A STUDY OF SALINE AND ALKALI SOILS IN THE SCOTT-FINNEY BASIN AREA OF WESTERN KANSAS

by

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NOMENCLATURE

CEC - Cation Exchange Capacity, (m.e./100 grams of soil)

EC - Electrical Conductivity of Saturation Extract, (mmhos/cm.)

ES - Exchangeable Sodium, (m.e./100 grams of soil)

ESP - Exchangeable Sodium Percentage, (ES x 100/CEC)

ESR - Exchangeable Sodium Ratio, (ES/CEC-ES)

ME - Moisture Equivalent

SAR - Sodium Adsorption Ratio, $(\mathrm{Na}^+ / \sqrt{(\mathrm{Ca}^+ + \mathrm{Mg}^+)/2}$

SP - Saturation Percentage

SS - Soluble Sodium, (m.e./liter)

TSC - Total Soluble Cations, (m.e./liter)

INTRODUCTION

Saline and alkali soil conditions reduce the value and productivity of many areas in the United States. More than one-quarter of the irrigated land in the United States does not produce abundantly because the soil is salt-affected.

Salts come from minerals of the earth's crust and are formed as weathering decomposes the minerals and releases the salts in soluble form. There is usually enough rainfall in humid regions to leach the salts through the soil, but in semi-arid regions rainfall is largely dissipated by evaporation and plant use. The buildup of salts by these factors alone is not usually extensive enough to cause harmful effects on plant growth. Saline soils usually occur in areas that receive salts from other areas with water as the primary carrier.

The soils studied in this paper were from the Scott-Finney Basin, a large depressional area beginning south of Scott City, Kansas, in Scott County and running south to the Arkansas River Valley in the northwestern portion of Finney County. The basin is the flood basin of the Whitewoman Creek, and has had a buildup of salts over a long period of time.

Irrigation is already being practiced in the area. Because of the relatively flat topography and an abundance of water at a shallow depth, further expansion of irrigation is anticipated. Irrigation intensifies the importance of knowing something of the nature of these soils, their reaction, the amounts and kinds of salts present, permeability, cation exchange capacity, gypsum content and other factors. This information may be used as a guide to study the effect continued irrigation may have on these soils in relation to plant growth and of the hazards involved.

LITERATURE REVIEW

Description of the Scott-Finney Basin

Latta (1944) and Waite (1947) made an extensive geological study of the basin from Garden City northward to Scott City. Latta referred to the portion of the basin that occurs in Finney County as the Finney Basin and Waite referred to the portion that occurs in Scott County as the Scott Basin. Since the basin is continuous, with parts of it in each county, it is referred to as the Scott-Finney Basin in this paper.

The basin is an asymetrical depression or trough and is the flood basin of the Whitewoman Creek. The eastern limit of the basin is, in most places, abrupt, but on the west there is no sharp limit to the depression and it slopes upward gradually to merge with the high plains surface.

The basin is subject only to normal precipitation during most years, but occasionally becomes flooded as a result of heavy precipitation along the tributary of the Whitewoman Creek. During periods of flood flow, considerable water stands in the basin forming a lake that sometimes covers several square miles. Most of this water sinks rapidly into the ground disappearing completely in a relatively short time.

In ancient times there was a period of folding during which the major features of the bed rock depressions of Scott and Finney counties were formed. A broad asymetrical trough developed with its axis extending from Garden City to Scott City northward. Whitewoman Creek is a stream whose course has been affected by the position of the underlying bedrock and has no connection with any other stream. In times of flood, Whitewoman Creek empties into the basin at its terminus.

The rise and fall of the water table is dependent on the amount of water pumped from wells, the extent and frequency of flooding, and the amount of water lost through transpiration and evaporation.

Recharge in the Scott-Finney Basin is accomplished by infiltration of flood waters discharged in the basin. After passing through the soil zone, much of the water moves on down through the more permeable intake materials to join the water table. There is little or no resistance to the downward movement of water because of the relative absence of impermeable material beneath the floor of the basin.

The suitability of water for use in irrigation is thought to depend mainly on the total quantity of soluble salts and the ratio of the quantity of sodium to the total quantity of dissolved salts.

Wells of the area, in general, have a high quality of water and are within safe limits for irrigation as outlined by U. S. Salinity Laboratory Staff (1954), but all water requires testing as some wells show an excess of soluble salts.

Measured depths to water in the basin vary from 9 to 50 feet below the land surface, and the zone of saturation is from 100-300 feet in thickness. Irrigation wells vary in yield from 400 to 1770 gallons per minute and are from 150 to 350 feet deep. Several test holes should be drilled before locating an irrigation well. The quality and thickness of sands and gravel vary even in short distances, and affect the yield of water greatly.

The normal annual precipitation varies from 18.61 inches in the north at Scott City to 20.22 inches at Garden City on the south. The average mean temperature varies from 53.5 degrees Fahrenheit at Scott City to 54.7 at

Garden City. The average growing season is about 170 days, but has varied from 132 to 200 days during the period for which records are available. About 75 percent of the moisture occurs from April through September which is the growing season for most crops in the area.

Salinization (Soluble Salts)

The soluble salts most commonly found in soils consist of various proportions of the cations sodium, calcium and magnesium, and the anions chloride and sulfate. Those that occur in ordinarily minor amounts are the cation potassium and anions bicarbonate, carbonate nitrate. The original source of all salt constituents are the primary minerals of the earth's crust. During the process of chemical weathering; which involves hydrolysis, hydration, solution, oxidation and carbonization, these constituents are gradually released and made soluble.

Although weathering of primary minerals is the indirect source of nearly all soluble salts, saline soils are seldom formed by this source alone. Saline soils usually occur in areas that receive salts from other locations with water the primary carrier.

Restricted drainage usually contributes to salinization of soils, which is true of the Scott-Finney Basin, especially surface drainage.

The electrical conductivity of solutions is dependent on the number and kinds of ions and accordingly serves as a measure of total salinity. The electrical conductivity of the saturation extract is more reliable than the electrical conductivity of saturated soil paste (Reitemeier & associates, 1945).

The total salts toxic effects on plants are due in part to the increase of osmotic pressure of the soil solution, as the increase in pressure makes it harder for plants to obtain water (U. S. Salinity Laboratory Staff, 1946). Several workers have propagated many different species of plants in solution on sand culture and in soil to which salts of different kinds were added. A comparable osmotic concentration of the salts was used in each kind of media. The amount of growth was found in many cases to be correlated with the osmotic pressure of the solutions used, or in the case of soil, with the osmotic pressure of the solutions used, or in the case of soil, with the osmotic pressure of the soil solution, (Gardner, 1960; Richards, 1959; Ayers, 1952; and Magistad, 1942). The kind of salts also influences plant growth (U. S. Salinity Laboratory Staff, 1946).

Plants do not all have the same salt tolerance. Bernstein and Ayers (1951) found that an average of 3.3 mmhos/cm. of the soil solution reduced yield of green beans about 50 percent. Some varietal differences for tolerance were noted in the same study. Ayers and associates (1951) found that lettuce produced only about 50 percent when the conductivity of soil solution reached 6 mmhos/cm. Bernstein and Ayers (1953) found that 50 percent reduction of yield on carrots to be 4.6 mmhos/cm. Bernstein and associates (1956) found 75 percent yield reduction on Lovell root stock to be at 5.1 mmhos/cm.

Ehlig and Bernstein (1958) found that strawberries are very sensitive to soluble salts and that 2.3-2.6 mmhos/cm. of the soil solution cut yields 50 percent, and that 3.0 to 3.6 mmhos/cm. killed the plants in the spring following planting.

Brown and Hayward (1956) found that alfalfa became more salt tolerant with age; in the first year the yield was reduced 50 percent at about 6.7

mmhos/cm. of the soil solution; 8.2 the second year; and it took 9.9 mmhos/cm. to reduce the yield 50 percent the third year. Some crops are less tolerant of salts at germination stage and are more tolerant later (Ayers, 1952; Bernstein & Fireman, 1951).

Many other studies have been made on the salt tolerance of small grains, grasses and other crops and show that plants vary greatly in this factor and that in most cases even varieties within a species vary in their salt tolerance (Ayers and associates, 1952 and 1953; Bernstein, 1958 - and others).

Alkalization (Exchangeable Sodium)

Soil particles adsorb and retain cations on their surfaces. The reaction whereby a cation in solution replaces an adsorbed ion is called cation exchange. Sodium, calcium and magnesium cations are always readily exchangeable. Other cations like potassium and ammonium, which are held tightly and exchange with great difficulty, are said to be fixed.

The capacity of a soil to adsorb and exchange cations can be measured and expressed in chemical equivalents. This is called the cation-exchange capacity. Cation adsorption, a surface phenomenon, is identified mainly with the fine silt, clay and organic matter of the soil.

Calcium and magnesium are the principal cations found in the soil solution and on the exchange complex of normal arid soils. When an excess of soluble salts accumulate, sodium frequently becomes the dominate cation in the soil solution. Thus, sodium may be the predominate cation to which the soil has been subjected or it may become dominate in the soil solution, due to the precipitation of calcium and magnesium compounds.

