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Effect of Slope and Exchangeable Sodium on Run-off, Erosion and Electrical Conductivities of Leachates from Cheyenne Sandy Loam Soil

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EFFECT OF SLOPE AND EXCHANGEABLE SODIUM ON RUN-OFF, EROSION AND ELECTRICAL CONDUCTIVITIES OF LEACHATES FROM CHEYENNE SANDY LOAM SOIL

BY

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THE EFFECT OF SLOPE AND EXCHANGEABLE SODIUM ON RUN-OFF, EROSION AND ELECTRICAL CONDUCTIVITIES OF LEACHATES FROM CHEYENNE SANDY LOAM SOIL

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor

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INTRODUCTION

The textbooks of soil science, discussing the effect of degree of slope on surface run-off and erosion, mention that the lowest amount of run-off occurs at (0) slope. As the degree of slope increases, the amount of surface run-off and erosion also increases. Different experiments report that an increase in the degree of slope is accompanied by an increase in surface run-off and erosion. However, in one experiment, Duley and Kelly (2) report that the degree of slope has only a slight effect on infiltration of water. Several experiments have been done on the effect of exchangeable sodium on the physical properties of soils. These experiments indicate that increase in the amount of exchangeable sodium caused a decrease in water permeability and thus water intake.

The objective of the following experiments was to combine these two different variables in a study on run-off and erosion. An attempt has been made to find out the influence of slope on surface run-off, erosion, and infiltration of water in the soil, at three levels of exchangeable sodium, and at the same time to see if the results of former experiments can be verified.

REVIEW OF LITERATURE

Effect of Degree of Slope on Run-Off and Erosion

A number of experiments have been done concerning the effect of slope on surface run-off and soil erosion. In an experiment by Duley and Hays (1) determinations of run-off and erosion were made by means of water applied to soil artificially to simulate rainfall. In one case, a tank which could be tilted so as to vary the degree of slope of the surface was filled with soil. In another test the plots were placed at different angles on a hillside so that slope ranged from level to that of the steepest part of the hill.

Run-off was found to increase rapidly as the slope increased from 0% to 3%. The increase in run-off was then very slight for any increase in slope beyond 3%.

The soil erosion increased very gradually until the slope was about 4%, then the increase was found to be more rapid up to about 7% or 8%, after which there was a greater increase in the rate at which the soil was removed from the plots. The amount of run-off required to erode one pound of soil decreased rapidly as the slope increased from 1% up to about 10%, after which the decrease was gradual and slight. Soil erosion is shown to depend not merely on the

physical properties of the soil, but also on the degree of slope and other factors.

In another experiment Duley and Kelley (2) in connection with investigation of run-off and erosion in the Great Plains, report that on four soils tested different slopes and different rates of water application were used. There was a tendency for the amount of water intake to decrease slightly with increase in slope. The greater intake was found to be on the more gentle slope, particularly the 2% slope or less.

According to Duley and Hays (1), the degree of slope had only a slight effect on infiltration.

Neal (4), reporting on the degree of slope and rainfall on run-off and soil erosion, stated that the highest rate of run-off during a rain occurred on a 16% slope when 4.04 inches of rain per hour were applied. For the slopes of 1% to 16% inclusive, the rate of infiltration was an inverse function of the slope.

It was found that slopes above 1% apparently had little or no effect on the percentage of run-off. On 8% slope a few small gullies occurred, on 16% gullying was very noticeable. The relative density of the run-off material increased as the slope increased. As the slope became steeper than 2%, there was a substantial increase in soil loss.

Effect of Exchangeable Sodium Percentage on Physical Properties of Soils[1]

Thorne and Peterson (7), discussing the influence of exchangeable sodium on soils, mentioned that exchangeable sodium exerts a twofold effect:

1. In promoting a poor physical condition of the soil.
2. In bringing about an unbalanced nutrition of plants.

According to them, when the exchangeable sodium becomes greater than 12%, soil permeability and aeration are decreased and soil is readily deflocculated. Decrease in permeability of soil to water is brought about because high exchangeable sodium accompanied by low amounts of salts causes the dispersion of clay particles and organic matter of the soil. The dispersed particles plug up the soil pores and thus cause a decrease in soil permeability.

In another experiment by Reeve, Bower, Brooks and Gschwend (5), a comparison was made between effects of exchangeable sodium and potassium upon physical conditions of the soils. The effects were compared by means of an

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[1]The exchangeable sodium percentage is the percentage of the total cation exchange capacity which is occupied by the sodium ion.

air to water permeability ratio and modulus of rupture[2] increased markedly with increasing exchangeable sodium percentage, whereas increase in exchangeable potassium had little effect. An increase in exchangeable sodium causes a decrease in water permeability because of dispersion of soil particles. The result is that air/water permeability ratio in soils increases as exchangeable sodium increases. Exchangeable potassium does not have the same ability to cause dispersion.

Three of the soils experimented with showed no change in air permeability with increasing exchangeable sodium. For all soils there was a decrease in water permeability with increasing exchangeable sodium and potassium. The sodium had a greater effect.

