ANALYSIS OF SOIL PROPERTIES ON IRRIGATED LANDS ALONG FARINRUWA RIVER, NASARAWA STATE, NIGERIA

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Samaila Kunden Ishaya[1]* and Madaki Hycenth Daleong[2]
[1]Department of Geography, Nasarawa State University, Keffi, Nigeria
[2]Department of Geography, Plateau State University, Bokkos, Nigeria
*Corresponding author: ikunden@yahoo.com

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Abstract: Water used for irrigation contains several substances that may affect the productive capacity of soils and yields of crops. The study analysed soil properties on irrigated lands along FarinRuwa River. A total of 8 soil samples were taken at both dry and raining seasons on irrigated fields near Mangar town in Wamba Local Government Area, Nasarawa State. Standard laboratory methods were used to determine the concentrations of the variables covered by this study. Electrical conductivity and pH were determine by Jenway portable meter, sodium, calcium and magnesium by Ammonium acetate leaching method, potassium by Atomic absorption spectrophotometer, nitrates, lead and boron by Cadmium extraction method, available phosphates using Olsen sodium bicarbonate method, Cation Exchange Capacity by Ammonium acetate method, nitrogen % by Macro Kjedhal wet oxidation method and particle size analysis by Hydrometer method. The results from this study showed that sodium 0.92 and 0.95 me/kg was low in the soil when compared to ions of calcium and magnesium. Trace elements such as iron 1.8 and 1.7 mg/kg, lead 0.11 and 0.15 mg/kg and boron 0.42 mg/kg for dry and rainy season, respectively in the soils were within the levels considered for irrigation. Nitrates 0.06 and 0.05 ppm, phosphates 3.0 and 3.19 ppm and nitrogen % 0.26 and 0.14 for dry and rainy season were low and deficient in the soil. The electrical conductivity of 202 and 490 uS/cm showed salinity built up in the soil for both dry and raining seasons. The pH of 4.47 and 4.92 were acidic below the level at which solubility could be reached. The study therefore recommends that there is the need to increase the application of organic and chemical fertilizers to raise nutrients deficient in the soil and raise the frequency in application of irrigation water to leach the excess salinity observed for the soils.

Keywords: Deficiency, internal drainage, productivity, salinity, sodicity

Introduction

One of the greatest challenges faced by most countries today is meeting the food need of the people. Increase in population, human activities, urbanization, wars, natural disasters and the threat posed by climate change have all posed serious problems in achieving food security for the ever growing population of the world. Most countries especially in the developing worlds are confronted with extreme malnutrition and hunger. To improve on the provision of food especially in countries characterized by seasonality in rainfall distribution irrigation offers a viable option (Ayoade, 2003).

In Nigeria irrigation is a common practice along river courses and low lying areas often referred to as fadama lands where soil residual moisture is high. The practice of irrigation augments rain-fed agriculture and keeps the farmers actively engaged throughout the year. Though irrigation is practiced however, the implications of the water quality use on the soils and for crop developmental processes have not been taken serious. The effects of irrigation with low quality water have been documented and have shown that most soils are affected by the nature of water used for irrigation (Kundu, 2012; Luo*et al.*, 2004; Majumdar, 2004; Miller and Gardiner, 2007; Samaila, 2015)

Water, whether surface or underground, contain impurities including dissolved salts most of which have the potential of affecting the productivity of the soil, the safety of the crops grown and consumers. Water used for irrigation has different ionic substances some of which are beneficial to the productive capacity of soils and yields of crops. However, substances from irrigation water may accumulate in the soil at intensities to affect the soil and crop yields. As observed by Food Agricultural Organization (FAO, 1997) major problem inherent during irrigation is the degradation of the soil due to salinity, soil permeability and toxicity of specific ions.

Nwa (2003) observed that a considerable irrigation lands have been affected by salinity from prolonged use of water for irrigation. To support this Abubakar*et al.* (2006) reported that some arid climate soils were free from excessive salts before cultivation but have been rendered non-productive by use of irrigation water containing excessive quantities of salts. Wright (2007) therefore estimated about 1.5 million hectres are lost yearly to salinization and waterlogging. Salinity in the soil has serious implication on the productivity of the soils and yields of crops. According to Baulder*et al.* (2012) soils affected by salinity results in unfavourable soil-water- plant relations as the concentration of soluble salts may reduce the ability of plants to absorb water and that at very high concentration water actually starts to move out of plants roots leading to the death of plants.

