

INTERSPERSED SALT-AFFECTED AND UNAFFECTED DRYLAND SOILS OF THE LOWER RIO GRANDE VALLEY: I. CHEMICAL, PHYSICAL, AND MINERALOGICAL CHARACTERISTICS

D. L. CARTER AND C. L. WIEGAND
*United States Department of Agriculture*¹

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The effects of soluble salts on soil productivity are global. Recent reports present information about saline soils in Spain (1), Iraq (2, 7), Canada (6), Egypt (16), and the United States (8, 10, 15, 19). Although in some areas much has been done towards reclaiming saline soils (5, 9, 17, 19), in other areas plagued by salinity problems (1, 6, 7), little or no progress is evident.

Approximately a fourth of the nonirrigated, cultivated land in the Lower Rio Grande Valley of Texas is markedly affected by soluble salts (8, 9). Much of the saline land produces no cultivated crops, and supports only weeds that are salt-tolerant. Saline areas can thus be considered wastelands. Yet, because their occurrence is random, farmers must cultivate saline areas along with the productive soil. As a result, farm operation costs in such areas are high and profits are low.

Since the nature of the salt problem varies among areas of occurrence, the first step toward solving that of a particular area is a proper evaluation of the problem. The quantities of ionic components composing the soluble salt must be determined, and, if possible the source of the salt, along with certain physical and chemical characteristics of the saline soils. Only thus can the salinity problem be properly evaluated and reclamation practices initiated.

This report presents results from an intensive study of the chemical, physical, and mineralogical properties of saline and adjacent soils of the nonirrigated area in the Lower Rio Grande Valley of Texas. The results presented form a basis for beginning reclamation measures in this area.

MATERIALS AND METHODS

Seven bare saline soils in cultivated fields were selected for study. At each site sampling loca-

¹ P. O. Box 267, Weslaco, Texas 78596.

tions were selected in: (a) the center of the bare saline area; (b) the transition area between bare and apparently nonsaline soil, where salt-stunted crops were growing; and (c) the adjacent soil where crops were growing with no apparent effects of salinity. The soils at the three sampling locations are referred to as, respectively, saline, transition, and unaffected soils. At each sampling location, samples were composited from two cores by depth increments of 0 to 3, 3 to 6, 6 to 12, 12 to 18, 18 to 24, 24 to 36, 36 to 48, and 48 to 60 inches.

All samples were analyzed for: EC_s (electrical conductivity of the saturation extract); CEC (cation-exchange capacity); ESP (exchangeable Na percentage) (17); particle-size distribution (3); silicate mineralogy (11, 13); and certain water-soluble and exchangeable-ion concentrations. The water-soluble ions determined were Na⁺, K⁺, Ca⁺⁺, Mg⁺⁺, Cl⁻, SO₄⁻², HCO₃⁻, and CO₃⁻² (12, 17). The exchangeable cations determined were Na⁺, K⁺ (17), Ca⁺⁺ and Mg⁺⁺. The latter two ions were determined by EDTA titration of NaOAc extracts (4). Total soluble cations and total soluble anions were obtained by summing concentrations of the water-soluble cations and anions, respectively. Other ions are probably present in small quantities.

The soils at each of the seven sampling locations were classified² according to Soil Conservation Standards. In the saline soils, sites 1 to 4 were Rio sandy clay loam, saline phase, and sites 5 to 7, Willacy sandy clay loam, saline phase. At four sites (sites 1, 5, 6, 7) the transition and saline soils were of the same soil series (at site 2, the transition soil was Raymondville sandy clay loam, and at sites 3 and 4, Willacy sandy clay loam). At all sites except one, the transition soils and unaffected soils were of the same soil

² The authors acknowledge the assistance of C. M. Thompson, Soil Conservation Service, U. S. Dep. Agr., Harlingen, Texas.

series (at site 1, the unaffected soil was Willacy sandy clay loam).

The entire nonirrigated study area has a regional water table that fluctuates between 1 and 8 feet below the soil surface in response to seasonal rainfall and evapotranspiration. The 30-year normal annual precipitation at nearby Raymondville is 26.53 inches. There are two seasonally high rainfall periods, May-June and August-September. Variability in annual precipitation is considerable.