Martin and Richards (3), in their experiment on the influence of exchangeable hydrogen, and calcium, and of sodium, potassium, and ammonia at different hydrogen levels on physical properties of soil, report that increasing

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[2]"Modulus of rupture" is the weight required to fracture a briquet of soil of specified dimensions and supported on beams a specified distance apart. It is a measure of the number of points of soil--soil contact per unit cross-sectional area.

sodium reduced soil aggregation and water conductivity. A review of several other experiments shows that increases in the amount of exchangeable sodium reduced permeability.

METHODS AND MATERIALS

A laboratory approach was used in these experiments. A galvanized sheet metal tray 30 cm wide and 50 cm long was used to hold soil being studied. The tray had a metal screen a few centimeters from the top. A piece of cloth was placed on the screen and the soil placed on the cloth. On one end of the tray there was a hole through which surface run-off and soil erosion could be collected, while the leachate was collected at the bottom of the tray. Differences in the degree of slope were obtained by putting four premeasured blocks in various combinations under one end of the tray. The slopes obtained were 2%, 8%, 14%, and 20%.

The soil was uniformly moistened before water application. The amount of artificial rain was applied by a sprinkler which discharged 11.2 ml of water per second with 40 pounds of pressure. Some preliminary tests were made to find out how long it would take the water to cause some surface run-off and erosion at the least degree of slope. It was found that after the sprinkler rotated seventeen rounds, some surface run-off occurred at the lowest degree of slope. It took the sprinkler 36.6 seconds on its course and 15 seconds on the tray to complete one

round. During this round, 410 ml of water were discharged and only 123 ml of water were received by the tray, since the course on which the sprinkler rotated was longer than the length of the tray. As a result 2091 ml of water were applied to the tray for the total of seventeen rounds. The time required was 255 seconds. To put it in terms of centimeters of water applied, the depth of water applied was 1.39 cm for all experiments, applied at a rate of 19.6 cm per hour.

The soil was obtained from the area used in the "Shadehill Irrigation Development Farm." This soil has been tentatively identified as Cheyenne loam, a description of which according to South Dakota Soil Series (6), a publication by the Soil Conservation Service, is as follows:

> The Cheyenne Series which includes chestnut soils developed on gravelly material of alluvial fans and aprons and stream terraces are not so dark as the Sioux and Fordville soils, which are true chernozems. In the following is the profile descriptions of these soils.
>
> Soil Profile: (Cheyenne Loam)
>
> 0 - 2" Brown (10YR 4/2, dry) to very dark brown. (10 YR 2/2, moist) loose mulch-like loam or sandy loam. 1 to 2 inches thick.
>
> 2 - 8" Brown (10 YR 4/2, dry) to very dark brown. (10 YR 2/2, moist) friable loam, which in places is weakly prismatic. 4 to 8 inches thick.
>
> 8 - 20" Brown (10 YR 4/2, dry) to dark brown. (10 YR 3/2, moist) friable loam. Weakly to moderately well developed prismatic. 8 to 15 inches thick.

20 - 40" Light grayish brown (2.5 Y 6/2, dry) to dark yellowish brown (2.5 Y 4/3, moist) sand and gravel, either loose or slightly cemented by calcium carbonate. 2 to many feet thick.

Topography: Nearly level or undulating. The slope is mostly about two percent.

Drainage: Surface drainage is good, internal drainage is good to excessive.

Vegetation: Short grasses such as grama, needle and buffalo grasses. Yucca is common.

Use: Under dry land farming these soils are used mainly for growing small grains, while on irrigated areas, sugar beets and alfalfa are grown. Many of the areas are used for pasture.

Distribution: Western parts of Nebraska, South Dakota, North Dakota, and the eastern parts of Montana and Wyoming.

Type Location: Cheyenne County, Nebraska.

Since the surface soil (0-6 inch depth) had been used in a former experiment which did not give satisfactory results, the soil from 6-12 inch depth was used. Soils from three separate plots at Shadehill were obtained and each lot was mixed thoroughly and after laboratory analysis for exchangeable sodium percentage, three levels were obtained. The levels were 9.8%, 15.6% and 20.1% of exchangeable sodium respectively. Exchangeable sodium percentage was done according to the procedure in USDA Handbook 60, "Diagnosis and Improvement of Saline and Alkaline Soils" (8).

The soil of each exchangeable sodium level was divided into twelve lots of 1950 grams each. Thus 36 lots

of soil were used in 36 experiments.

Surface run-off was measured and soil erosion was obtained by means of centrifuging aliquot portions of the total volume. The same method was used for measuring the leachates. The electrical conductivities of the leachates were finally measured for each experiment, using a platinized electrode conductivity cell.

In addition to the above treatments, a sample of soil was taken from each level of exchangeable sodium on which soil aggregate analysis, and permeability to air and water were measured.

The aggregate analysis by the wet sieve method was done by a modification of the method used in USDA Handbook 60, "Diagnosis and Improvement of Saline and Alkaline Soils", as follows: The soil aggregates, according to the modified method, were placed on a nest of sieves which were raised and lowered in the water. This subjected the aggregates to a destructive force of water. The more stable aggregates remained on the upper sieves, while the more unstable aggregates were washed through the sieves.

