that are nonsaline and nonsodic.

Vegetation Data

Transects no. 1 and no. 3 exhibited mostly mixed vegetation and had significantly less saltgrass than did transect no. (Table 2). Species composition across the transect lines reflected in general the following magnitude of ground cover distribution over the 1979-1983 seasons: blue grama > alkali sacaton > saltgrass > western wheatgrass. Western wheatgrass made up a substantial portion of the vegetation only on transect no. 1 (about 20% average), and was predominantly associated with the lower areas near the creek that were higher in N and P.

Ground cover and species composition changes (1979-1983) were a function of available soil water as reflected by the rainfall distribution pattern over the last 6 years (1977-1982). The wet years (average precipitation = 400 mm) after 1978 (average precipitation = 260 mm for 1977 and 1978) resulted in a large increase in cover. There was no year × transect interaction in total cover or species.

Table 2 provides an indication of the variation within each year and within each transect. Generally total cover was less variable than species composition. In transects 1 and 3 blue grama showed the least variability, and in transect 2, saltgrass showed the least variability. Comparisons are not valid among different species, nor among cover and composition.

Forage chemical composition reflected soil properties and species plant genetic capabilities to root deep or shallow under adverse conditions. While generally the Mg concentrations appeared to be low and Na and Cl concentrations high in certain areas (Table 3), these species did not exhibit any adverse visible symptoms (apart from probable biomass reduction), that might be expected from nutrient deficiency or toxicity. Everitt et al. (1982) did a similar study on saline South Texas Plains soils. A lack of sodicity makes comparison difficult because sodicity affects not only sodium uptake but also water and nutrient availability.

The species concentration pattern of nutrients (Table 3) indicated the western wheatgrass assimilated much more N and K than the other species. Saltgrass contained generally the least concentration of N and P. Saltgrass appeared to be assimilating primarily NaCl, while alkali sacaton was assimilating primarily Na_2SO_4. The low amount of Cl and SO_4 (sulfate data not shown) in blue grama is a direct result of blue grama roots being largely confined to the nonsaline A and B horizons (McGinnies et al. 1976). Herbage of saltgrass contains a much higher percentage of nonchlorophyll-bearing stems than do the other species; this no doubt is the reason for the lower amounts of N and P in saltgrass herbage. Calcium appeared to be the most constant element across all species and all soils.

Blue grama cover was positively correlated ($\alpha = 0.05$) with thickness of the A horizon, depth to salinity, depth to C horizon. It is not very salt tolerant and tends to have a shallow root system that avoids soil salinity. Thus, blue grama was growing most abundantly on the best sites with deepest soil. Where the higher salt levels were near the surface, total plant cover was much reduced and saltgrass became the dominant species because other species were unable to grow on these sites with shallow saline horizons. Total cover was directly related ($R = 0.57$ $\alpha = 0.01$) to the depth to the C horizon (quadratic response) and to the soil N concentration (linear response). Western wheatgrass and alkali sacaton were not strongly influenced by salinity, but N content of the surface 10 cm was correlated with cover and % composition of western wheatgrass ($\alpha = 0.05$). No western wheatgrass grew on sodic sites (high Na low salts) probably because of water stress created by a highly dispersed soil that does not allow water to infiltrate. Saltgrass responded negatively to N (probably due to greater species competition), and positively to SAR ($\alpha = 0.01$).

Conclusion

Soil and climatic conditions are integrated and expressed in plant growth (vegetation cover and species composition), and researchers can draw inferences and make predictions about inherent soil capability based on vegetation. This approach is primarily used by Soil Conservation Service scientists and land managers when dealing with rangelands. Under cultivation management, inherent soil fertility is sampled in order to predict crop productivity potential. Both these approaches are needed to rehabilitate saltgrass meadow soils. It is conceivable that based upon the predominance of saltgrass, certain areas within a meadow should not be immediately brought into improved pasture renovation. There may be a need to increase organic matter content first to improve water infiltration. This may be done by roto-tilling under kochia *(Kochia scoparia)* or some other deep-rooted salt-tolerant species which are high in N, P, and K. This cycling of organic matter and nutrients from the deeper depths to the top soil should improve seedbed preparation, which in turn should improve germination and establishment. Other areas, because of erodibility hazards, probably should be left undistrubed. Areas of mixed vegetation, largely lacking in slick spots after rainfall (slick spots indicate high Na), and having at least 15 cm of A horizon, may be ideally suited for rehabilitation with improved water conservation practices and with improved salt-resistant forages such as Russian wildrye *(Psathyrostachys juncea).*

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