High sodium ion in the soil over that of calcium and magnesium may result in breakdown of soil structure and permeability problem. The soil tends to seal and becomes hard and compact thus reducing infiltration and aeration in the soil. These problems are more pronounced in fine textured soils such as clays and loams. Adamu (2013) observed high sodium adsorption ratio ranging from 6.88 to about 10.17 for water used for irrigation in Watari Irrigation Project. This has shown that sodium accumulation in the soil is likely to occur from the use of water for irrigation if proper management is not observed.

Certain ions are potentially harmful substances in irrigation water as they accumulate in the soil at concentrations high enough to cause toxicity problems especially when taken by plants in excess and reduce yields in some crops. The degree of damage depends on the uptake and the crop sensitivity. The concentration of these substances though may appear minute in water, constitute some of the most hazardous substances that can bio-amplify (Zwieg*et al.*, 1999). Trace metals are not biodegradable and have a density of at least five times that of water. Toxicity results when the concentrations of the elements exceed the tolerance limits of the plants resulting in marginal leaf burn and inter-veinalchlorosis to some specific crops. Damage often occurs at relatively low ion concentration for sensitive crops. Most studies on irrigation water quality have taken into consideration the presence of toxic elements such as boron, lead, chloride, sulfate, nitrate and phosphate as having marked influence on irrigation water and cause toxicity to some plants when taking from the soil in extreme concentrations. It has been observed that boron as little as 0.6 mg/l may produce toxicity symptoms in citrus leaves (Mass, 1990).

Materials and Methods

River FarinRuwa is located at the north eastern section of the basement complex formation of Nasarawa state, Nigeria. The river is a small tributary of the Dep River. It is popular because of the well-known FarinRuwa fall which cut across the river on its flow from the Bokkos hills into Nasarawa State. The river itself takes its source from the Bokkos hills of the Jos Plateau and flows through the lower segment of the Plateau into Nasarawa state. The river has generated a lot of interests especially its potential for tourism and hydroelectric power generation. Along the river was the Kwarra dam near Mangar, irrigation is practiced on farm plots along the dam. The river joins with other rivers into River Dep to form the eastern boundary of the state and subsequently drains into the River Benue.

The seasonality of rainfall has attracted irrigation along perennial streams, rivers and ponds (Samaila and Binbol, 2007). The alluvial soils of stream deposition and the presence of water in perennial streams are major considerations of the farmers engaging in irrigation in the area. Irrigation as practiced in the area provides the food and garden crops requirement of the state. Indigenous irrigation practices are common, with traditional methods largely employed (Rahaman, 2007). This study therefore analysed soil properties on irrigated lands along FarinRuwa River, Nasarawa State, Nigeria.

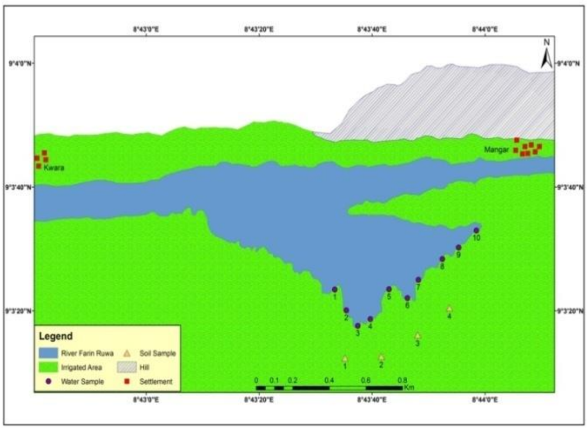

Fig. 1: Water and soil sampling points at Kwarra dam near Manger town along FarinRuwa River

The transient method of soil sampling was used to determine sampling points of soils on the irrigated fields along FarinRuwa River so as to fix the points at which soil samples were taken. The soil samples were taken at both dry and raining seasons, at peak periods of irrigation (February) and raining season (August).