In order to measure the stability of soil aggregates, some of the bulk soil between 4.76 mm and 2.0 mm sieves was sieved. The aggregates passing through the 4.76 mm screen but remaining on the 2.0 mm screen were used for aggregate analysis. Twenty-five grams of sieved air-dry

soil were weighed out for aggregate analysis and an extra sample was taken for moisture determination. With the sieves in motion, the 25 gram sample was distributed over the top sieve. The motor was allowed to raise and lower the sieves for 30 minutes. The sieves were then taken, still in their carriers, out of the rack and left to drain into the can. The sieves were taken apart, and each sieve was placed in an evaporating dish. After oven drying the weight of material on each sieve was obtained. Calculations were made from the following formulas.

If sample "E" is regarded as the extra sample, we can define "W" as follows:

$$W = \frac{(\text{air dry wt. of "E"}) - (\text{oven dry wt. of "E"})}{(\text{air dry wt. of "E"})}$$

Now, if sample "S" is regarded as the one used for sieving, then its oven dry weight is as follows:

Oven dry wt. of Sample "S" = (air dry wt. of "S") - (W) x (air dry wt. of "S")

The end results of the wet sieves were weights of soil remaining on the individual sieves in the nest. "Distribution Percent by Weight", referred to as DPW, is calculated from these weights. The "DPW" is calculated as follows:

$$DPW = \frac{(\text{oven dry wt. of soil remaining on a certain sieve})}{(\text{oven dry wt. of Sample "S"})} + 100$$

Permeability of soil to air was done by the use of a permeameter and measuring the length of time it took a

certain volume of air to pass through the column of soil. This permeability was measured by the following formula:

$$K = \frac{V}{t} \frac{N}{\Delta P} \frac{L}{A}$$

K = Intrinsic Permeability (cm^2)

V = Volume of Air Discharged (cm^3)

t = Time in Seconds

N = Viscosity of Air (poise) - the Viscosity of moist air at Atmospheric Pressure is close to [190 - 0.49 (26 - tc)]

ΔP = Gauge Pressure Gradient ($dynes/cm^2$)

L = Length of Soil Column (cm)

A = Area of the Soil Column (cm^2)

Permeability of soil to water was measured by using the permeameter and measuring the length of time it took a certain volume of water to pass through the soil column. This permeability was measured by the following formula:

$$P = \frac{Q\,L}{TAH}$$

P = Permeability

Q = ml of water

L = Length of Soil Column (cm)

T = Time in Seconds

A = Cross-sectional area of Soil Column (cm^2)

H = Hydraulic Head (cm)

Measurements on run-off, erosion and leachates were done in triplicate and interpretations of the results were made on the basis of the averages.

RESULTS AND DISCUSSION

Effect of Slope on Run-Off at Three Levels of Exchangeable Sodium

As was mentioned earlier, the experiments on run-off and erosion were done in triplicate, and interpretations of the results were made on the basis of the averages. Tables I, II and III show the complete data on run-off, erosion, and electrical conductivity of leachates for artificial rain on soils at 9.8%, 15.6% and 20.1% exchangeable sodium, respectively.

TABLE I. RUN-OFF, EROSION, AND ELECTRICAL CONDUCTIVITIES OF LEACHATES FOR ARTIFICIAL RAINFALL ON SOIL AT 9.8% EXCHANGEABLE SODIUM

Replicate	A	B	C	D	E	F	G
I	2	0.06	4.3	0.79	56.8	0.30	1.30
	8	0.15	10.7	0.60	43.1	0.30	1.30
	14	0.28	20.1	0.41	29.4	0.30	1.40
	20	0.20	14.3	0.48	34.5	0.50	1.40
II	2	0.12	8.6	0.71	51.0	0.40	1.30
	8	0.13	9.3	0.57	41.0	0.50	1.30
	14	0.35	25.1	0.41	29.4	0.60	1.30
	20	0.20	14.3	0.57	41.0	0.40	1.20
III	2	0.17	12.2	0.78	56.1	0.40	1.40
	8	0.25	17.9	0.60	43.1	0.50	1.40
	14	0.42	30.0	0.22	15.8	0.40	1.50
	20	0.34	24.4	0.45	32.3	0.40	1.30
Average	2	0.11	8.3	0.76	54.6	0.36	1.33
	8	0.17	12.6	0.59	42.4	0.46	1.33
	14	0.35	25.0	0.34	24.8	0.43	1.40
	20	0.24	17.6	0.50	35.9	0.43	1.30

A = % of Slope

B = Depth of total surface run-off (cm)

C = % of Run-Off

D = Depth of total leachate (cm)

E = % of Leachate

F = Soil erosion (g)

G = Electrical conductivities of leachate (mmhos/cm)

TABLE II. RUN-OFF, EROSION, AND ELECTRICAL CONDUCTIVITIES OF LEACHATES FOR ARTIFICIAL RAINFALL ON SOIL AT 15.6% EXCHANGEABLE SODIUM

