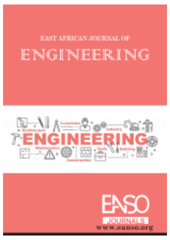

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Original Article

Analysis of the Effect of Thematic Irrigation Schemes on Soil and Water Quality in Butaleja, Uganda

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ABSTRACT

Irrigation processes have been at the forefront of reasons for increased food production. However, the soil and water parameters are areas of focus when considering irrigation. The study aimed to assess the effect of irrigation on soil and water parameters in the Doho irrigation scheme in Eastern Uganda. The methodology used was generally quantitative, following experimental designs. Water and soil samples were picked from randomly selected blocks for experiments conducted directly in the field and in the laboratories. Parameters tested include the pH, Electrical conductivity, salinity, Ca, K and Na among others. Findings revealed that irrigation affected all the parameters either negatively or positively regarding soil and water considerations. Irrigation increased salinity (0.1 – 0.2), electrical conductivity (1.49 – 4.2) and sodium (0.75 – 1.53) levels in soil and water, while prolonged irrigation lowered calcium (2.8 – 3.25) and potassium (0.45 – 0.76) levels. There was no considerable effect on water and soil pH. A variation was recorded in water and soil parameters where the highest concentrations were recorded in water samples. Prolonged irrigation affects water and soil parameters because it causes leaching of soil, causing a high concentration of ions in down layers of soil. Furthermore, the equipment that is often used to construct these schemes is often heavy compacting soil, and resulting oil spills alter physical and chemical properties. The study recommends that there should be continuous assessment of chemical and physical properties for water and soil parameters in Doho and other similar irrigation projects around the globe.

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INTRODUCTION

Agriculture remains Uganda's most important sector through which people are directly or indirectly linked and employed to meet most of their basic needs. In the year 2012/13, employment by the agricultural industry was about 66% of the country's working population, of which three-quarters of the workforce were women (JICA, 2017). In addition, agriculture serves as a major source of raw materials used in the local processing industry. The sector contributes about 40% of the total goods exported, thereby providing a high potential for income generation, eradicating poverty, and furthering economic and social growth. It is important to note that for the agricultural sector to yield satisfactorily, irrigation serves as one of the basic factors that are considered in addition to fertilisers and other factors such as labour. However, water and soil parameters must be well balanced for a better yield, including electrical conductivity (EC), pH, sodium (Na), calcium (Ca), magnesium (Mg) and potassium (K), among others. These parameters have been reported by previous authors to be essential for proper crop growth and are also needed for the physiology of crops.

The agricultural sector has been facing the challenges of low productivity in the past years due to unreliable rainfall conditions (Ahamefule, 2015). In a bid to improve this fundamental sector of the economy, the government of Uganda, through the Ministry of Water and Environment, put up mitigation measures through the construction of a number of irrigation schemes like the Agoro irrigation scheme in Lamwo district, and Doho irrigation scheme in Butaleja district. However, these Schemes are associated with side effects that change water and soil parameters, thereby hindering the quality of rice yields.

Therefore, this study assessed and analysed the variations in the water and soil parameters within the six blocks of the Doho irrigation scheme and further highlighted how distinct they were compared to the recommended amounts of the parameters that enable proper growth of crops within the scheme.

METHODOLOGY

Study Area

The study was carried out in the Doho 1 Irrigation Scheme situated in Mazimasa and Kachonga sub-counties of Bunyole County, Butaleja district, Eastern Uganda. It is located 49 km from Tororo town, 25 km away from Mbale, and about 260 km from Kampala, the capital city of Uganda. The rice scheme is the second largest in Uganda, covering about 2500 hectares of land.

Doho Irrigation Scheme was purposively selected because of its location and its importance as a centre of ecological biodiversity. Being a seasonal wetland, the Doho irrigation scheme supports local communities and sustains about 20,000 rice farmers.