Soil samples were collected on irrigated fields near Mangar in Wamba Local Government Area close to Kwarra Dam in Nasarawa State. The irrigated fields were chosen because they lay just at the points at which water from the dam along the river was used for irrigation. The choice of the irrigated fields was based on the duration of not less than ten years at which irrigation has been in practiced on such a field. Four soil samples were taken at 50 metres interval on the irrigated lands along the river covered by this study for each season. A total of 8 soil samples were taken for the dry and raining seasons.

A soil auger was used to burrow a hole thirty centimetres deep into the soil. The soil was thoroughly mixed and a 1kg representative sample was collected in polythene bags and taken for laboratory analysis. Properties measured of soils included pH and electrical conductivity by Jenway portable meter, sodium, calcium and magnesium by Ammonium acetate leaching method, potassium by Atomic absorption spectrophotometer, nitrates, lead and boron by Cadmium extraction method, available phosphates using Olsen sodium bicarbonate method, Cation Exchange Capacity by Ammonium acetate method, nitrogen % by Macro Kjedhal wet oxidation method and particle size analysis by Hydrometer method. The results of laboratory analysis for both the soils were summarized in tables.

Results and Discussion

The result presented in Table 1 shows the chemical properties of soils on irrigated lands along River FarinRuwa. The pH of 4.87 and 4.92 were highly acidic for both the two seasons. Samaila*et al.* (2011) observed mean pH of 6.89 for irrigated soils along River Kaduna. The pH values of the soil are highly acidic for the soils and are likely to affect solubility. As observed by Brady (1990) a pH 6.0 to 6.8 are ideal for most crops as it coincides with optimum solubility of the most important plant nutrients. Low pH observed for the soils could be attributed to erosion which leached basic cations and replace them with hydrogen ion. The pH values for the soils indicated that there is the need to raise pH in the soil by liming with calcium carbonate or increase in organic matter.

The electrical conductivity of soil extracts showed the mean concentrations were 490 uS/cm for the rainy season and 202 uS/cm for dry season. The values of electrical conductivity however increased during the rainy season due to increase in organic and chemical fertilizers and increase in bases from weatherable rocks. Tivy (1990) observed that at above 200 uS/cm in the soil yield of sensitive crops may be restricted and going by the present state of dissolved salts in the soils as indicated by EC yield of many crops may be restricted.

The soils recorded 28.0 and 23.9 meq/kg of calcium for dry and raining seasons respectively. Calcium mean values were higher for the dry season water which was likely due to high evaporation, low flow of water and application of organic manure and chemical fertilizers. Luo*et al.* (2004) recorded 6.5 mg/kg for Horotiu soils in China. The high calcium observed for the soil implies that the ion may not precipitate to a level in the soil to impact negatively on internal drainage and affect the performance of plants in their development.

Magnesium for FarinRuwa River was between 3.5 and 4.52 meq/kg, respectively for the seasons. The increase observed for soils along FarinRuwa River in the raining season could be attributed in parts to high organic matter and chemical fertilizers on farmlands accumulation of the element due to low leaching of the soil from erosion.

The mean concentration of sodium for dry season was 0.92 meq/kg for FarinRuwa while 0.95 meq/kg was recorded for raining season. The mean values varied slightly with a higher concentration recorded for the raining season soils. Sodium is very soluble and a large amount in the clay fraction will affect the physical properties for plant growth (Fawaz*et al.*, 2013). The concentration of sodium in the soil when compared to cations of calcium and magnesium was lower. The low concentration of sodium to that of calcium and magnesium indicates that sodium will not accumulate in the soil at level to precipitate these divalent cations and interfere with the internal structure of the soil to affect crops yields.

The mean value for potassium for soils in the dry season along FarinRuwa was 1.38 meq/kg while the raining season mean value was 2.1 meq/kg. There was an increase in the raining season concentrations for potassium in the soils. Potassium however was low for the soils for the seasons. This implies that the application of water for irrigation in the area will not raise potassium in the soil at chronic levels to interfere with normal growth of crops. Luo*et al.* (2004) observed a very low range of potassium (0 to 0.17 mg/kg) for Manawata soils in China.