Replicate	A	B	C	D	E	F	G
I	2	0.36	25.8	0.49	35.2	1.05	1.40
	8	0.44	31.6	0.42	30.2	0.75	1.35
	14	0.44	31.6	0.42	30.2	1.60	1.20
	20	0.68	48.9	0.31	22.3	2.10	1.40
II	2	0.31	22.3	0.59	42.4	1.00	3.50
	8	0.42	30.0	0.52	37.4	1.10	1.40
	14	0.46	33.0	0.30	21.5	1.70	1.40
	20	0.66	47.4	0.22	15.8	2.00	1.42
III	2	0.34	24.4	0.50	35.9	0.70	1.90
	8	0.35	25.1	0.39	28.0	1.30	1.00
	14	0.50	35.9	0.35	25.1	1.35	1.40
	20	0.61	43.8	0.35	25.1	3.80	1.30
Average	2	0.33	24.1	0.52	37.8	0.91	2.26
	8	0.40	28.9	0.44	31.8	1.05	1.25
	14	0.46	33.5	0.35	25.6	1.55	1.33
	20	0.65	46.7	0.29	21.0	2.63	1.37

A = % of Slope

B = Depth of total surface run-off (cm)

C = % of Run-Off

D = Depth of total leachate (cm)

E = % of Leachate

F = Soil erosion (g)

G = Electrical conductivities of leachate (mmhos/cm)

TABLE III. RUN-OFF, EROSION, AND ELECTRICAL CONDUCTIVITIES OF LEACHATES FOR ARTIFICIAL RAINFALL ON SOIL AT 20.1% EXCHANGEABLE SODIUM

Replicate	A	B	C	D	E	F	G
	2	0.54	38.8	0.35	25.1	1.20	2.65
	8	0.70	50.3	0.23	16.5	2.65	2.65
I	14	0.75	53.8	0.28	20.1	12.30	1.35
	20	0.81	58.2	0.19	13.6	10.90	1.35
	2	0.67	48.2	0.36	25.8	1.20	1.20
	8	0.66	47.4	0.37	26.6	1.10	1.10
II	14	0.58	41.7	0.26	18.7	7.00	1.20
	20	0.67	48.2	0.17	12.2	10.90	1.25
	2	0.51	36.6	0.43	30.9	0.90	1.05
	8	0.45	32.3	0.46	33.0	1.35	1.35
III	14	0.75	53.8	0.23	16.5	1.40	1.10
	20	0.67	48.2	0.23	16.5	10.90	1.25
	2	0.57	41.2	0.38	27.2	1.10	1.63
	8	0.60	43.3	0.35	25.3	1.70	1.70
Average	14	0.69	49.7	0.25	18.4	8.90	1.21
	20	0.71	51.5	0.19	14.1	10.90	1.28

A = % of Slope

B = Depth of total surface run-off (cm)

C = % of Run-Off

D = Depth of total leachate (cm)

E = % of Leachate

F = Soil erosion (g)

G = Electrical conductivities of leachate (mmhos/cm)

In order to show the results in more clear and simple forms, Tables IV and V, from which graphs were drawn, have been added (Figures 2 and 3).

Effect of slope on run-off at three levels of exchangeable sodium, therefore, can be discussed from the following Table and Figure.

TABLE IV. EFFECT OF SLOPE ON RUN-OFF AT THREE LEVELS OF EXCHANGEABLE SODIUM (RUN-OFF EXPRESSED AS % OF WATER APPLIED)

Slope %	9.8% Exchangeable Sodium	15.6% Exchangeable Sodium	20.1% Exchangeable Sodium
2	8.3	24.1	41.2
8	12.6	28.9	43.3
14	25.0	33.5	49.7
20	17.6	46.7	51.5

Effect of Slope on Run-Off

As shown in Table IV and Figure 2, surface run-off at 2% slope in soils with 9.8% exchangeable sodium was 8.3% of the water applied. At 8% slope run-off was 12.6% of the water applied or 4.3% higher than that at 2% slope. Run-off at 14% slope was 25.0% of the water or 12.4% higher than that at 8% slope, while run-off at 20% slope was 7.4% lower than that at 14% slope. The results from