In general, half or more of the soluble cations must be sodium before significant amounts are adsorbed by the exchange complex.

When 50 percent or more of soluble salts is sodium, upon leaching the soil may become strongly alkaline, the particles disperse, and the soil becomes unfavorable for the entry and movement of water and for tillage.

Some of these soils contain gypsum and when such soils are leached, calcium dissolves and the replacement of exchangeable sodium by calcium takes place concurrently with the removal of excess salts.

Soils with a high exchangeable sodium percentage content and a low soluble salt content tend to increase the rate of hydrolysis of the exchangeable sodium and often causes the rise in the pH reading of the soil. As the proportion of exchangeable sodium increases, the soil tends to become more dispersed and the sodium saturated clay particles may be carried downward in the soil and accumulate at the lower levels.

Ratner (1935) found that the unfavorable influence of exchangeable sodium upon physical properties of a soil is marked, even with small amounts, also that its harmfulness to plant growth is greater in soils of high organic matter than in poorer soils. Yields decreased when exchangeable sodium exceeded 40 percent and death occurred in most plants when the exchangeable sodium percent reached between 60 and 70 percent (Ratner, 1935; Thorne, 1944).

Fireman and Wadleigh (1951) found that exchangeable sodium effect could be predicted from pH with greater precision than could exchangeable sodium content. The status of calcium compounds need to be taken into account if exchangeable sodium percent values are to be estimated from pH.

Gardner (1959) found that the settling volume, percentage of dispersion, and pH were not straight line functions of sodium percentage. He also found that permeability was due to many factors, and sodium was only one of these factors. He concluded that the poor physical condition of many saline soils is modified by so many factors that it is not always directly correlated with either the percentage of replaceable sodium or the concentration of salts found in the soil.

The Salinity Laboratory Staff (1954) states that gypsum is important because it usually determines whether the use of chemical amendments are needed for reclamation. Also the presence of considerable amounts of gypsum may permit use of water having an unfavorably high sodium content.

Alkaline-earth carbonates influence the texture of the soil when present in appreciable amounts, for the particles commonly occur in the silt size fraction. Presence is thought to improve physical conditions of the soils. They are also important as a potential source of soluble calcium and magnesium for the replacement of exchangeable sodium.

Reaction (pH)

The composition of the exchangeable cations, the nature of the cation-exchange materials, the composition and concentration of soluble salts, and the presence or absence of gypsum and alkaline-earth carbonates are known to influence pH readings. The statistical study of Fireman and Wadleigh (1951) permit the following general statements regarding the interpretation of pH readings of the saturated soil paste: (1) pH values of 8.5 or greater almost invariably indicate an exchangeable-sodium-percentage of 15 or more and the presence of alkaline-earth carbonates; (2) the exchangeable-sodium-percentage of soils having pH values of less than 8.5 may or may not exceed 15; (3) soils having pH values of less than 7.5 almost always contain no alkaline-earth carbonates and those having values of less than 7.0 contain significant amounts of exchangeable hydrogen.

METHODS AND MATERIALS

Sampling

Eight profile samples were taken of the major soil types at random over the area. Samples were obtained by hand with a spade. Any visible or textural change in the profile was recorded and a sample taken for each homogeneous horizon. The profile samples were obtained between the surface and the water table or to a depth where no change occurred for several inches. Considerable precipitation had fallen previous to sampling and the water table was higher than average. Samples were air-dried, passed through a 10-mesh sieve, mixed and stored. Every soil sample in the soil profile was analyzed and treated as an individual soil in this study. There were forty-two samples analyzed.

After the samples used in this research were obtained, the Soil Conservation Service completed a detailed survey of these soils. Some of the soils are still officially unnamed and were given field names by the survey party. A description of each of these soils as used by the S.C.S. is recorded in the appendix.

"Finn" Silt Loam (field name). This profile sample was taken in the SW1/4 of 20-23-32 from a field located in a large depressional area and was partially flooded. The land around the edge of the depression had been cultivated sometime in the past. The soil was covered with a heavy stand of salt grass. Considerable salt crusting on the surface was noted and the water table was at 2 feet. Samples were taken at depths of 0-6", 6-12", and 12-24".

<u>Ulysses</u> <u>Silt</u> <u>Loam</u>. The profile sample was taken in the SE1/4 of 18-23-32, 400 yards west of the SE corner of field on the edge of a deep gully along the road. The gully was formed by water from an irrigation ditch and the upper part of the field was irrigated. The gully was formed on a three percent slope and was ten feet wide and eight feet deep. Samples were taken at depths of 0-12", 12-24", 24-36", and 36-48".

"<u>Tennis</u>" <u>Silty</u> <u>Clay</u> <u>Loam</u> (field name) I. The profile sample was taken in the N1/2 of 3-22-33, fifty yards west of the SE corner of the field along the fence, that was approximately one-quarter of a mile north of an old farmstead. The land south of the fence was cultivated and salt grass was growing north of the fence. The area was hummocky with slick spots or blowouts in between. Samples were taken at depths of 0-6", 6-12", 12-22", 22-52", 52-69", and 69-80".

"<u>Church</u>" <u>Clay</u> (field name). The profile sample was taken in the W1/2 of NE1/4 of 19-18-32 about two-hundred-fifty yards south of the road on the north side of the field and along the east edge of a cut on a newly leveled field. The cut was about eighteen inches deep. This field was leveled in the summer of 1946 and a poor stand of wheat was growing on the area when the samples were taken. The field is in the flood basin of the Whitewoman Creek. Samples were taken at depths of 0-10", 10-20", 20-32", 32-42", and 42-52".

"<u>Tennis</u>" <u>Silty</u> <u>Clay</u> <u>Loam</u> (field name) II. This sample was taken in NE1/4 of 13-30-33 one hundred yards north and twenty yards west of a fence corner on Highway 83. The vegetation was predominately salt grass with a few patches of Buffalo grass. Samples were taken at depths of 0-4", 4-10", and 10-14".

"Tennis" Silty Clay Loam (field name) III. This profile sample was taken in NW1/4 of 11-21-33 twenty yards north and fifty yards east of the southwest corner. The vegetation was predominately salt grass with a few patches of Buffalo grass. Samples were taken at depths of 0-6", 6-18", 18-32", 32-37" and 37-48".

Richfield Silt Loam (saline) I. This profile sample was taken at the Garden City Experiment Station in SW1/4 of 3-24-32 thirty yards east of the west fence on the north side of the field. The field, which was in salt grass sod had not been irrigated. The top soil appeared to be blown material about six inches deep and was very loose and granular with much organic matter and roots. There were concretions at about six feet and the soil felt gravelly. Samples were taken at depths of 0-6", 6-16", 16-24", 24-34", 34-48", 48-60", 60-72", and over 72".

Richfield Silt Loam (saline) II. This profile sample was taken on an irrigated alfalfa field 30 yards south of Richfield silt loam (saline) above. The elevation of this field was 12 inches lower than sample I. Heavy alfalfa roots went down at least four feet including twenty-eight inches of salt accumulation. The roots were still about 1/4" thick at four feet. The land was irrigated by a well one-thousand feet from the sample and the water table was at sixteen feet. This field was broken in 1932 and planted in 1935. Samples were taken at depths of 0-9", 9-15", 15-20", 20-28", 28-34", 34-60", 60-78", and over 78".

Analytical Procedures

Reaction (pH). A soil suspension having a 1:1 soil-water ratio was prepared using distilled water and air-dried soil. The pH was determined using a Leeds-Northrup glass electrode pH meter and recorded to the nearest one-tenth reading.

Moisture Equivalent (ME). Duplicate samples of thirty-one grams of air-dried soil were weighed. The samples were soaked two to four hours, dried two to four hours and were placed in a moisture equivalent centrifuge for forty minutes at 2400 rpm. The weight was recorded and the samples were oven dried at 110 degrees centigrade. The moisture equivalent as a percent was determined on the oven-dry weight basis.

Saturation Extract. A saturated soil paste was prepared. The saturation percentage was calculated, the saturation extract obtained, and the electrical conductivity of the extract (EC) determined as given by the U. S. Salinity Laboratory (1947).

Water Soluble Cations. The water soluble sodium, potassium, and calcium were determined by taking aliquots of the saturation extract and adding sufficient lithium salt to make the final solution concentration of 100 ppm of lithium. The amount of sodium, potassium, and calcium, respectively, were then determined with a Perkin-Elmer Model 52A flame photometer by the internal standard method.

The water soluble magnesium was determined by the photoelectric colorimeter method as given by the U. S. Salinity Laboratory staff (1947).

Water Soluble Anions. Water soluble anions were determined by methods given by the U. S. Salinity Laboratory staff (1947).

Bicarbonate was determined by the titration method with methyl orange as the indicator; sulfate by precipitating as barium sulfate; nitrate was estimated qualitatively by using color differences with diphenol-ammine; and chloride was determined by titration with silver nitrate.

Gypsum. Gypsum was determined by precipitation with acetone as given by the U. S. Salinity Laboratory staff (1947).