At sampling locations where the water table was reached, water samples were collected for salinity analyses, the detailed results of which are not given in this report.

RESULTS AND DISCUSSION

The CEC, ESP, and particle-size distribution are of the same magnitude for all seven sampling locations within each of the three sampling categories—saline, transition, and unaffected soils. Since changes of these properties with profile depth follow the same patterns within each sampling category, only average values for salinity categories are presented. Among the soil sampling categories, however, the variation in these properties is great, indicating some important differences among soils in addition to salinity differences.

Statistical comparisons showed that clay content is significantly greater in saline soil than in unaffected soil below a depth of 12 inches. The ESP is significantly higher in saline than in nonsaline soil throughout the sampling depth. EC_e varies greatly in the surface 6 inches of the saline soils. The maximum and minimum values for the surface 3 inches were 110.0 and 18.0 mmhos./cm., respectively. The second lowest value for this depth was 35.2 mmhos./cm. All seven saline soils sampled were bare because of high salinity. Variations in salinity level were found among the transition soils, but the variations in this case were much less than for saline soils. EC_e levels of the unaffected soil were less than 4.0 mmhos./cm. to a depth of 36 inches, and the variations were minor.

The soluble-salt concentration decreases sharply with depth in saline soils (fig. 1). The average EC_e at a depth of 1 foot is approximately 25 compared with a value of over 60 in the surface 3 inches. These saline soils have extremely high concentrations of salts in the sur-

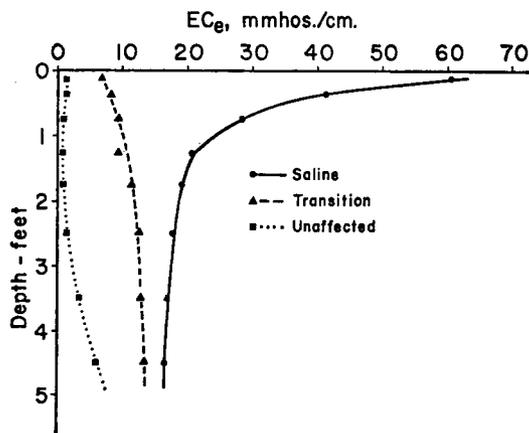


FIG. 1. Average salinity level in relation to depth for soils of the three sampling categories.

face few inches, indicating continued evaporation of saline water from the surface. The EC_e of transition soils increases with depth, and below 3 feet approaches that for saline soils. Unaffected soils exhibit an increase in EC_e below a depth of 3 feet. This increase with depth was expected, because the water table was saline at all but one sampling location where the water table was reached. In the one exception, a water sample at a deeper depth probably would have been saline, since the water table underlying the entire nonirrigated area is saline.*

The Cl⁻ salts dominate in saline and transition soils, and in unaffected soils (fig. 2) contribute approximately 50 per cent of the total soluble anions below a depth of 2 feet. The Cl⁻ composes over 90 per cent of the anions in the surface few inches of the saline soils. The data indicate that the accumulation of soluble salts in these soils is largely an accumulation of chloride salts. The cations accompanying Cl⁻ are Na⁺, Ca²⁺, and Mg²⁺. In all soils the quantities of SO₄²⁻, CO₃²⁻ and HCO₃⁻ were small and of little importance. None of these ions are important in the salinization of the soils in the study area.

The proportion of soluble Na⁺ compared to other cations is not high enough to indicate a serious sodic soil problem. Only below a depth of over 2 feet does the ratio of soluble Na⁺ to total cations reach 60 per cent (fig. 3). Furthermore, even though the ESP is relatively high in the saline soils, and increases with depth in the transition and unaffected soils (fig. 4), leaching

* Unpublished data.