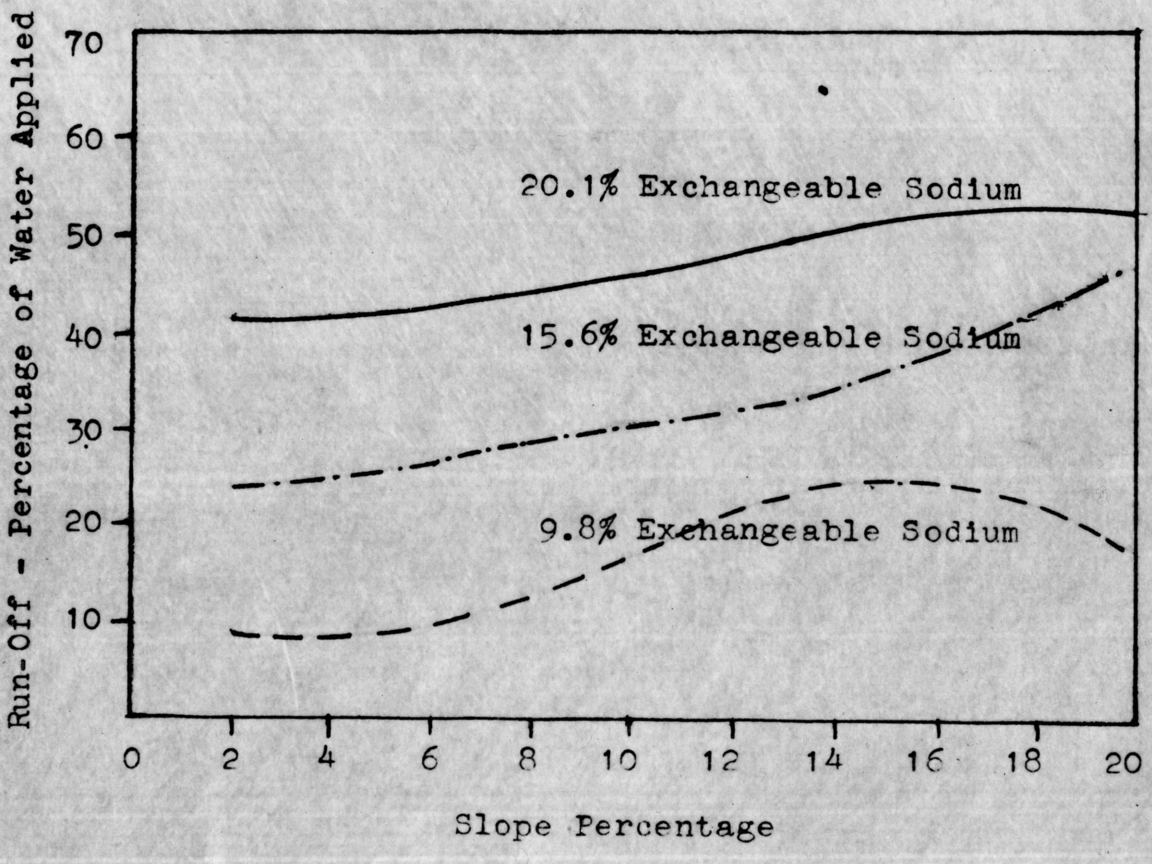

Figure 2. Effect of Slope on Percentage Run-Off At Three Levels of Exchangeable Sodium

soil with 9.8% exchangeable sodium indicate that the highest rate of increase in run-off, as slope is increased every 6% from 2% to 20%, occurs in the 8% to 14% slope group.

The inconsistency in the case of 20% slope at which run-off is lower than that at 14% slope may be due to the fact that the soils which were used at 14% and 20% slope did not necessarily have identical physical characteristics, and apparently were not at the same original water content.

In soils with 15.6% exchangeable sodium, run-off at 2% slope was 24.1% of the water applied. Run-off at 8% slope was 28.9% or 4.8% higher than that at 2% slope. At 14% slope run-off was 33.5% of the water applied or 4.6% higher than that at 8% slope, while run-off at 20% slope was 46.7% or 13.2% higher than that at 14% slope.

The results in soils with 15.6% exchangeable sodium indicate that the highest rate of increase in run-off occurs at the 14-20% slope group, while the rates of increase at 2-8% and 8-14% were not significantly different.

In soils with 20.1% exchangeable sodium run-off at 2% slope was 41.2% of the artificial rain applied; at 8% slope 43.3%; at 14% slope 49.7%; and at 20% slope 51.5% of the water applied.

The results in soils with 20.1% exchangeable sodium, like in soils with 9.8%, indicate that the highest rate of increase in run-off occurs at 8-14% slope. According to

the results on soils with the lower and higher levels of exchangeable sodium, when slope was increased each 6% from 2% to 20%, the highest rate of increase in run-off occurred at 14% slope, while in soils with 15.6% exchangeable sodium, the highest rate of run-off was at 20% slope.

Effect of Exchangeable Sodium on Run-Off

In the previous discussions the influence of slope was discussed. In the following the discussion concerns the influence of exchangeable sodium on run-off for each percentage of slope.

Run-Off at 2% Slope

Run-off from soils with 15.6% exchangeable sodium was 15.8% higher than from soils with 9.8% exchangeable sodium at the same slope. Soils with 20.1% exchangeable sodium showed 17.1% higher run-off than those with 15.6%. At 2% slope surface run-off increases as the amount of exchangeable sodium increases. The highest rate of increase is between 15.6% and 20.1% exchangeable sodium.

Run-Off at 8% Slope

Run-off from soils with 15.6% exchangeable sodium was 16.3% higher than that from soils with 9.8%. Run-off from soils with 20.1% exchangeable sodium was 14.4% higher than that from soils with 15.8%. According to the results, the highest rate of increase in run-off at 8% slope occurs

between 9.8% and 15.6% exchangeable sodium.