Cation Exchange Capacity. Samples of air-dried soil were placed in a centrifuge tube and 1N potassium acetate was added. The samples were mixed well and centrifuged for five minutes. This treatment was repeated five times, pouring off the supernatant liquid after each centrifuging. The exchangeable potassium was displaced by treating the sample with ammonium acetate. A sufficient quantity of lithium salt was added to make the final concentration of lithium 100 ppm. The potassium content of the solution was determined on the Perkin-Elmer model 52A flame photometer by the internal standard method.

Exchangeable Sodium (ES). Samples were weighed out and ammonium acetate was added. The contents were agitated and then filtered using gentle suction. The soil was rinsed with ammonium acetate and each rinsing was added to the funnel. A measured portion of lithium nitrate stock solution in ammonium acetate was added. The final solution contained the exchangeable bases from ten grams of soil and 100 ppm. of lithium. Exchangeable sodium in this solution was determined with a Perkin-Elmer model 52A flame photometer by the internal standard method.

Insoluble Carbonates. Insoluble carbonates were determined qualitatively by effervescence with acid as described by U. S. Salinity Laboratory staff (1947).

Permeability. Duplicate samples of fifty-five grams of soil were weighed and placed in a tube and dropped 1 inch 40 times. A constant head of distilled water was maintained for six hours. The leachate was measured and recorded the first hour, the last hour, and the total for the six hour period (Fireman, Milton, 1944).

EXPERIMENTAL RESULTS

Table 1 shows analytical results for pH, saturation percentage, moisture equivalent and permeability.

pH. The pH of a 1:1 soil suspension varied from 7.0 to 9.0 on these soils and the pH of the surface soils varied from 7.0 on the "Tennis" silty clay loam I to 8.3 on the Ulysses silt loam. The composition of the exchangeable cations, the nature of the cation exchange materials, the composition and concentration of soluble salts, and the presence or absence of gypsum and alkaline earth carbonates are known to influence pH readings. All of the soils analyzed in this study that had a pH value of 8.5 or more and an exchangeable sodium percentage of 14.9 or higher had alkaline earth carbonates present.

All soils with a pH of 7.6 or less had no alkaline earths present and a value of less than 1.82 for the EC. Where calcium or magnesium was the principle cation present in the saturation extract the pH never exceeded 8.3, except for the "Tennis" III 37-48" depth which had a very high(37.2%) ESP.

Saturation Percent (SP). The saturation percentage varied from 32.5 to 79.9 on all the samples that were analyzed. Surface soils varied from 32.5 to 57.9 in SP.

Moisture Equivalent (ME). The moisture equivalent of the horizons

Table 1. Laboratory analyses of the pH, saturation percentage, moisture equivalent, and permeability of 8 soil profiles in the Scott-Finney basin.

Soil description	Sample depth in inches	pH	Saturation percentage	Moisture equivalent	Laboratory permeability		
					inches/hour		Total inches 6 hours
					Initial hour	Final hour	
"Finn" silt loam	0-6	7.9	46.8	21.5	.43	.35	9.9
	6-12	7.8	49.6	23.9	.24	.05	2.5
	12-24	7.9	58.5	28.4	.32	.30	7.2
Ulysses silt loam	0-12	8.3	50.2	24.0	.28	.13	4.4
	12-24	8.2	54.1	25.6	.11	.07	2.1
	24-36	7.9	50.0	23.9	.29	.21	5.5
	36-48	7.9	48.1	24.4	.27	.22	5.5
"Tennis" silty clay loam I	0-6	7.7	57.9	31.9	.21	.09	3.5
	6-12	7.9	40.0	34.3	.22	.10	3.3
	12-22	8.2	43.7	34.7	.08	.07	1.6
	22-52	7.8	52.5	30.2	.35	.31	7.1
	52-69	8.1	41.5	32.5	.19	.18	4.1
	69-80	8.1	37.8	32.1	.13	.13	2.8
"Church" clay	0-10	7.9	41.7	36.5	.20	.08	2.8
	10-20	8.0	69.6	30.6	.19	.13	4.0
	20-32	8.4	74.0	37.5	.09	.07	1.7
	32-42	7.9	68.0	33.5	.15	.16	3.5
	42-52	8.1	47.7	36.9	.15	.14	3.3
"Tennis" silty clay loam II	0-4	7.6	32.5	25.3	.20	.12	3.3
	4-10	7.9	37.6	32.1	.05	.06	1.0
	10-14	8.5	57.5	44.0	.13	.04	1.6

Table 1. (concl.)

Soil description	Sample depth in inches	pH	Saturation percentage	Moisture equivalent	Laboratory permeability inches/hour Initial hour	Laboratory permeability inches/hour Final hour	Laboratory permeability Total inches 6 hours
"Tennis" silty clay loam III	0-6	7.0	54.7	25.8	.19	.07	2.7
	6-18	7.9	62.9	33.5	.17	.09	2.9
	18-32	7.8	72.2	36.2	.00	.00	.25
	32-37	7.7	68.7	30.3	.22	.15	4.4
	37-48	9.0	79.9	54.1*	.00	.00	trace
Richfield silt loam (saline) I	0-6	7.4	45.6	20.3	.26	.05	2.5
	6-16	8.2	69.4	32.3	.00	.00	0.1
	16-25	7.9	69.9	28.5	.19	.20	4.7
	25-34	8.3	68.4	28.2	.11	.13	2.8
	34-48	9.0	65.0	27.4	.33	.36	7.6
	48-60	8.9	60.5	26.3	.32	.31	8.1
	60-72	8.7	59.3	30.2	.11	.08	2.1
	over 72	8.5	58.5	32.8	.00	.00	trace
Richfield silt loam (saline) II	0-9	7.4	45.1	22.1	.45	.19	7.1
	9-15	8.3	59.9	29.5	.32	.26	6.1
	15-20	8.0	57.4	25.0	.66	.54	12.8
	20-28	7.9	46.4	22.8	.58	.40	10.3
	28-34	7.9	48.4	21.8	.53	.36	7.3
	34-60	8.0	46.2	20.9	.41	.34	8.2
	60-78	8.4	66.8	40.9*	.00	.00	trace
	over 78	8.6	60.1	29.7	.00	.00	trace

*Water stood after centrifuging.

samples was variable. The horizons varied from 20.3 to 44.0 with two samples having free water on the surface after centrifuging. The surface soils varied from 20.3 on the Richfield silt loam I to 36.5 percent on the "Church" clay. These results indicated differences in the texture of these soils and some variation in texture at the different depths in the profiles. When the ME increased within a soil profile, the permeability in general was less.

Permeability. The permeability was quite variable. All samples analyzed varied from virtually 0 to .66 inches/hour in the first hour and from 0 to .54 inches/hour in the final hour. The total leachate in the six hour period varied from a trace to 12.8 inches.

The surface samples varied in permeability from .19 to .45 inches/hour the first hour and from .05 to .35 inches/hour in the final hour.

The total leachate in the six hour period varied from 2.5 inches in the Richfield silt loam I to 9.9 inches in the "Finn" silt loam. In all but five samples of the forty-two tested the rate of permeability was the same or lower the final hour than during the initial hour, and in these five cases only a small increase of leachate was measured the final hour. All of the profiles tested had a zone or layer of low permeability below the surface 6-12 inches in the soil profile.

Table 2 shows analytical data for soluble cations (calcium, magnesium, sodium, and potassium) and soluble anions (bicarbonate, sulfate, chloride, and nitrate).

Soluble Calcium. The soluble calcium in the saturation extract varied from 0 to 33.0 milliequivalents/liter and varied on the surface soils from 0 in the Ulysses silt loam to 29.5 m.e./liter in the "Finn". The percentage

Table 2. Laboratory analyses of the soluble cations and soluble anions in the saturation extract of 8 soil profiles in the Scott-Finney basin.

Soil description	Horizon depth in inches	Soluble cations m.e./liter				Soluble anions m.e./liter			
		Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO_3*
"Finn" silt loam	0-6	29.5	116.5	293.8	20.5	7.9	324.7	108.4	.3
	6-12	18.2	35.0	71.7	7.4	4.3	116.9	18.8	.5
	12-24	21.9	60.1	52.1	5.9	4.1	100.2	13.9	2.5
Ulysses silt loam	0-12	0.0	7.3	4.8	1.4	7.5	7.7	1.6	.6
	12-24	0.0	6.4	6.2	1.2	8.5	.8	1.3	.8
	24-36	16.8	23.4	14.7	4.3	11.0	49.7	10.1	.2
	36-48	6.8	23.0	14.2	3.4	13.5	37.7	3.9	trace
"Tennis" silty clay loam I	0-6	2.8	6.8	.9	1.1	9.6	3.4	1.5	trace
	6-12	4.3	4.7	.8	.6	9.6	4.2	.7	.2
	12-22	4.0	7.2	12.5	.7	6.2	15.4**	2.2	.6
	22-52	33.0	9.4	10.6	1.6	2.9	60.3	2.8	.8
	52-69	19.3	3.1	125.9	2.8	5.0	156.8	3.8	6.0
	69-80	18.4	18.8	85.7	2.4	6.5	110.5	2.0	6.0
"Church" clay	0-10	5.4	5.5	.9	2.5	7.2	4.7	.4	1.5
	10-20	4.8	2.3	6.7	.9	4.4	9.0	1.7	.6
	20-32	1.0	.8	5.8	.6	4.4	35.9	2.2	.6
	32-42	23.4	23.6	23.3	2.1	2.5	88.6	2.0	1.5
	42-52	19.9	35.7	50.8	2.8	3.1	98.9	2.8	4.0
"Tennis" silty clay loam II	0-4	5.6	11.4	6.3	1.6	11.0	18.8	2.1	.4
	4-10	0.0	9.6	10.7	.3	9.5	17.1	.8	trace
	10-14	0.0	7.1	9.2	1.6	7.6	14.8	1.2	1.5

Table 2. (concl.)