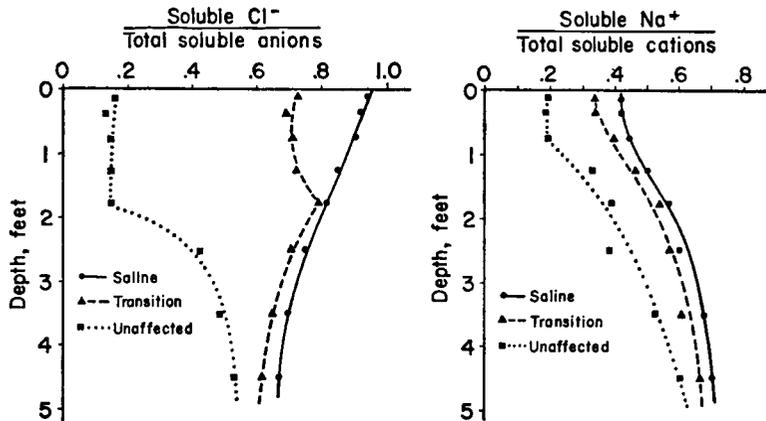


FIG. 2. Average ratios of soluble Cl^- to total soluble anions in relation to depth for soils of the three sampling categories.

FIG. 3. Average ratios of the soluble Na^+ to total soluble cations in relation to depth for soils of the three sampling categories.

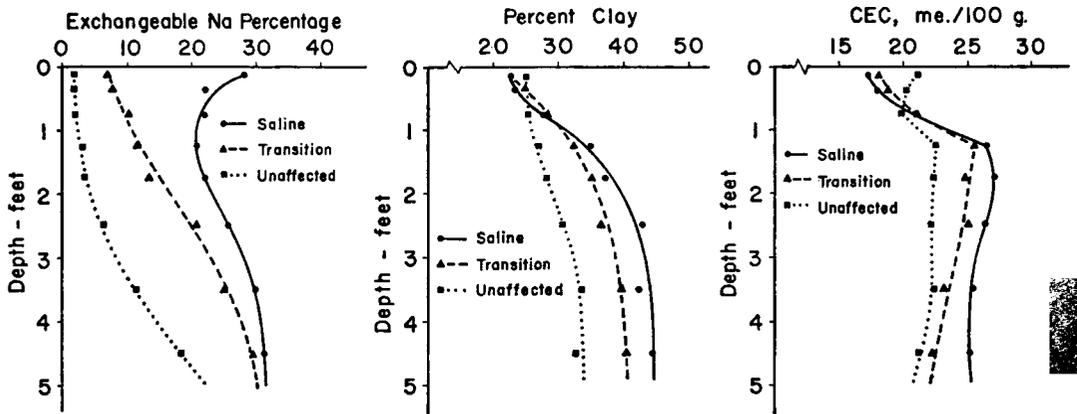


FIG. 4. Average exchangeable Na percentage in relation to depth for soils of the three sampling categories.

FIG. 5. Average clay percentages in relation to depth for soils of the three sampling categories.

FIG. 6. Average cation-exchange capacities in relation to depth for soils of the three sampling categories.

is not likely to form sodic soils (9), because relatively large amounts of soluble Ca^{+2} and Mg^{+2} are present. According to definitions, these soils with ESP values greater than 15 per cent would be classified as saline-sodic soils (17), but these definitions apply only to a present situation and not to what might occur with leaching.

Differences in the per cent clay and the CEC are the primary fundamental soil properties differing among the three soil categories. The per cent clay increases sharply with depth in both saline and transition soils (fig. 5), but

higher contents occur in saline soils. Clay content also increases with depth in unaffected soils, but the increase is more gradual and does not reach as high a level as in the saline and transition soils. Unaffected soils have a slightly higher clay content in the surface 3 inches, but within the next few inches this relationship is reversed. The relation between clay content and EC, or salt content, found in a detailed study of one saline soil (8) is generally true for the geographic area studied.