Run-Off at 14% Slope

Run-off from soils with 15.6% exchangeable sodium was 8.5% higher than that from soils with 9.8%. Soils with 20.1% exchangeable sodium showed 16.2% higher run-off than those with 15.6%. Like the results at 2% and 8% slopes, the results at 14% slope show that run-off increases as exchangeable sodium increases. The highest rate of increase in run-off occurs between 15.6% and 20.1% exchangeable sodium.

Run-Off at 20% Slope

Run-off from soils with 15.6% exchangeable sodium was 29.1% higher than that from soils with 9.8%, while run-off from soils with 20.1% exchangeable sodium was 4.8% higher than that from soils with 15.6%. The results at 20% slope were similar to those at 2%, 8% and 14% slopes in that an increase in exchangeable sodium was usually accompanied by an increase in surface run-off. However, at 14% slope the highest rate of increase in run-off occurred between 9.8% and 15.6% exchangeable sodium.

Effect of Slope on Soil Erosion at Three Levels of Exchangeable Sodium

The effect of slope on soil erosion at three levels

of exchangeable sodium is presented in Table V and Figure 3.

TABLE V. GRAMS OF SOIL ERODED AT THREE LEVELS OF EXCHANGEABLE SODIUM AND FOUR SLOPES (1.39 CM OF WATER APPLIED)

Slope %	9.8% Exchangeable Sodium	15.6% Exchangeable Sodium	20.1% Exchangeable Sodium
2	0.36	0.91	1.10
8	0.46	1.05	1.70
14	0.43	1.55	6.90
20	0.43	2.63	10.90

According to the data, in soils with 9.8% exchangeable sodium the amounts of soil eroded at 2%, 8%, 14% and 20% slopes were 0.36, 0.46, 0.43 and 0.43 grams respectively. The amount of soil eroded at 8% slope was 0.10 grams more than that at 2% slope, while 14% and 20% slopes each caused 0.03 grams less erosion than that at 8% slope.

In these experiments, using soil with 9.8% exchangeable sodium, erosion was not a function of the slope, at the rate of application used.

In soils with 15.6% exchangeable sodium soil erosion losses at 2%, 8%, 14% and 20% slopes were 0.91, 1.05, 1.55 and 2.63 grams respectively. Soil erosion at 8% slope was 0.14 grams more than that at 2% slope. At 14% slope soil erosion was 0.50 grams more than that at 8% slope, while