Soil description	Horizon depth in inches	Soluble cations m.e./liter				Soluble anions m.e./liter			
		Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO_3*
"Tennis" silty clay loam III	0-6	3.7	6.9	1.9	3.9	7.0	5.5	1.7	1.5
	6-18	4.5	2.1	3.2	1.3	4.7	45.6	2.4	2.5
	18-32	1.4	.8	12.7	.8	4.8	16.7	2.0	.8
	32-37	1.2	.7	22.6	.1	2.3	79.6	2.5	.6
	37-48	26.0	10.1	17.1	2.1	6.4	35.9	2.5	.6
Richfield silt loam (saline) I	0-6	2.5	7.1	3.3	5.0	7.0	6.0	2.5	1.5
	6-16	4.7	1.3	11.7	2.4	3.5	13.7	1.5	trace
	16-25	21.5	25.4	41.3	2.4	4.5	84.8	2.2	.8
	25-34	22.5	31.7	111.3	2.2	2.8	176.9	22.6	15.0
	34-48	21.9	68.3	258.4	4.9	3.7	310.9	48.9	15.0
	48-60	22.9	51.9	235.0	4.5	4.5	266.9	38.5	--
	60-72	23.3	41.7	184.4	3.8	4.2	206.5	33.7	3.0
	over 72	20.0	32.1	147.5	3.7	2.2	171.3	27.5	1.5
Richfield silt loam (saline) II	0-9	3.3	2.3	7.1	1.0	4.3	12.4	2.0	.8
	9-15	2.5	1.8	6.3	.9	5.4	5.5	2.4	.2
	15-20	28.6	9.6	3.5	2.6	4.7	41.5	2.0	.6
	20-28	26.9	25.9	17.8	4.6	4.3	78.8	3.5	.2
	28-34	25.8	24.1	38.0	3.9	3.2	70.6	3.6	trace
	34-60	24.0	22.4	34.3	3.4	2.8	75.4	6.5	1.5
	60-78	10.6	19.5	86.9	2.2	3.7	105.3	7.6	trace
	over 78	13.9	22.5	113.1	2.8	3.3	115.6	10.9	2.5

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*Approximately.

**Total soluble cation minus the sum of HCO_3, Cl and NO_3.

of soluble calcium in the saturation extract was comparatively low in most of these soils.

Soluble Magnesium. The soluble magnesium in the saturation extract varied from .7 to 116.5 m.e./liter and the surface soil varied from 2.4 in the Richfield silt loam II to 116.5 m.e./liter in the "Finn". Magnesium was the principle salt in the saturation extract of the surface soils in five of the seven soil profiles studied.

Soluble Sodium (SS). The soluble sodium in the saturation extract of these horizons varied from .8 m.e./liter to 293.8 m.e./liter and the surface soil varied from .9 m.e./liter in the "Tennis" to 293.8 in the "Finn". In general, sodium is the principle cation present in the saturation extract of these soils and where the EC was high the SS content was also high.

Soluble Potassium. The soluble potassium in these horizons varied from .1 to 20.5 m.e./liter. The surface soil varied from 1.0 in the Richfield II to 20.5 m.e./liter in the "Finn". Soluble potassium was found in lesser amounts than any of the other soluble cations analyzed.

Soluble Bicarbonate. Soluble bicarbonate anions were present in every sample tested. The results varied from 2.2 to 13.5 m.e./liter and the surface soils varied from 4.3 in the Richfield silt loam II to 11.0 in the "Tennis" silty clay loam II. These amounts were not high and the variability was less than the cations present in the saturation extract.

Soluble Sulfate. The soluble sulfate anion concentration varied from .8 to 324.7 m.e./liter and varied from 3.4 to 324.7 in the surface soils. Sulfate was the principle anion in the saturation extract.

Soluble Chloride. Soluble chlorides varied from .4 to 108.4 m.e./liter and the extremes were the same for all profiles and the surface soils in this analysis. Since chloride was not the principle anion in these soils, it should present no problem.

Soluble Nitrate. Nitrates did not form a significant portion of the soluble anions. They varied from a trace to 15.0 m.e./liter and the surface soil varied from a trace to 1.5 m.e./liter. Nitrates do not appear to be a problem in these soils.

Table 3 presents data from laboratory analyses of cation exchange capacity, exchangeable sodium, exchangeable sodium percentage, electrical conductivity of the saturation extract and sodium adsorption ratio.

Cation Exchange Capacity (CEC). The cation exchange capacity of these soils varied from 15.3 to 37.8 m.e./100 grams of soil. The lowest exchange capacity for a surface soil was 15.6 for the "Finn", and 37.8 was the highest in the "Church". The exchange capacity was related to the ME, and shows a rather large spread from the high to the low.

Exchangeable Sodium Percentage (ESP). This relationship was dependent on the exchangeable sodium and the exchange capacity (ES x 100/CEC). A variability from 0 to 42 percent was noted in these samples.

Electrical Conductivity (EC). The electrical conductivity of the saturation extract varied from .7 to 31.6 mmhos/cm. in all the horizons analyzed. The surface soils varied from .9 in the Richfield silt loam II to 31.6 in the "Finn". These results indicated the wide variation in the amounts of soluble cations that were present in these soils. The EC tended to increase with depth in the profile. The "Finn" silt loam was an exception to this as the surface soil was higher in soluble salts.

Sodium Adsorption Ratio (SAR). This is a ratio of the concentration of sodium to the concentration of calcium and magnesium in the saturation extract

Table 3. Laboratory analyses of the cation exchange capacity, exchangeable sodium, electrical conductivity, exchangeable sodium percentage, and the sodium adsorption of 8 soil profiles in the Scott-Finney basin.

Soil description	Horizon depth in inches	Exchange capacity m.e./100 gm	Exchangeable Na m.e./100 gm	Exchangeable Na percentage	EC of* saturation extract mmhos/cm.	SAR** of saturation extract
"Finn" silt loam	0-6	15.6	2.9	19.1	31.6	34.7
	6-12	19.9	1.4	7.5	10.5	13.9
	12-24	21.1	1.4	7.1	9.2	8.1
Ulysses silt loam (1 to 3%)	0-12	17.2	.2	1.7	1.3	2.5
	12-24	19.6	.4	2.5	1.2	3.4
	24-36	18.6	.1	.4	6.1	3.2
	36-48	19.0	.3	1.8	5.0	3.6
"Tennis" silty clay loam I	0-6	30.2	.2	.9	1.1	.4
	6-12	29.0	.3	1.0	1.0	.4
	12-22	24.6	1.9	7.9	1.9	5.3
	22-52	28.2	0.0	0.0	3.1	2.3
	52-69	25.7	7.7	30.1	11.7	37.5
	69-80	24.7	6.4	25.9	9.6	19.9
"Church" clay	0-10	37.8	.1	.5	1.2	.4
	10-20	31.7	.1	.5	.7	3.5
	20-32	24.2	1.1	4.7	.7	6.0
	32-42	29.1	1.7	5.9	4.7	4.8
	42-52	30.3	5.8	19.5	8.7	9.6
"Tennis" silty	0-4	22.7	.4	2.2	1.8	2.1
	4-10	28.1	2.0	7.2	1.2	4.8
	10-14	31.4	4.7	14.9	1.2	4.9

Table 3. (concl.)

Soil description	Horizon depth in inches	Exchange capacity m.e./100 gm	Exchangeable Na m.e./100 gm	Exchangeable Na percentage	EC of* saturation extract mmhos/cm.	SAR** of saturation extract
"Tennis" silty clay loam III	0-6	21.4	3.1	14.7	1.3	.8
	6-18	29.5	3.6	12.4	.7	1.8
	18-32	24.4	3.3	13.5	1.0	11.7
	32-37	24.8	.4	1.6	2.2	22.9
	37-48	24.6	9.1	37.2	3.9	4.0
Richfield silt loam (saline) I	0-6	16.2	2.7	17.0	1.4	1.5
	6-16	24.8	1.1	4.7	.8	6.7
	16-25	20.9	1.6	7.8	7.4	8.5
	25-34	20.1	8.4	42.0	14.2	21.3
	34-48	21.1	7.7	36.8	25.2	38.4
	48-60	20.6	7.9	38.8	23.2	38.4
	60-72	21.8	7.0	32.1	18.6	32.3
	over 72	22.5	6.1	27.1	15.7	28.8
Richfield silt loam (saline) II	0-9	19.7	.1	.3	.9	4.1
	9-15	25.5	.5	2.1	.8	4.2
	15-20	19.4	.6	3.2	3.3	.8
	20-28	18.6	.5	3.1	5.0	3.4
	28-34	15.3	0.0	0.0	5.0	5.3
	34-60	16.5	1.9	11.8	6.7	7.1
	60-78	24.5	5.5	22.5	11.3	22.4
	over 78	20.5	5.5	26.9	11.3	26.5

*Electrical conductivity at 25 degrees C.

