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Research Article

Assessment of Soil Salinity under Irrigation Farming Along the Delimi River of the Jos Plateau

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Abstract: Salinity is a major threat to productivity of agricultural soils; the objective of this study was to evaluate the current state and severity of soil salinity under irrigation farming along the Dilimi river in Jos metropolis. The study area was stratified based on land form characteristics. Soil samples were taken at a depth of 0-15cm and 15-30cm from each of the landform unit. Soil samples were analyzed in the laboratory for pH, exchangeable bases and cation exchangeable capacity. Mean pH and Electrical conductivity were 5.74 and 0.43ds/m respectively. Mean content of Ca, Mg, K, and Na in the soils were 7.92, 2.91, 0.36 and 0.38 cmol/Kg respectively. The mean exchangeable sodium percentage (ESP) was 2.69%. Consequently, the current state of soil salinity in the study area is within the safe limit for horticultural crop production.
Keywords: Salinity, irrigation, Delimi River, Soil.

Introduction

Irrigated fields are vulnerable to rise in salt levels especially in dry tropical climates. The amount and timing of rainfall in significant areas of the world are not adequate to meet the moisture requirements for commercial crop production. Consequently, it is imperative to make adequate provisions for irrigated farming if high crop yields are to be attained (Michael and Ojha, 2005).

The problem of salinity in affected areas is mostly due to accumulation of salts brought to the soil through irrigation. It has been observed that on global basis around one third of the total world's irrigated land and 7% of the world's total land area is considered salt-affected (Epstein *et al*. 1980; Munns and Tester 2008). Furthermore, salt affected soils cover at least 20% of the world's cultivated land (Ghassemi *et al*., 1995).

Salt-affected soils are found in almost all continents (Almansouri *et al*. 2001) and under all climatic conditions, however, they are relatively more widespread in the arid and semi-arid climates compared to humid regions. Raghunath, (1982) and Rhoades, (1986) reported that the use of poor quality irrigation water for crop production often leads to detrimental effects of salinization on the soil. The Delimi River has been the source of water for irrigation in farmlands located along its bank however water quality from the River has been of great concern to environmentalists. This is due to pollution arising from large scale dumping of sewage, municipal and industrial wastes into the river (Njoku and Keke, 2003; Sabo et al, 2013). The study area has been under prolonged and intensive irrigated agriculture since the onset of Jos metropolis but not much has been done to determine the salinity status of the soils.

The objectives of this study therefore is to assess the status of soil salinity in irrigated farmlands along the Delimi River of the Jos Plateau; and provide baseline data for future research and conservation planning.

Materials and Methods

Study Area

The study area is located at the northern part of the Jos Plateau State. Geological details of the area are presented in Figure 1.

The area has distinct wet and dry seasons, with the rainy season lasting from April to October. Though situated in the tropical zone, a higher altitude means that the Jos Plateau has a near temperate climate with an average temperature of about 22 °C (Owonubi, 2017).

The warmest temperatures usually occur in the dry season months of March and April. The mean annual rainfall varies 1050 to 1403 mm. The highest rainfall is recorded during the wet season months of July and August.

Field and Laboratory Study

The site chosen for this study was horticultural farming area along the Delimi River in Jos metropolis. Field study involved classifying the study area into different landform units (upper and lower terrace). Soil samples were taken from each of the landform units at depths of 0-15 and 15-30 cm, with the aid of a soil auger.

Oral interviews were carried with farmers on the site while land use inventory of the site was also performed.

Soil salinity was evaluated in the laboratory by determining the electrical conductivity and the exchangeable percentage (ESP) of the soil using the method described by Agbenin (1995). In addition, the pH of the soils was determined in 0.01m $CaCl_2$ solution at a soil: solution ratio of 1:2.5 as described by McLean (1982), exchangeable cations (Ca, Mg, Na and K) and cation exchange capacity (CEC) were also determined using the method (Thomas, 1982; Rhoades, 1982). The independent t test was used to analyze soil data.

Result and Discussion

Land use characteristic of the study area

A major portion of horticultural farming areas along the Delimi River had been under the influence of mining activities in time past. This has intensified the ruggedness of the terrain. The geology comprises of biotite granite in the southern part and undifferentiated migmatite in the northern part. The entire land area is made up of fragmented land holdings and almost the entire land area is cultivated. Small portions of land are left to serve as foot paths. In areas with rock outcrops some additional farm lands were created by crushing the rocks and then leveling the land surface.

Manual tillage involving the use of hoes is the preferred form of cultivation. Irrigation is practiced in the dry seasons or when the rainy season is yet to fully commence. Basin irrigation is practiced in this area, while water pumps are used to convey water from the river to farm lands. Due to high demand for horticultural crops on the Jos Plateau, the area is cultivated all year round in three or more cropping sequence in the upper slope positions. For the lower slope positions, the period of cultivation is limited to about nine months due to the occurrence of floods at the peak of the rains.