Phosphate for dry season soils was 3.0 and 3.19 ppm for raining season. There was a slight increase in the raining season phosphate in the irrigated soil along the river. The relative low value recorded during the dry season could be attributed to leaching and assimilation of these ions into plants during this period. Afsin*et al.* (2007) recorded a relatively higher value of phosphate for soils of Shiraz suburban area of S.W. Iran.

Nitrate had mean value for dry season soils of 0.06 ppm while the raining season mean value was 0.05 ppm. The mean values for both seasons were generally low for the soils on the irrigated fields and this was likely due to the low organic matter of soils in the area and the low application of nitrate rich fertilizer during cultivation. High values of nitrate were recorded for water in Makera drain, Kaduna and were attributed to the effluents from federal superphosphate companies which discharge wastewater to enrich the drain with this substance (Samaila and Gimba, 2007).

Mean chloride concentration in dry season soil was 21.5 ppm while the raining season mean recorded 18.8 ppm. Chloride concentration observed for the soils on irrigated fields for the area was low when compared to over 300 mg/kg recorded for soils on irrigated lands in Makera, Kaduna Township (Samaila*et al.,* 2011). Results of chloride in the soils had indicated that the soil had not witnessed severe accumulation of this anion to impact negatively on plants growth.

Lead, was low for the soils on the irrigated fields. The concentration for the dry season was 0.11 mg/kg and 0.15 mg/kg for raining season. Ogundiran and Osibanjo (2008) observed a range of lead in soils on abandoned auto battery dumpsites was as high as 1310 – 19600 mg/kg. The low values observed for the soil indicates that the present level of lead 0.05 mg/L is within the limit considered safe and with no degree of problem on human health for irrigation (Ayers and Westcots, 1994).

The concentration of iron in the soils were highest when compared to other traced metals. The mean dry season iron concentration was1.8 mg/kg while the raining season mean concentration was 1.7 mg/kg. The mean concentration of iron for the soils in the seasons showed very slight variation. Okere and Kakalu (2011) observed high concentration of iron of as much as 6.0 to 7.0 mg/kg in the wet season and 7.6 to 8.5 mg/kg for dry season soils in mining and agricultural areas in Nasarawa state.

The mean concentration of boron was 0.42 mg/kg for dry season while 0.42 mg/kg was observed for the rainy season. The concentration of boron in the soil was low that even sensitive plants will not be affected when used for irrigation. This implies that the application of water in the area for irrigation will likely not be accompanied by boron accumulation in the soil at levels to impair the normal developmental processes in plants.

The mean concentration of cation exchange capacity of the soils in the dry season was 33.6%. The rainy season recorded 18.6%. Cation exchange capacity dropped for raining season soils which was likely due to the leaching of the bases from the soils as a result of storm run off during the season. The mean values of cation exchange capacity were low for the soils in the seasons which can be attributed to the type of clay (kaolinite) and the low organic matter generally observed for the area. Luo*et al.* (2004) observed very low cation exchange capacity (6.2 to 7.7) for soils in Manawata, China.

Nitrogen percent for the soils during the dry season was 0.26% while raining season was0.14%. Nitrogen percent was generally low for the soils in both seasons. The low percentage of nitrogen observed for the soils was low like in many West African soils (Essiet, 1988). The low nitrogen observed for the area may be attributed to farming methods practiced in the area which, involved removal of crop residues for domestic purposes after harvest and the burning of whatever is left especially during land clearance to prepare the farm for the next planting season.