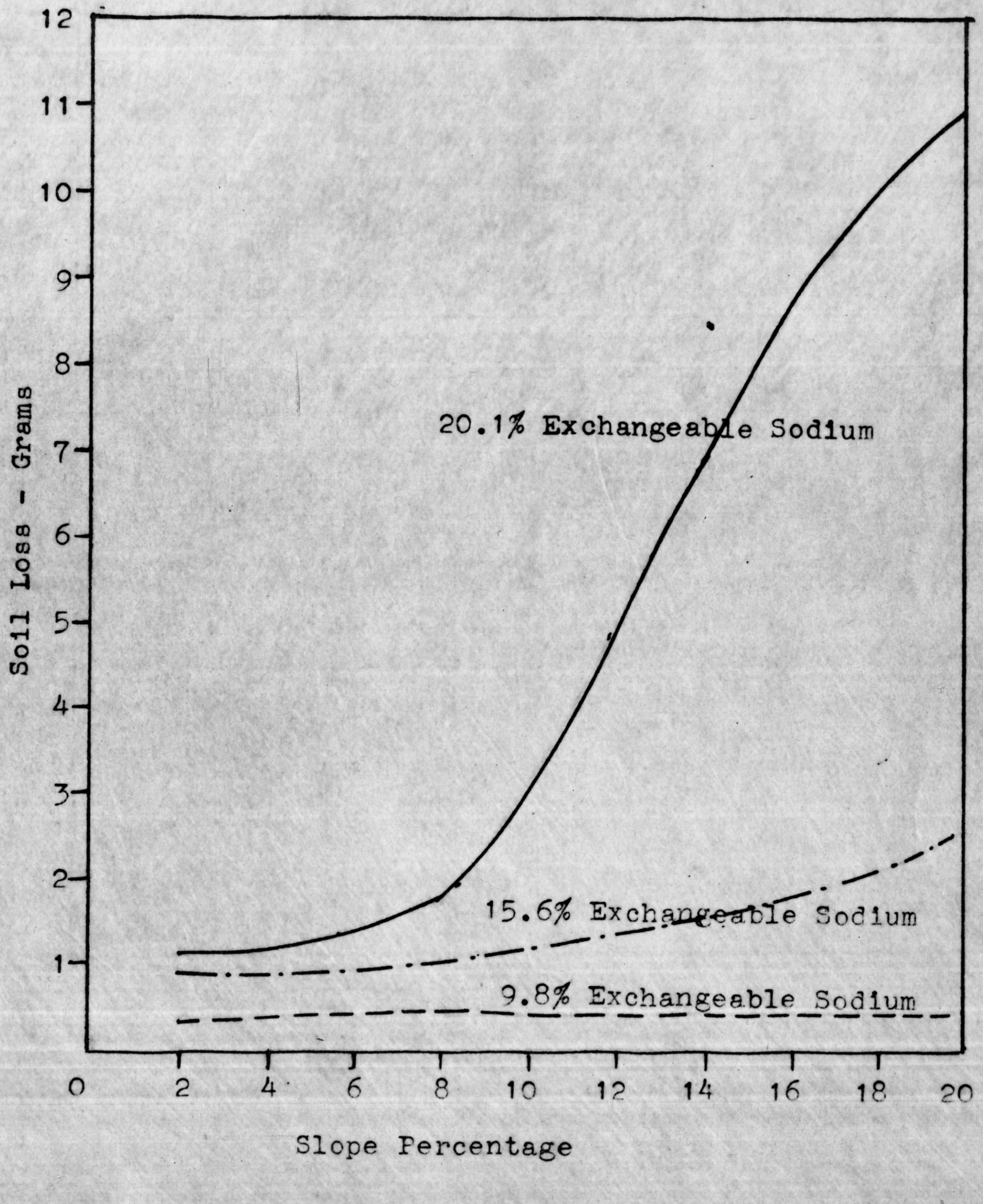

Figure 3. Effect of Slope on Soil Erosion at Three Levels of Exchangeable Sodium

20% slope had 1.08 grams more erosion than that at 14% slope.

The results in soils with 15.6% exchangeable sodium indicate that, unlike soils with 9.8% exchangeable sodium, soil erosion loss is significantly related to the slope.

In soils with 20.1% exchangeable sodium soil erosion at 2%, 8%, 14% and 20% slopes was 1.10, 1.70, 6.90 and 10.90 grams respectively. The highest rate of increase in erosion occurred between 8% and 14% slope.

The results with soils with 20.1% exchangeable sodium indicate that at this level, erosion is more closely correlated with the slope than at 9.8% or 15.6% exchangeable sodium. Comparison of the rates of soil erosion at the three levels of exchangeable sodium indicates that in soils with relatively low amounts of exchangeable sodium, soil erosion is not significantly a function of the slope.

As the amount of exchangeable sodium increases, soil erosion becomes greater and more significantly a function of the slope. In addition, soil erosion at higher levels of exchangeable sodium occurs at a higher rate for each 6% increase in slope until 14% slope is reached after which there seems to be a slight decrease in the rate of erosion.

Effect of Slope on Electrical Conductivities of the Leachates at Three Levels of Exchangeable Sodium

Results of the measurements of the influence of

slope on the conductivities of the leachates collected are presented in Table VI.

TABLE VI. EFFECT OF SLOPE ON ELECTRICAL CONDUCTIVITIES OF THE LEACHATES AT THREE LEVELS OF EXCHANGEABLE SODIUM

Slope %	9.8% Exchangeable Sodium (mmhos/cm)	15.6% Exchangeable Sodium (mmhos/cm)	20.1% Exchangeable Sodium (mmhos/cm)
2	1.33	2.26	1.36
8	1.33	1.25	1.70
14	1.36	1.33	1.21
20	1.33	1.37	1.28

It appears that neither slope nor exchangeable sodium had any significant effect on the electrical conductivities of the leachates from the soil. It was thought that conditions leading to greater percentages of infiltration would result in lower conductivities of the leachates, but this did not prove to be so.

Aggregate Analysis of Soils

Tables VII, VIII and IX show the results of the aggregate analysis of the soils with the three levels of exchangeable sodium.

TABLE VII. AGGREGATE ANALYSIS OF SOIL WITH 9.8% EXCHANGEABLE SODIUM

Sieve Size mm	Particle Size mm	Distribution % by Weight	Percent Greater than the Size Indicated
2.00	>2.00	10.45	10.45
1.00	1.00-2.00	14.58	25.03
0.50	0.50-1.00	15.10	40.13
0.25	0.25-0.50	17.70	57.83
Passing Through Finest Sieve	0.25	42.17	

TABLE VIII. AGGREGATE ANALYSIS OF SOIL WITH 15.6% EXCHANGEABLE SODIUM

Sieve Size mm	Particle Size mm	Distribution % by Weight	Percent Greater than the Size Indicated
2.00	>2.00	10.41	10.41
1.00	1.00-2.00	9.89	20.30
0.50	0.50-1.00	12.76	33.06
0.25	0.25-0.50	12.50	45.56
Passing Through Finest Sieve	0.25	54.44	

Soil aggregate analysis was made to determine the stability of soil aggregates against the dispersing forces of water. Results with this soil, measured in terms of percentage distribution by weight of soil particles which

TABLE IX. AGGREGATE ANALYSIS OF SOIL
WITH 20.1% EXCHANGEABLE SODIUM

Sieve Size mm	Particle Size mm	Distribution % by Weight	Percent Greater than the Size Indicated
2.00	>2.00	7.85	7.85
1.00	1.00-2.00	9.60	17.53
0.50	0.50-1.00	11.51	29.04
0.25	0.25-0.50	11.51	40.55
Passing Through Finest Sieve	0.25	59.53	

remained on each sieve, indicate that the lower the exchangeable sodium, the more stable were the aggregates.