**Sodium adsorption ratio.

(NA/ $\overline{\text{/Ca + Mg) /2}}$. The ratio varied on these soils from .4 to 38.4.

Table 4 shows the results of analyses for gypsum, exchangeable sodium ratio, insoluble carbonates and classification on saline and alkali properties.

Gypsum. Gypsum was present in nearly all of these soils but varied from 0 to 14.5 m.e./100 grams of soil.

Exchangeable Sodium Ratio (ESR). This ratio is similar to the ESP but is calculated as ES/CEC-ES. This ratio varied from 0 to .72.

Insoluble Carbonates. Insoluble carbonates were present in large amounts in all of the soils deeper than the first foot and were variable above that depth.

Classification. A normal arid soil has been defined by the U. S. Salinity Laboratory (1947) as a soil with an electrical conductivity of the saturation extract (EC) of less than 4 mmhos/cm. and an exchangeable sodium percentage (ESP) of less than 15. Twenty horizons of the forty-two analyzed were in this class.

A saline soil is defined as a soil with an EC of more than 4 mmhos/cm. and an ESP of less than 15. Nine horizons were in this class.

A saline-alkali soil is defined as a soil that has an EC of more than 4 mmhos/cm. and an ESP of more than 15. Eleven horizons were in this class.

A non-saline-alkali soil is defined as a soil that has an EC of less than 4 mmhos/cm. and an ESP of more than 15. Only two of these horizons were in this class.

Table 4. Gypsum content, insoluble carbonates, exchangeable sodium ratio, and chemical classification of 8 soil profiles in the Scott-Finney basin.

Soil description	Horizon depth in inches	Gypsum m.e./100 gm	ESR*	Insoluble carbonate test**	Classification***
"Finn" silt loam	0-6	8.7	.22	0	saline-alkali
	6-12	.2	.08	0	saline
	12-24	10.1	.07	+	saline
Ulysses silt loam	0-12	.1	.01	+++	normal arid
	12-24	.1	.02	+++	normal arid
	24-36	.0	.00	+++	saline
	36-48	.3	.01	+++	saline
"Tennis" silty clay loam I	0-6	.1	.00	++	normal arid
	6-12	.1	.01	+++	normal arid
	12-22	.1	.07	+++	normal arid
	22-52	14.5	.00	+++	normal arid
	52-69	11.1	.43	+++	saline-alkali
	69-80	13.5	.34	+++	saline-alkali
"Church" clay	0-10	.1	.00	++	normal arid
	10-20	.1	.00	+++	normal arid
	20-32	.1	.04	+++	normal arid
	32-42	2.8	.06	+++	saline
	42-52	11.8	.24	+++	saline alkali
"Tennis" silty clay loam II	0-4	.1	.02	0	normal arid
	4-10	.2	.07	0	normal arid
	10-14	.1	.17	+	normal arid

Table 4. (concl.)

Soil description	Horizon depth in inches	Gypsum m.e./100 gm	ESR*	Insoluble carbonate test**	Classification***
"Tennis" silty clay loam III	0-6	.1	.17	+	normal arid
	6-18	.1	.14	+++	normal arid
	18-32	.1	.15	+++	normal arid
	32-37	4.5	.01	+++	normal arid
	37-48	.2	.59	+++	non-saline alkali
Richfield silt loam (saline) I	0-6	.1	.20	0	non-saline alkali
	6-16	.1	.05	0	normal arid
	16-25	5.8	.08	+++	saline
	25-34	4.8	.72	+++	saline-alkali
	34-48	14.0	.58	+++	saline-alkali
	48-60	14.0	.63	+++	saline-alkali
	60-72	2.7	.47	+++	saline-alkali
	over 72	.3	.37	+++	saline-alkali
Richfield silt loam (saline) II	0-9	.1	.00	0	normal arid
	9-15	.1	.02	+	normal arid
	15-20	13.0	.03	+++	normal arid
	20-28	5.1	.03	+++	saline
	28-34	8.2	.00	+++	saline
	34-60	10.0	.13	+++	saline
	60-78	.1	.29	+++	saline-alkali
	over 78	0.0	.36	+++	saline-alkali

*Exchangeable sodium ratio (ES/CEC-ES).

**Qualitative test.

***Classified as in the U. S. Salinity Laboratory Handbook No. 60.

DISCUSSION

Application of Findings to Use of Soil in the Scott-Finney Basin

The "Finn" silt loam, "Tennis" silty clay loam and "Church" clay soils are located in basins or on the edges of the basins or blowouts where free water stands in times of flood. These soils were developed in saline lacustrine deposits. The surface soil in "Church" clay is heavier than the "Tennis" silty clay loam, and the surface soil of "Tennis" is heavier than the "Finn" silt loam. In other ways all of these soils are similar; somewhat poorly drained, intrazonal soils having fine textured subsoils.

"Finn" Silt Loam. The "Finn" silt loam soil is found around intermittent lakes or basins, which receive runoff from higher areas in Finney County and is of lighter surface soil texture than any of the other profiles sampled with the possible exception of Ulysses silt loam. The water table of the profile sampled in this study was at twenty-four inches when this sample was taken and the native vegetation was predominately salt grass. The surface twenty-four inches of this soil were higher in total soluble cations, sodium adsorption ratio and exchangeable sodium percentage than any of the other soils studied. The above factors were highest at the surface and decreased with depth in the profile, showing a high accumulation of salts with much surface crusting. The salts evidently came up from the shallow water table and evaporation caused the high accumulation of salts at the surface. The saturation extract of the whole profile was above an EC of 4 mmhos/cm. and the ESP was above 15, which was high enough to affect yields of most crops. The top foot had no alkaline earth carbonates present and only small amounts were present in the next foot.

Permeability was good, but since the water table was near the surface and the surface drainage was poor, reclamation would be a problem unless artificial drainage was provided. The salt concentration goes up and down with the water table. In dry periods, when the water table is down, some of these soils are irrigated. A drainage ditch has been constructed through the area and helps in the drainage of some of these soils. Crop production is somewhat restricted, but satisfactory in dry periods for production of grain sorghums and alfalfa.

"Tennis" Silty Clay Loam. "Tennis" silty clay loam consists of dark, moderately fine textured, calcareous soils developed on lacustrine deposits on benches around and slightly higher than the intermittent lakes in the Scott-Finney Basin. They receive runoff from higher areas and have poor surface drainage, though the soils are moderately well drained internally. Depth to the water table ranges from 5 to 20 feet in years of normal rainfall but during periods of excessive rainfall the water table may rise to within a foot of the surface. "Tennis" is darker in color and finer textured throughout the profile than the Ulysses silt loam. The soil conservation service has found the "Tennis" soil to be generally calcareous to the surface but was non-calcareous to a depth of fifteen inches in a few profiles. "Tennis" is found predominately on slopes of less than 1 percent and the native vegetation is salt grass and western wheatgrass.

In profile samples analyzed in this study, "Tennis" did nothave an EC of over 4.0 until a depth of four feet was reached. The ESP was not above 15 until a depth of 3 to 4 feet was reached. This indicates these soils are satisfactory for crop production from a soluble salt and exchangeable sodium standpoint (U. S. Salinity Laboratory, 1954). Permeability is satisfactory for soils of this texture and if the water quality is acceptable, no particular problems should be encountered in irrigation. Except for the danger of flood, crop production is satisfactory using such crops as alfalfa, wheat and grain sorghum.

"Church" Clay. "Church" clay consists of calcareous, somewhat poorly drained, intrazonal soils of fine textured surface and subsoil. This soil has developed in saline, lacustrine deposits on the floor of the Whitewoman Basin within the Scott-Finney Basin physiographic area, just south of Scott City, Kansas. Runoff from surrounding areas and from Whitewoman Creek, which drains parts of Scott, Wichita, Greeley and Wallace counties, empties into the Whitewoman Basin and causes ponding over much of the area each spring. This basin at one time (1951) was under 8 to 12 feet of water in the lower lying areas. External and internal drainage is poor. Depth to the water table ranges from 2 to 20 feet. The native vegetation is predominately salt grass and western wheatgrass.

In the profile sample analyzed in this study, "Church" clay had an EC of less than 4.0 to a depth of 32" and an ESP of less than 15 to a depth of 42". Much of the area is cultivated with grain sorghum being the principle crop. Some of the area is being irrigated and except for periods of flooding, the crops raised (mainly sorghums) are satisfactory.