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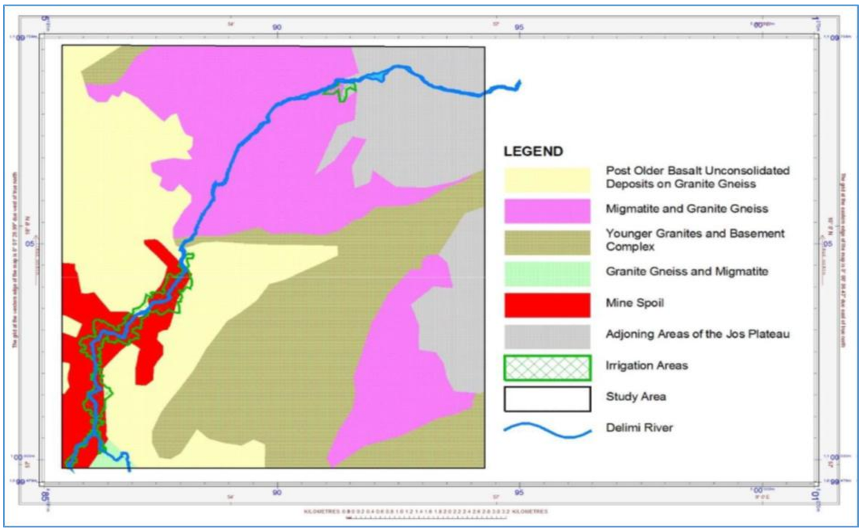

Figure 1. Map of the Study Area

Horticultural farming in the area is a special case of land use intensification involving mixed cropping in addition to crop rotations and continuous cropping. This is practiced to maximize profits from every square inch of land. Manure and fertilizers (usually N: P: K 20: 10: 10) were used by famers in the study area to improve soil fertility. The crops planted by famers in the study area during the period of this study included: cabbage, onion, spinach, Chinese cabbage, lettuce, carrot, Rosemary, cassava, cauliflower, Roselle, beetroot, tomatoes, Radish, sweet potatoes, green beans, maize and broccoli.

General Characteristics of Soils in the Study Area

General characteristics of soils in the study area for the upper and lower terrace landform classes is shown in Table 1. Mean sand, silt, clay and gravel contents of the study area in the upper terrace was 729.85 (standard deviation (SD): 59.91), 109.48 (SD: 24.22), 161.10 (SD: 46.37) g/kg and 28.62 (SD: 14.36 %) respectively. For the lower terrace soils, the mean sand, silt, clay and gravel content was 716.63 (SD: 60.11), 137.38 (SD: 48.14), 143.63 (SD: 18.12) g/kg and 17.94 (SD: 28.62 %) respectively. The analysis of variance revealed that there was no significant difference in ($p > 0.05$) in particle size distribution between the landform units. However, 78%- 80% of the upper terrace and lower terrace soils have sandy loam textures (Table 2). Furthermore, greater than 50 % of soils of the study area are gravelly to extremely gravelly.

Mean soil organic matter in the lower and upper terrace soils was 1.78 and 1.34 % with a standard deviation of 0.68 and 0.73 % respectively. However, there was no significant difference ($P > 0.05$) in the level of organic matter between land form units and between surface and subsurface soils in the study area. Generally, there was low level of soil organic matter in the surface and subsurface soil of the upper and lower terrace with 60 – 81% of the surface soils and 87 -100% of subsurface soils having low organic matter content.

Soil pH and Electrical Conductivity

The pH value of soils of the study area varied from 5.16-6.62 with mean value of 5.97 (Table 3) which indicate that the soil is moderately acidic for lower terrace, similarly that of upper terrace varied from 4.40-7.11 with the mean value are said to be within safe limit for irrigation. Analysis of variance indicated that there was significant difference ($P<0.05$) in soil pH between soil of upper and lower, with the upper terrace having the higher pH values. Electrical conductivity of the soil sample ranged from 0.129-1.577 with a mean value of

0.36-0.50 for both lower and upper terrace which indicate that there is no salinity risk to soil (EC < 4 ds/m). However, there was significant difference in EC values between surface and subsurface soils with surface soils having higher values. This is not unexpected as irrigation water is directly applied to surface soils in the study area thereby leading to relative increase in salt build up in the surface soils.