Since the salts are water-soluble and, there-

fore, are transported by water, there are evidently differences in the water-transporting properties, both upward and downward, of the soils. Measured infiltration rates are about 3 times greater in the unaffected than in the saline soils.⁴ Furthermore, saline soils are higher in surface elevation than the adjacent, unaffected soils.⁵ These elevation differences also affect relative upward and downward movement of water in the saline and unaffected soils, because rainfall runs off saline soils. The transition and unaffected soils may be in the process of becoming saline by slow upward advance of salt from the underlying saline water table. This process would be enhanced by dry climatic conditions, that is upward flow of ions would not be offset by rainfall-induced leaching. Farmers of the area report that saline areas increased markedly during the drought of the early 1950's. During periods of normal rainfall, upward and downward water movement in these soils is in closer balance, so that salinity changes are gradual.

The CEC of the study soils follows a pattern with depth similar to that of clay percentage. On the basis of x-ray diffraction analyses, montmorillonite, mica, and kaolin minerals are present in all soils sampled. A few surface samples also contain a little vermiculite. X-ray diffraction patterns indicate a slight increase in the proportion of micaceous minerals with increased depth in the profile. Since micaceous minerals are lower in CEC than montmorillonites, the increase in the proportion of micaceous minerals with depth is reflected by a decrease in the CEC of the soil (fig. 6).

On the basis of x-ray diffraction analyses, there are no appreciable mineralogical differences among the three soil categories studied. Types of minerals found in these soils agree generally with results of other studies of soils from the area (14).

Differences in clay content below the surface few inches, slight differences in surface elevation, and the deliquescence of some salts present combine to partially or fully account for differences

in salinity of the soils in the study area. It is generally known that capillary rise of water increases with clay content of the soil. Since the saline soils have higher clay contents below the 12-inch depth than transition and unaffected soils, their higher capillary rise of saline water could contribute to greater amounts of surface salt accumulation than is the case for the other soils. Furthermore, the deliquescence of CaCl_2 and MgCl_2 maintains a moist soil surface, as can be observed. Greater moisture evaporation from the moist soil surface (18) results in more upward movement of salt and additional salt accumulation. The combined slower infiltration rates and slightly higher surface elevations of saline soils result in greater runoff and less leaching than is the case for adjacent soils.

Management practices are also important in relation to upward and downward movement of water and salts in these nonirrigated soils. For example, applications of surface mulches several inches thick to saline soils may bring about salt leaching and result in an unaffected or transition soil (9). Climatic factors, such as prolonged droughts and wet periods, also influence the salinity status of soils in the area. Consequently, it is not advisable to use clay content alone to predict salinity status of the soil in this area. The relation of clay content, surface elevation, and deliquescent salts to the upward and downward movement of water and salts is, however, of primary importance with respect to salinity accumulation.

SUMMARY

Nonirrigated soils of the Lower Rio Grande Valley of Texas were sampled by depth increments according to three salinity categories: (a) bare saline, (b) transition, where crop growth was stunted by salinity, and (c) unaffected by salinity. All samples were analyzed for total salinity, constituent water-soluble ions, exchangeable ion status, particle-size distribution, CEC, and mineral type.

The accumulated soluble salts are mainly the Cl^- salts of Na^+ , Ca^{++} , and Mg^{++} . The water-soluble Na^+ concentration in the saline soils is not excessive. The ESP is high enough to classify the saline soils as saline-sodic soils, but no serious sodium problem is expected from leaching because of high Ca^{++} and Mg^{++} levels.

Differences in clay content, CEC, and surface elevation are the main distinguishing measured

⁴Manuscript in preparation: Interspersed salt-affected and unaffected dryland soils of the Lower Rio Grande Valley: II. Infiltration rates and profile characteristics in relation to the occurrence of salinity.

⁵Ibid.

features likely to influence the salinity status of the study soils. Mineral types are essentially the same, and CEC and clay content therefore follow the same general pattern with depth in the soil. The primary factor responsible for soil salinity appears, therefore, to be clay content. Clay content increases sharply with depth in saline soils, whereas only slight increases with depth occur in unaffected soils. Transition soils exhibited clay contents between the other two. Differences in soluble-salt accumulation in soils studied seem to reflect the influence of clay content upon both the infiltration of rainwater and upward flow of water from the saline, regional, shallow water table.

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