Ulysses Silt Loam. Ulysses silt loam consists of calcareous, well-drained, medium-textured surface and subsoil with no B horizon. This soil is usually on a 1 to 3 percent slope and eroded. The native vegetation is western wheat grass and buffalo grass.

The profile sample analyzed in this study had a value of less than 4.0 for the EC to a depth of 24" and an ESP value of less than 15 to a depth of 48". The crops grown on this soil in the area are mostly alfalfa, wheat and grain sorghums. No adverse symptoms were noted that could be attributed to salts or sodium.

Richfield Silt Loam (saline). The Richfield silt loam (saline) samples in this study were taken on the extreme eastern limit of the basin at the Garden City Experiment Station about fifteen feet on each side of a fence line separating an irrigated alfalfa field and virgin salt grass sod. The alfalfa field was broken and irrigated for about twelve years at the time the sample was taken. The irrigation water was analyzed at the station and shows it to have an electrical conductivity of 2000 micromhos per centimeter and a soluble sodium percentage of 37.6, which puts the water in a doubtful to unsuitable irrigation rank. However, the soil was satisfactory in production of crops and the analysis of the two samples show a great improvement in the irrigated soil.

Effect of Irrigation on Richfield Silt Loam (Saline)

The profile samples analyzed were higher in total salts than any of the other soils throughout the area other than the "Finn". The EC was under 4.0 to a depth of 16 inches on the non-irrigated soil sample of Richfield and the surface soil had an ESP over 15.

The sample of Richfield that had been irrigated over a 12 year period had an EC of less than 4.0 to a depth of 20 inches and the ESP was not above 15 until a depth of five feet was reached. In general, the permeability was satisfactory.

The EC of the whole profile of the irrigated soil was less than that of the non-irrigated soil at each depth (Plate I, Fig. 1). The SAR was lower in the whole profile except for the surface soil and at a depth of 75 inches (Plate I, Fig. 2). The ESP was lower in the whole profile of the irrigated soil to a depth of 75 inches and was higher at that depth than the non-irrigated soil (Plate II, Fig. 3). Also, the soluble sodium, soluble sulfate, soluble chloride and soluble magnesium were greatly reduced in the irrigated soil, especially below a depth of twenty inches (Plate 2, Fig. 4; Plate 3, Figs. 5 and 6; Plate 4, Fig. 7).

The changes in the seven relationships presented above of irrigated and non-irrigated Richfield soils were very similar. In the irrigated soil the values were lowest at the surface and gradually increased with depth in the soil profile. In the first few inches of the virgin non-irrigated soil, the values were low, but these values increased rapidly to a peak at the 30 to 50 inch depth, where they started down. At the 70 to 80 inch depth both soils approached the same values. These values are not of the same magnitude for each relationship, but are taken at each profile depth.

With soluble calcium (Plate 4, Fig. 8), soluble potassium, soluble bicarbonate and soluble nitrate, the changes were small and variable between the irrigated and non-irrigated profiles.

The pH was about the same in both profiles at depths of zero to twenty inches and below eighty inches. In the twenty to eighty inch zone the irrigated soil had a much lower pH than the non-irrigated (Plate V, Fig. 9).

The final and total permeability of the disturbed soil samples of the irrigated soil was greater than on the non-irrigated until a depth of about 45 inches was reached and then the permeability of the irrigated soil was less (Plate V, Fig. 10).

EXPLANATION OF PLATE I

Fig. 1. Comparison of EC of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

Fig. 2. Comparison of SAR of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

PLATE I

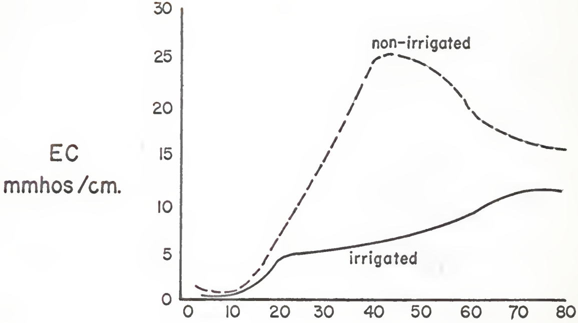

FIG. 1.

Depth in Inches

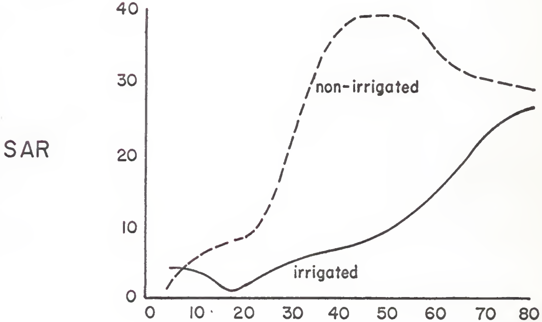

FIG. 2

Depth in Inches

EXPLANATION OF PLATE II

Fig. 3. Comparison of ESP of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

Fig. 4. Comparison of SS of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

PLATE II

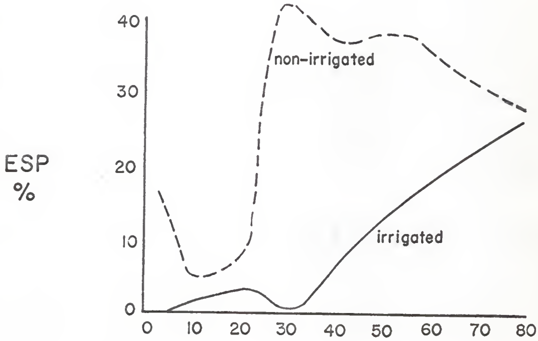

FIG. 3

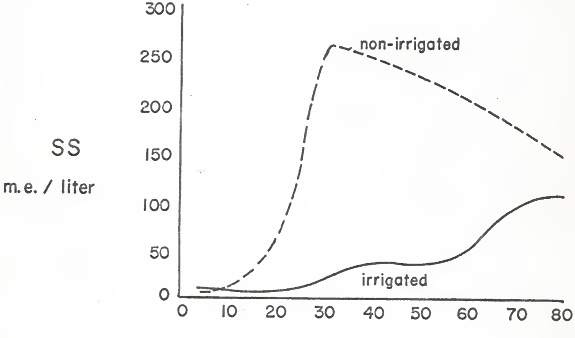

FIG. 4

EXPLANATION OF PLATE III

Fig. 5. Comparison of soluble sulphate of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

Fig. 6. Comparison of soluble chloride of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

PLATE III

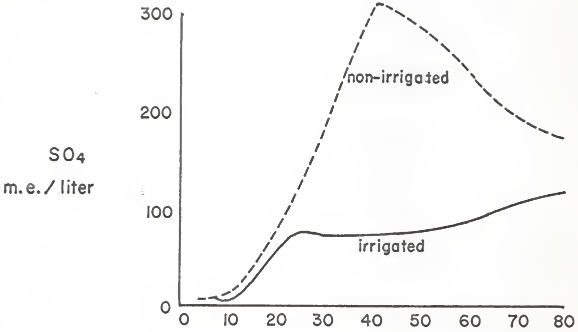

FIG. 5

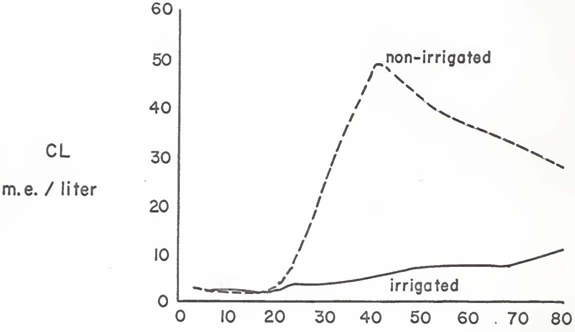

FIG. 6

EXPLANATION OF PLATE IV

Fig. 7. Comparison of soluble magnesium of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

Fig. 8. Comparison of soluble calcium of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

PLATE IV

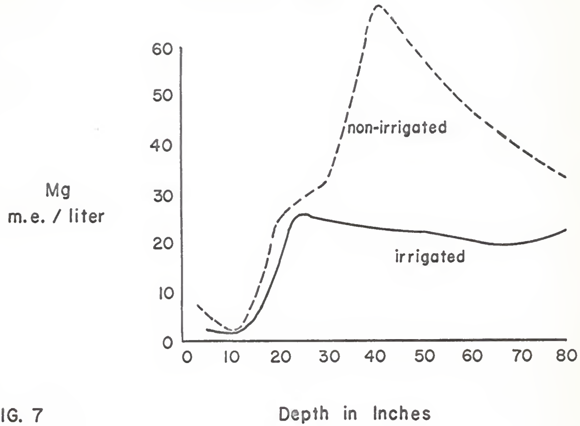

FIG. 7

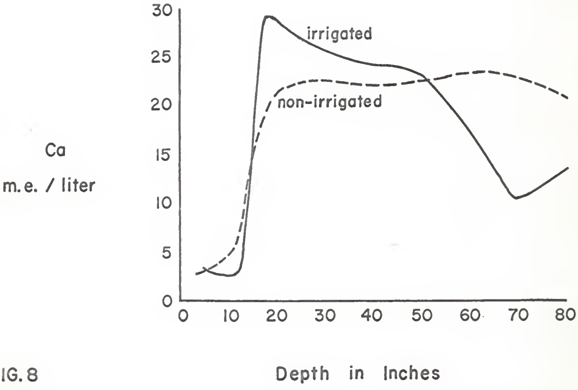

FIG. 8

EXPLANATION OF PLATE V

Fig. 9. Comparison of pH of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

Fig. 10. Comparison of rate of permeability of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