The relative percentage distribution by weight of soil particles as shown in Tables VII, VIII and IX are highest on any given size sieve for the soil with the lowest exchangeable sodium percentage. Since, in the measurement of the soil aggregates, four sieves with sizes 2.00, 1.00, 0.50 and 0.25 mm were used, some of the soil that was put on the sieves went through the 0.25 mm sieve, it was lost to the water.

According to Table VII, 42.2% of the soil with 9.8% exchangeable sodium was lost through the finest sieve.

As indicated by Table VIII, 54.4% of the soil with

15.6% exchangeable sodium went through the finest sieve, while according to Table IX, 59.5% of the soil with 20.1% exchangeable sodium passed through the finest sieve. The results indicate that soil aggregates in soil with 9.8% exchangeable sodium were considerably more stable than those with 15.6% and 20.1%. The results emphasize the fact that the higher the exchangeable sodium percentage, the more dispersion of the soil aggregates we should expect.

The dispersion of soil aggregates and organic matter in soils with a relatively high amount of exchangeable sodium cause soil to be more easily washed away by the forces of water.

Permeability of the Soils to Air and Water

In order to determine more emphatically the physical characteristics of the soils with the three levels of exchangeable sodium, permeability to air and water was also determined. The results of these determinations are in Table X.

Permeability to Air

Experiments on the permeability of soil to air showed that in soils with 9.8% exchangeable sodium ($K = \frac{V}{t} \frac{N}{\Delta P} \frac{L}{A}$) K = 0.35 (cm^2). In soils with 15.6%

TABLE X. PERMEABILITY OF CHEYENNE LOAM SOIL TO AIR AND WATER AT THE THREE LEVELS OF EXCHANGEABLE SODIUM

Soil	Air $K = \frac{V}{t}\frac{N}{\Delta P}\frac{L}{A}$	Water $P = \frac{QL}{TAH}$	Air/Water Ratio $\frac{K}{P}$
9.8% Exchangeable Sodium	0.35	0.273	0.128
15.6% Exchangeable Sodium	0.29	0.0012	241.66
20.1% Exchangeable Sodium	0.51	0.000056	9107.14

K = Intrinsic Permeability
P = Permeability

K = 0.29 (cm^2), and in those with 20.1% K = 0.51 (cm^2). According to these figures, soils with 9.8% exchangeable sodium were more permeable to air than soils with 15.6%, but those with 20.1% were significantly more permeable to air than the other two.

Permeability to Water

The permeability of the soils to water was measured in terms of P = QL/TAH (cm/sec). Results showed that in soils with 9.8% exchangeable sodium P = .273, in soils with 15.6% P = .0012, and in those with 20.1% P = .000056.

These results substantiate the results in the previous experiments in that the higher the exchangeable sodium percentage, the lower is the permeability of the soil to water.

Comparing the results with soil of 20.1% exchangeable sodium, it is of interest to note that in this soil permeability to air is higher than in those with 9.8% and 15.6% exchangeable sodium, while its permeability to water is lower.

SUMMARY

Experiments were conducted to determine the influence of slope and exchangeable sodium on run-off, erosion, and artificial rainfall. Four slopes, 2%, 8%, 14% and 20%, were used. The three levels of exchangeable sodium used were 9.8%, 15.6% and 20.1%.

Concerning the influence of slope on run-off, soil erosion and electrical conductivity of the leachate, it was found that in general an increase in slope was accompanied by an increase in surface run-off.

The exception was in the use of soils with 9.8% exchangeable sodium in which run-off at 14% slope was more than that at 20% slope. The experiments indicated that contrary to some of the reports in the literature, run-off is a function of the slope. Although it is not possible to develop a regression between run-off and slope on one hand and run-off and exchangeable sodium on the other, it seems that at the highest and lowest levels of exchangeable sodium, the highest rate of increase in run-off occurs between 8% and 14% slope, while if exchangeable sodium is intermediate, the highest rate of increase in run-off occurs between 14% and 20% slopes.

Run-off is also a function of the exchangeable sodium, providing that soluble salts remain approximately

constant as exchangeable sodium changes. The higher the exchangeable sodium, the greater the run-off which occurred.

The most significant results were perhaps those obtained with respect to soil erosion. It was found that at relatively low levels of exchangeable sodium, in these experiments (9.8%), soil erosion is not significantly a function of the slope. When the exchangeable sodium was 15.6%, differences in the amount of soil erosion, as affected by slope changes, became greater. At the highest level of exchangeable sodium, 20.1%, soil erosion became markedly correlated with slope.

However, the highest rate of increase in erosion occurred between 8% and 14% slopes after which there was a slight decrease. In soils with 15.6% exchangeable sodium the highest rate of increase was between 14% and 20% slopes.

Not only is soil erosion a function of the slope, but more important than that, soil erosion is a function of the exchangeable sodium. The influence of slope is almost negligible as long as exchangeable sodium is low.

Neither slope nor exchangeable sodium level had consistent influence on the electrical conductivities of the leachates. This is interpreted to indicate that there was no appreciable effect of exchangeable sodium on the ionic exchange reactions with the tap water used as artificial rain in these experiments.

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