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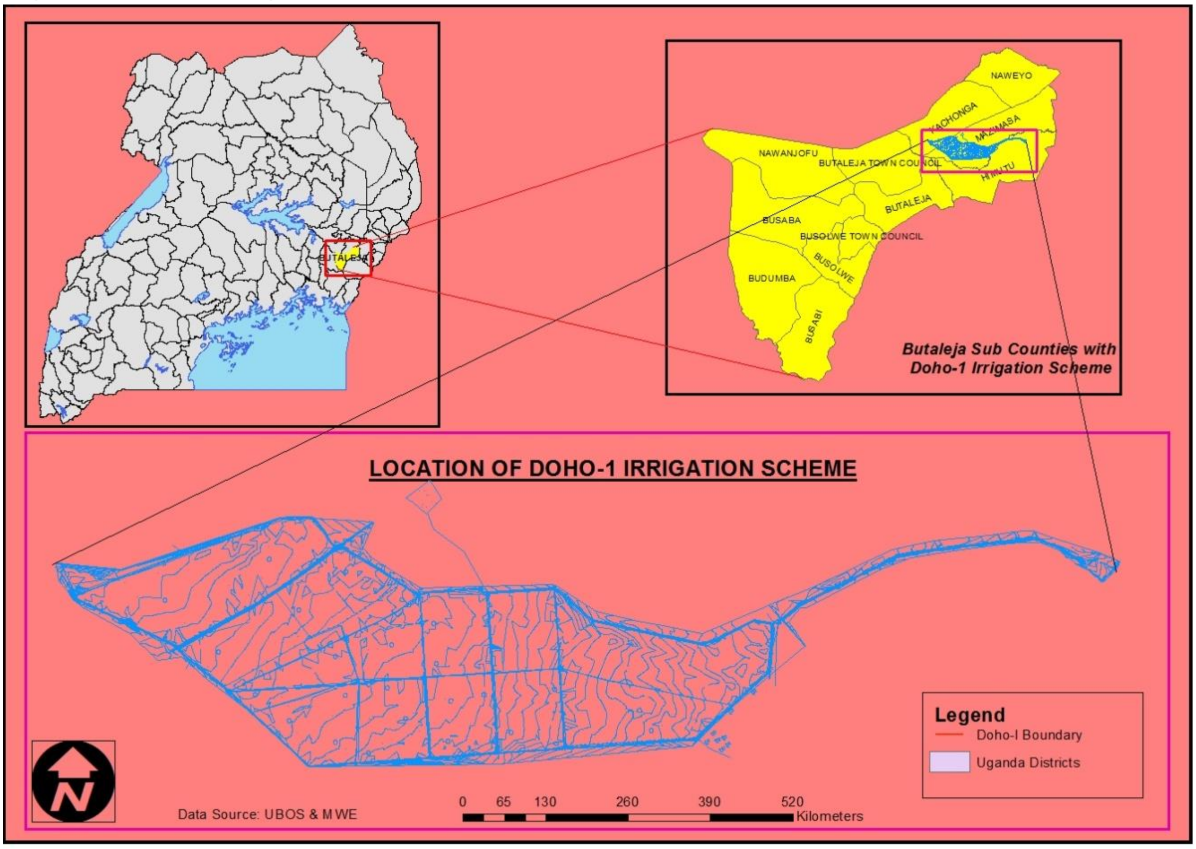
Figure 1: Doho I Irrigation Scheme Location and Soil Pits Distribution Patterns



Sampling Procedures and Data Collection

A completely randomised study design was employed to guide soil and water sampling in the Doho irrigation scheme. Soil sampling was randomly done in all six blocks in the Doho irrigation scheme, taking a minimum of five soil samples from each block. On identification of sites where the soil samples had to be taken, GPS points were recorded. Using soil augers, the soil was picked and packed in a zip lock bag and labelled. The augers were cleaned and sterilised to ensure non-contamination. Sampling was done in triplicates, making a total of three samples from each block. A total of 34 labelled soil samples were transported and taken to the soil Laboratory at Makerere University, Kampala.

On the other hand**, s**ix water samples used for irrigation were collected from the different blocks, and the seventh sample (control) was from the main river (Manafwa) that supplies the scheme with water. These water samples were packaged in clean bottles and taken to the laboratory for testing.

Laboratory Analysis

In the laboratory, the soil samples were air dried, crushed and then tested following standard testing procedures of Rhoades (1996) for these parameters: Electrical conductivity mS/cm, Salinity, Potassium me/litres, Sodium me/litres, Calcium me/litres. Water parameters were tested for the chemical properties. EC; Electrical Conductivity, TSS; Total Soluble Salts, Ca; Calcium; Mg; Magnesium; K; Potassium; Na; Sodium

Data Analysis

The total of 34 samples taken for analysis were averaged, making a total of Six samples, each reading corresponding to a block. Data was treated and tabulated, and the comparisons of Soil and water parameters were also generated using Microsoft Excel.

RESULTS AND DISCUSSION

The results from the laboratory experimentations showed that irrigation had both positive and

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negative impacts on the soil quality. There was a variation in the pH, electrical conductivity, salinity, Potassium, sodium, and Calcium in all the six blocks that were sampled in the Doho irrigation scheme.

The Variations in Soil Parameters in the Doho Irrigation Scheme:

Results indicated considerable variations within the soil parameters in the different blocks in the Doho irrigation scheme (*Table 1*). The results were in line with those of Al-Ghobari (2011), who concluded in a similar study that prolonged irrigation altered the physio-chemical parameters of soil.

Soil pH

There were variations within the pH values in all six blocks, ranging from 5.79 to 6.22. The optimum and recommended pH range is between 5.5 and 7.0 (WHO, 2011), meaning that almost all the soils have a pH within the optimum levels. Moreover, a soil pH between 6.0 and 7.5 is acceptable for most plants (FAO. 2021). This indicated that irrigation showed no significant effect on the PH of the soil. In a similar study by Rodolof (2007), the results of the chemical data showed just a slight change in the PH of non-irrigated soils and irrigated soil (6.13 to 6.45, respectively), and the values were also within the optimum PH for plant growth. It is important to conclude that irrigation has no adverse effect on the soil pH.