PLATE V

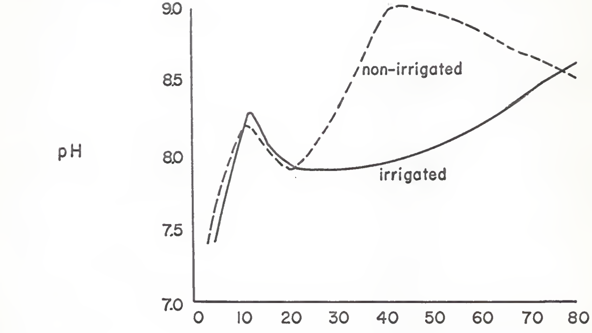

FIG. 9

Depth in Inches

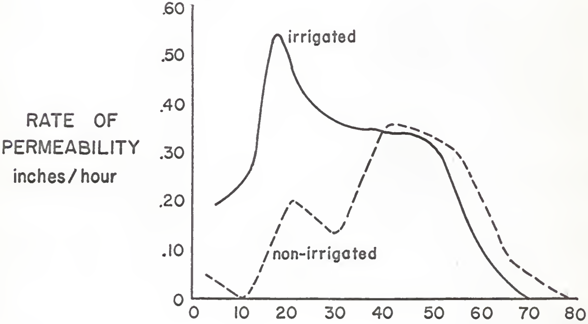

FIG. 10

Depth in Inches

The moisture equivalent and the saturation percentage of the irrigated soil was lower until a depth of 70 inches was reached. At the surface and again at the 80 inch depth both samples were about the same (Plate VI, Figs. 11 and 12). Water stood after centrifuging at the 69 inch depth of the irrigated soil and a second test produced the same results which indicates this was not a true point.

In this particular analyses, irrigation was of great benefit in lowering the concentration of soluble salts and in lowering the ESP. Whether continued irrigation with this particular water will further lower the EC and the ESP is doubtful. There is no reason to believe that continued irrigation will further inhibit plant growth so long as the water table does not rise and the drainage remains satisfactory.

Using the prediction of Jacobs and associates (1961), this soil is still not at equilibrium with the irrigation water. However, in this case the EC and ESP of the soil were decreasing with time while the soils they studied, the EC and ESP were increasing with time.

Interrelationships of Laboratory Analyses

All of the samples analyzed in the basin were alike in many ways. The EC correlated very closely with the TSC (correlation coefficient .99), Table 5. The exchangeable sodium correlated very closely with the ESR (.98). The TSC also correlated very closely with the soluble sodium (.98). This indicates that although the soils varied in the amount of TSC, sodium made up a nearly constant portion of the cations present.

The CEC correlated closely with the ME of these soils (.82).

The SAR correlated closer with the ESP (.75) in this study than with

EXPLANATION OF PLATE VI

Fig. 11. Comparison of ME of irrigated and non-irrigated profiles of Richfield silt loam (saline).

Fig. 12. Comparison of SP of irrigated and non-irrigated soil profiles of Richfield silt loam (saline).

PLATE VI

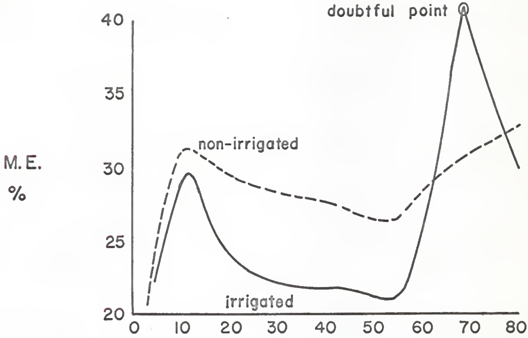

FIG. 11

Depth in Inches

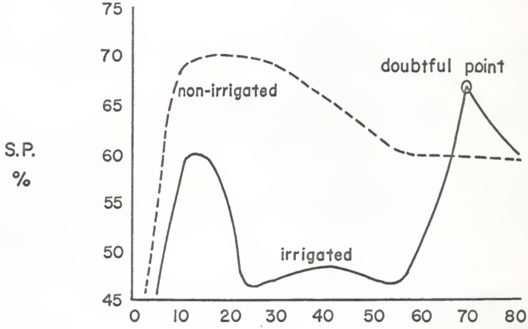

FIG. 12

Depth in Inches

Table 5. Correlation coefficients of several relationships in soils of the Scott-Finney Basin.

y	x	b	Y	r*
ES	SAR	.142	1.18 + .142x	.59
ES	TSC	.026	1.46 + .026x	.68
ESP	TSC	1.22	6.02 + 1.22x	.71
ESP	SAR	.796	3.21 + .796x	.75
ME	CEC	.952	6.99 + .952x	.82
SS	TSC	1.47	11.86 + 1.47x	.98
ESR	ES	.067	-.021 + .068x	.98
TSC	EC	13.73	-2.23 + 13.7x	.99

*All relationships are significant at the 1% level.

the TSC (.71). However, TSC was better correlated to ES (.68) than was SAR (.59).

Other workers in Kansas have found somewhat better correlations between ESP and SAR (.956 by Dixon, 1960; .81 by Naddih, 1960; and .81 by Jacobs and associates, 1961). However, these results were taken on well drained soils of Western Kansas and the soils of the Scott-Finney Basin are poorly drained, particularly on the surface. Other workers have found similar relationships (U. S. Salinity Laboratory, 1954; Longenecker & Lyerly, 1959).

SUMMARY AND CONCLUSIONS

Results of this study may be summarized as follows:

1. The soils of the basin were variable in texture. These soils varied from silt loam to clay at the surface. The subsoils were fairly

heavy, but variable. The heavier soils were usually developed on the floors of the basins or lakes within the physiographic area of the Scott-Finney Basin, and the soils became lighter as they moved up on the perimeters of these lakes.

2. The soils of the area were variable in the amounts of salts that had accumulated, but the composition of these salts was similar, i.e.:

   a. There was a high correlation between total soluble cations and soluble sodium.
   b. Sodium was the principle soluble cation of these samples.
   c. Sulfate was the principle anion of these samples.
   d. The amount of soluble magnesium was higher in general than soluble calcium.
   e. Gypsum was present in nearly all samples, but was variable in amounts.
   f. Insoluble carbonates were present in all profiles, but varied in amounts in the surface twenty-four inches.

3. About one-half of the horizons studied were in the normal arid classification with an electrical conductivity of the saturation extract of less than 4.0 mmhos/centimeter and an exchangeable sodium percentage of less than 15.

The rest of the horizons were primarily in the saline and/or saline-alkali classification. Except for the "Finn" soil, these horizons were all located in the lower portions of the profile.

Only two horizons were in the non-saline-alkali classification; one at the surface, and the other deep in the profile. Since both occurred only at one depth in the profile, they do not appear to be a major problem in the area.

4. In the Richfield (saline) soils in this study the one that was irrigated for twelve years with the doubtful to unsuitable quality water was greatly improved. The electrical conductivity, exchangeable sodium percentage, sodium adsorption ratio, soluble sodium, soluble magnesium, soluble sulfate, and soluble chloride in the soil profile were greatly lowered in the irrigated soil.

The moisture equivalent, saturation percentage, and cation exchange capacity were lowered in the irrigated soil to a depth of about six feet where the increase on the irrigated soil was rapid.

Permeability was improved to a depth of four feet by irrigation but below that point the irrigated soil was less permeable than the non-irrigated soil.

5. If the other soils respond like the Richfield to use of irrigation water, no problems should be encountered in reclaiming them. Though the exchangeable sodium percentage was high in some of these samples, it wasn't as high in the other soils as in the Richfield. In the Richfield soil, sodium appeared to be replaced with magnesium and/or calcium, and was leached down or out of the soil profile, when irrigated. Since the other soils were similar in chemical makeup there is no reason to believe they will not respond similarly if drainage is provided. If they are not well drained, the installation of a drainage system would be needed with the addition of water.

6. A number of significant positive correlations were found. These were: exchangeable sodium with sodium adsorption ratio and total soluble cations; exchangeable sodium percentage with total soluble cations and

sodium adsorption ratio; moisture equivalent with cation exchange capacity; soluble sodium with total soluble cations; exchangeable sodium ratio with exchangeable sodium; and total soluble cations with electrical conductivity.

7. Further study on more soil and water samples and study on the varying water table depth to salt accumulation is needed to answer some of the salt problems in the area.

ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to his major instructor, Dr. R. V. Olson, Head, Department of Agronomy, for his guidance and help in preparing this manuscript.