Exchangeable bases

The distribution of exchangeable bases in soils of the study area is shown in Table 4. Ca, Mg, K, and Na had a mean of 7.71 (SD: 3.66), 1.99 (1.68), 0.24 (SD: 0.08) and 0.27 (SD: 0.09) cmol/kg in soils of the lower terrace respectively. For the upper terrace soils, Ca, Mg, K, and Na had Na had a mean of 8.14 (SD: 0.06), 1.9 (SD: 1.13) 0.23 (SD: 0.09) and 0.26 (SD: 0.06) cmol/kg in soil of the upper terrace respectively. The mean distribution of base saturation in soils of the study area was 28.93 (SD: 31.50) and 12.50 (SD: 2.72) % for lower and upper terrace soils respectively while mean distribution of cation exchange capacity (CEC) was 12.07 (SD: 4.55) and 11.54 (SD: 2.14) for lower and upper terrace soils respectively. This indicates according to the classification of Holland *et al* (1989) that base saturation and CEC in the soils are low to very low. Implying that the soils have low nutrient reserve for plant growth. This may be as a result of the continuous and intensive cultivation of crops ongoing in the study area.

Table 1. General characteristics of soils of the study area

Particle Size	Landform	Soil Depth	Mean	Std. Deviation
Sand (g/kg)	Lower Terrace	Surface soil	715.2500	76.06341
		Subsurface soil	718.0000	44.19438
	Upper Terrace	Surface soil	742.6364	56.56019
		Subsurface soil	715.8000	63.25399
Silt (g/kg)	Lower Terrace	Surface soil	140.5000	60.51918
		Subsurface soil	134.2500	35.78407
	Upper Terrace	Surface soil	109.7273	25.51898
		Subsurface soil	109.2000	24.07765
Clay (g/kg)	Lower Terrace	Surface soil	139.5000	19.35385
		Subsurface soil	147.7500	17.23576
	Upper Terrace	Surface soil	148.0909	42.67190
		Subsurface soil	175.4000	48.17376
Gravel (%)	Lower Terrace	Surface soil	16.3750	7.24938
		Subsurface soil	19.5000	10.35098
	Upper Terrace	Surface soil	22.6364	11.73263
		Subsurface soil	35.2000	14.60441
Organic Matter (%)	Lower Terrace	Surface soil	1.9313	.89675
		Subsurface soil	1.6400	.40200
	Upper Terrace	Surface soil	1.4755	.80784
		Subsurface soil	1.2010	.65155

Table 2. Percentage distribution of the soil texture in the study area

Soil Texture Class	Landform Class	
	Upper Terrace (%)	Lower Terrace (%)
Loam	10	11
Sandy loam	80	78
Sandy clay loam	10	11
Total	100	100

Table 3. Descriptive statistics of soil pH and EC in the study area

Variable	Soil Depth	Landform	Mean	Std. Deviation
pH	0-15cm	Lower Terrace	5.9762	.46601
		Upper Terrace	5.4782	.61013
	15-30cm	Lower Terrace	5.9613	.53064
		Upper Terrace	5.5460	.85478
EC	0-15cm	Lower Terrace	.6514	.45705
		Upper Terrace	.4707	.21081
	15-30cm	Lower Terrace	.3498	.22501
		Upper Terrace	.2443	.13908

Table 4. Soil chemical properties of the study area

	Landform	Mean	Std. Deviation
Ca	Lower Terrace	7.6813	3.65549
	Upper Terrace	8.1491	2.05349
Mg	Lower Terrace	1.9925	1.67756
	Upper Terrace	1.8464	1.13159
K	Lower Terrace	.2425	.07760
	Upper Terrace	.2255	.08618
Na	Lower Terrace	.2713	.08526
	Upper Terrace	.2564	.06201
CEC	Lower Terrace	12.0750	4.54525
	Upper Terrace	11.5455	2.14446
ESP	Lower Terrace	2.5888	1.26086
	Upper Terrace	2.2327	.55223
BS	Lower Terrace	28.9375	31.50928
	Upper Terrace	12.4800	2.71640

Conclusion

The result of soil analysis of the study area reveals that irrigated soils are not saline in nature. This is because EC of soils in the study area is less than 4.0 (ds/m) as shown in Table 1. Despite the frequent use of irrigation water from the river in the study area, the following could be responsible for the low salinity level of the soils:

1) Intensive olericultural crop production in the area whereby almost every inch of land is used for cultivation.

2) Continuous cultivation: At least three cycles of cultivation is practice yearly in the study area.

3) 70 to 100% of the entire crop is harvested and sold to consumers with little or no crop residue returned to the soil.

The above factors therefore, are a special case of nutrient mining and most likely responsible for the low salinity level of the soil.

Furthermore, Table 1 and 2 also show that the soils are not sodic or saline-sodic because the EC is less than 4.0ds/m, ESP is less than 15% while pH is less than 8.5. Therefore, the study area is suitable for irrigated horticultural crop production because the salinity and sodicity status of the soils are within the safe limit for crop production.

Conflicts of interest: The authors declare no conflicts of interest.

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