Table 1: Mean chemical properties of soils on irrigated fields along River FarinRuwa for dry and raining seasons

Variables	Unit	Dry season (Mangar) FarinRuwa	Raining season (Mangar) FarinRuwa
pH	–	4.87	4.92
ECe	Us/cm	202.5	490
Ca	meq/kg	28.0	23.9
Na	meq/kg	0.92	0.95
Mg	meq/kg	4.52	5.48
K	meq/kg	1.38	2.13
PO_3	ppm	3.0	3.19
NO_3	ppm	0.06	0.05
Cl	ppm	21.5	18.8
Pb	mg/kg	0.11	0.15
Fe	mg/kg	1.8	1.70
B	mg/kg	0.42	0.42
CEC	%	33.6	8.59
N	%	0.26	0.14

Suitability of the soils for irrigation

The results from this study has shown that most of the parameters evaluated of the soil on irrigated farmlands along River FarinRuwa have not accumulated to levels to impact negatively on the soils and yields of crops. Sodium was low in the soil when compared to the combined concentrations of divalent cations of calcium and magnesium. This implies that the soils will not result in the precipitation of calcium and magnesium in a manner as to cause sodicity and cause dispersion of the internal structure of the soil. Waterlogging condition likely to occur from sodium accumulation will not affect plants growth.

Trace elements in the soils were within the levels considered for irrigation and will not pose toxicity problem in the use of water for the area. The low mean values of boron observed for the soils in both seasons indicates that even sensitive crops will not be affected by the present concentration of boron observed for the soil. The elements have not accumulated in the soil at intensities to bio-amplify and to cause ailments in for use of the crops. Leaf burns likely to occur from chloride will not result due to the low values observed for the soils.

Nitrates, phosphates and nitrogen which are very essential nutrients required by most plants were however low and deficient in the soil. If the soils are to meet the nutrient requirements in respect to these elements then water or additives rich in these substances have to be applied. The salinity of the soil is high and as indicated by the high electrical conductivity recorded for both dry and raining seasons soils. The high salinity of the soil indicates salinity built up that will cause difficulty in plants extracting water and nutrients from the soil thus leading to low yields of crops. The pH of the soils were acidic below the level at which solubility could be reached. This will therefore affect the nutrient availability in the soils and can be accompanied by leaching.

The particle size of the soils as shown in Table 2 showed the soils were sandy loams and were therefore better structured. Such soils will allow easy passage of water and will avail the plants nutrients required for their growth. Since the soils have better structure sodium accumulation will not result to impede on internal drainage and affect the free flow of water into the soils. The soils can be used for both dry and wet season agriculture without fear of deflocculating of the soil aggregates likely to affect the internal structure of the soil.

Table 2: Particle size analysis of soils on irrigated fields along River FarinRuwa

Texture	Dry season FarinRuwa	Raining season FarinRuwa
% Sand	73.4	70.9
% Silt	3.1	3.4
% Clay	23.5	25.7
Textural class	SL	SL

SL = Sandy loam

Conclusion

The soils on irrigated farms along River FarinRuwa have shown low concentration of some of the parameters investigated for this study. Sodium in the soil was generally low when compared to ions of magnesium and calcium. The sodium in the soil will not precipitate the ions of magnesium and calcium in such a manner as to impinge on the internal drainage. Salinity built up in the soil as indicated by the electrical conductivity indicates the soil when used for irrigation is likely to affect the osmotic pressure of most plants which will interfere with the uptake of water and nutrients by plants thus leading to low crop yields. The low pH values recorded for the soils implies that solubility in the soil will be affected which will increase leaching and lower nutrient availability to plants. Since the soils are better textured the application of water during irrigation will not result in obnoxious accumulation of substances in the soil to impact negatively on the growth processes of most crops especially with increase in the frequency of application of irrigation water.

Recommendations

Since the soils have been found to be deficient in some of the nutrients necessary for plants growth, there is the need for addition of organic or chemical fertilizers. The addition into the soil of about half a ton of NPK per hectare will greatly enrich the soil with nutrients which are a necessity for plants growth.

Due to the high salinity observed for the soils the increase in the frequency in the application of irrigation water will be of advantage as to leach out the excess salts in the soil root zone.

Further studies should be undertaken on the effect of irrigation on crops in the area to determine the suitability of the crops for human use and precautionary measures to adopt in the use of water for irrigation.

Farmers in the area should be encouraged to engage in both dry and raining seasons agriculture as the soils to a certain level can withstand such practices and as well provide the food requirements of the people in the study area. Farmers in the area should be enlightened on the problems they are likely to face from the use of the soil for crop production and methods to adopt in addressing such problems.

Conflict of Interest

Authors declare that there are no conflicts of interest.

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