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APPENDIX

Profile Descriptions

"Tennis" silty clay loam

A_1	0-6"	Dark grayish brown heavy silty clay loam; moderate fine granular; hard; friable; numerous worm casts; calcareous; clear smooth boundary to
AC_1	6-12"	Gray heavy silty clay loam; moderate fine granular and weak fine subangular blocky; very hard; firm; numerous worm casts; calcareous; clear smooth boundary to
AC_2	12-22"	Light gray heavy silty clay loam; moderate fine granular and weak fine subangular blocky; very hard; firm; worm casts not as numerous as in above horizon; calcareous; gradual smooth boundary to
C_1	22-33"	Light brownish gray heavy silty clay loam; moderate very fine subangular blocky; very hard; firm; few worm casts; calcareous; few fine threads of lime; gradual smooth boundary to
C_{1cs}	33-54"	Same as above except this horizon contains crystals of calcium sulphate; gradual smooth boundary to
C_{2cs}	54-78"	Light brownish gray mixed with light gray heavy silty clay loam; weak granular; hard; friable; lower part of horizon is peppered with black concretions about one mm. in diameter; few crystals of calcium sulphate; diffuse boundary to
C_3	78-92"	White mixed with light brownish gray silty clay loam; weak granular; hard; friable; calcareous.

Richfield silt loam (Saline)

A_p	0-5"	Dark grayish brown heavy silt loam; weak granular with some weak platy in lower two inches; slightly hard; friable; noncalcareous; rests with plow slice contact on
B_{21}	5-10"	Dark grayish brown silty clay loam; weak fine prismatic breaking to moderate very fine subangular blocky; hard; firm; continuous clay skins; worm casts; non-calcareous; clear smooth boundary to
B_{22}	10-18"	Grayish brown heavy silty clay loam; weak fine prismatic breaking to moderate fine subangular blocky; very hard; firm; continuous clay skins; calcareous; threads and few threads and few concretions of lime; clear smooth boundary to
B_{3ca}	18-27"	Light brownish gray silty clay loam; moderate fine subangular blocky; hard; firm; calcareous; threads and few soft concretions of lime; gradual boundary to
C_{cs}	27-37"	Light gray light silty clay loam; weak fine subangular blocky; slightly hard; friable; calcareous; numerous threads of calcium sulfate; gradual boundary to
C_{ca}	37-60"	Light gray heavy silt loam; weak granular; slightly hard; friable; black concretions smaller than a pin head; calcareous; lime concretions.

"Finn" silt loam

A_1	0-5"	Grayish brown silt loam; weak granular; slightly hard; friable; worm casts; non-calcareous; abrupt smooth boundary to

A_2	5-7"	Light brownish gray silt loam; weak granular; slightly hard; friable; non-calcareous; abrupt smooth boundary to
B_{21}	7-10"	Dark grayish brown heavy clay loam; moderate fine columnar breaking readily to moderate very fine and fine subangular blocky; very hard; firm; continuous clay skins; pockets of worm casts; few root channels are filled with material from the A2 horizon; non-calcareous; clear smooth boundary to
B_{22}	10-14"	Grayish brown heavy clay loam; moderate very fine subangular blocky; very hard; firm; clay skins; worm casts; non-calcareous; clear smooth boundary to
B_{3cs}	14-19"	Brown clay loam; moderate fine subangular blocky; hard; firm; few worm casts; mixture of calcareous and non-calcareous materials; few soft lime concretions; numerous threads of calcium sulfate; clear smooth boundary to
C_{cs}	19-36"	Pale brown clay loam; weak very fine subangular blocky; hard; firm; calcareous; few soft lime concretions; numerous threads of calcium sulfate; gradual smooth boundary to
C_{ca1}	36-66"	Pale brown light clay loam; weak granular; slightly hard; friable; calcareous; concretions and threads of lime; gradual boundary to
C_{ca2}	66-132"	Pale brown heavy loam or light clay loam grading to silt loam below 90"; color is variable; calcareous; concretions and threads lime.

Ulysses silt loam, 1 to 3% slopes, eroded.

A_p	0-6"	Grayish brown silt loam; weak granular; hard; friable; calcareous; rests with plow slice contact on
C_{ca1}	6-10"	Pale brown silt loam; weak granular; slightly hard; friable; porous; calcareous; small lime concretions; clear smooth boundary to
C_{ca2}	10-60"	Very pale brown silt loam; massive; porous; calcareous; fine soft lime concretions.

"Church" clay

A_1	0-2"	Gray heavy silty clay loam; powdery; plastic; calcareous; this surface layer is high in organic matter; rest on
A_1	2-9"	Gray light clay; moderate fine irregular blocky; extremely hard; very firm; surface of peds are shiny; calcareous; grades within 2 inches to
AC	9-17"	Gray clay; massive to compact; extremely hard; very hard; very firm; strongly calcareous; grades within 3 inches to
C_1	17-34"	Gray olive gray clay; massive; very hard; very firm; strongly calcareous; few scattered salt crystals; grades to
C_2	34-42"	Light gray light clay; massive; very hard; very firm; strongly calcareous; nests and threads of crystalline salts.

A STUDY OF SALINE AND ALKALI SOILS IN THE SCOTT-FINNEY BASIN AREA OF WESTERN KANSAS

by

ROY EMERSON GWIN

B. S., Kansas State University, 1943

AN ABSTRACT OF A MASTER'S THESIS

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MASTER OF SCIENCE

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1963

Saline and alkali soil conditions reduce the value and productivity of many areas in the United States.

The soils studied for the research reported in this thesis were from the Scott-Finney Basin, a large depressional area beginning south of Scott City, Kansas, in Scott County and running south to the Arkansas River Valley in the northwestern portion of Finney County. The basin is the flood basin of the Whitewoman Creek, and has had a buildup of salts over a long period of time. Since irrigation is practiced in the area, a knowledge of the nature of these soils, their reaction, the amounts and kinds of salts present, permeability, cation exchange capacity, gypsum content, and other factors is important. This information may be used as a guide to further study of the effect continued irrigation may have on these soils in relation to plant growth and of the hazards involved.

Eight profile samples were taken of the major soil types at random over the area. Samples were taken for each homogeneous horizon between the surface and the water table or to a depth where no change occurred for several inches. There were forty-two samples analyzed.

Most analytical procedures were taken from the publication "The Diagnosis and Improvement of Saline and Alkali Soils," published in 1947 by the U. S. Salinity Laboratory, Riverside, California, with some modification.

Results of this study may be summarized as follows:

1. The soils of the basin were variable in texture. These soils varied from silt loam to clay at the surface. The subsoils were fairly heavy, but variable. The heavier soils were usually developed on the floors of the basins or lakes within the physiographic area of the Scott-Finney Basin, and the soils became lighter as they moved up on the perimeters of these

lakes.

2. The soils of the area were variable in the amounts of salts that had accumulated, but the composition of these salts was similar, i.e.,

   a. There was a high correlation between total soluble cations and soluble sodium.
   b. Sodium was the principle soluble cation of these samples.
   c. Sulfate was the principle anion of these samples.
   d. The amount of soluble magnesium was higher in general than soluble calcium.
   e. Gypsum was present in nearly all samples, but was variable in amounts.
   f. Insoluble carbonates were present in all profiles, but varied in amounts in the surface twenty-four inches.
   g. About one-half of the horizons studied were in the normal arid classification with an electrical conductivity of the saturation extract of less than 4.0 mmhos/centimeter and an exchangeable sodium percentage of less than 15.

The rest of the horizons were primarily in the saline and/or saline-alkali classification. Except for the "Finn" soil, these horizons were all located in the lower portions of the profile.

Only two horizons were in the non-saline-alkali classification; one at the surface, and the other deep in the profile. Since both occurred only at one depth in the profile, they do not appear to be a major problem in the area.

4. In the Richfield (saline) soils in this study the one that was irrigated for twelve years with the doubtful to unsuitable quality water was

greatly improved. The electrical conductivity, exchangeable sodium percentage, sodium adsorption ratio, soluble sodium, soluble magnesium, soluble sulfate, and soluble chloride in the soil profile were greatly lowered in the irrigated soil.

The moisture equivalent, saturation percentage, and cation exchange capacity were lowered in the irrigated soil to a depth of about six feet, where the increase on the irrigated soil was rapid.

Permeability was improved to a depth of four feet by irrigation; but below that point the irrigated soil was less permeable than the non-irrigated soil.

5. If the other soils respond like the Richfield to use of irrigation water, no problems should be encountered in reclaiming them. Though the exchangeable sodium percentage was high in some of these samples, it wasn't as high in the other soils as in the Richfield. In the Richfield soil, sodium appeared to be replaced with magnesium and/or calcium, and was leached down or out of the soil profile, when irrigated. Since the other soils were similar in chemical makeup there is no reason to believe they will not respond similarly, if drainage is provided. If they are not well drained, the installation of a drainage system would be needed with the addition of water.

6. A number of significant positive correlations were found. These were: exchangeable sodium with sodium adsorption ration and total soluble cations; exchangeable sodium percentage with total soluble cations and sodium adsorption ratio; moisture equivalent with cation exchange capacity; soluble sodium with total soluble cations; exchangeable sodium ratio with exchangeable sodium; and total soluble cations with electrical conductivity.

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