Table 1: Chemical properties of irrigated soils of Doho Irrigation Scheme in Butaleja District

Block/ sample sites	pH	EC	Salinity	K	Na	Ca
B1	6.15	197.3	0.01	0.72	1.015	2.8
B2	6.22	247.67	0.01	0.68	0.97	3.25
B3	5.79	241	0.01	0.455	0.75	2.86
B4	5.98	420.09	0.02	0.76	1.17	3.53
B5	6.2	222.05	0.01	0.66	0.79	3.13
B6	5.94	149.53	0.01	0.59	1.53	3.08

Electrical Conductivity (EC) and Salinity

There was a variation in all the blocks, with the highest EC recorded in Block 4 (4.20). The lowest (1.49) was recorded in Block 6. The commended EC value, according to WHO (2011), is between 0.7 to 3.0 uS/cm. The high EC recorded in Block 4 is possibly attributed to the continuous use of artificial fertilisers, oil spills from irrigation equipment and a considerable amount of salts that are often carried by irrigation water. Kachi and others (2016) reported a very high EC value in the study that was carried out in an irrigation scheme in Perimeter, Guelma, Algeria, and the results were attributed to high salts that are usually carried along with irrigation water. Therefore, there is a positive correlation noted between EC and Salinity and was noted in Block 4, where a higher salinity level matched the high EC. No considerable variation in the salinity was reported. This could be attributed to the high salt concentrations within the soil, which increases the Saline concentrations. A study done by Girma, Mohammed Ali, & Gebeyaneh (2016) found a decline of 0.16 g of rice with an increase in salinity of between 0 and 12 dSm^{-1}. For proper rice growth, a salinity of 3 dSm^{-1} is ideal (Grattan, Zeng, Shannon, & Roberts, 2002). Therefore, anything above three dSm^{-1} would lead to poor growth of rice and, hence, a reduction in rice yields. Therefore, there was a significant effect of irrigation on both the EC and the salinity of the soil in the Doho Irrigation Scheme with all its effects on rice yields.

Potassium (K)

The average value of Potassium in the sample of the soil was 0.6 cmol/kg, with the highest potassium value recorded in Block 4. The critical value for soil potassium is 0.5 cmol/kg (WHO, 2011). The results revealed slightly higher potassium values in most of the blocks apart from

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Block 3, which was below the recommended value. Most of the soil samples tested had insufficient levels of Potassium; the only exceptions are those samples with potassium content of less than 0.5 cmol/kg of soil. The high levels of salts are an indicator of salts that continuously build up from either artificial fertiliser application or prolonged irrigation. In this case, salts are carried in the irrigation water and, therefore, a considerable effect of irrigation on the potassium levels within the soil that regulators need to mind.

Sodium (Na)

The average sodium content in the soil was 1.0375 cmol/kg as compared to the critical value of sodium in the soil, supposedly less than 1.00 cmol/kg (WHO, 2011). This implied that apart from soil samples B1, B4, and B6, whose sodium levels were above the critical values, the rest of the soil samples from other blocks had sodium levels within the normal range. There is a considerable negative effect of irrigation on the sodium contents of the soil that needs to be checked.

Calcium (Ca)

The total concentration of Calcium in the different soils varied from 2.86 cmol/kg to 3.53 cmol/kg with an average of 3.10. The critical value for Calcium is five cmol/kg of soil. This shows there were low levels of Calcium in the soil samples. This is due to the fact that prolonged irrigation causes leaching of the soil, causing a high concentration in the down layers of the soil, which makes the elements inaccessible to the plants. Therefore, prolonged irrigation has a significant effect on soil calcium. This may also require deeper excavations and a series of irrigation schedules.

The Variations in Water Parameters in the Doho Irrigation Scheme

The water parameters were also analysed, as observed in *Table 2*. The samples were considered for particular blocks B1-B6 for various tests of parameters like pH, EC, Turbidity, Hardness, Mg, Ca, and Na, among others.

Table 2: Chemical properties of irrigation water of the scheme

Sample ID	pH	EC (uS/cm)	Turbidity (NTU)	TSS (mg/L)	Total hardness (mg/L)	Ca-Hard (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)
B1A-SI	6.3	388	1056	19.6	87	48	19.2	9.36	8	52.6
B2A-SI	7.2	265	44.1	37	185	79	31.6	25.44	4.5	20.8
B3-SI	7.2	196	122	47	108	65	26	10.32	5	14.2
B4-SI	7.3	241	68	61	140	69	27.6	17.04	8.6	47.8
B5-SI	6.9	350.5	1085	25.5	123	73.5	29.4	11.88	7.1	26.9
B6-SI	6.85	290	788.5	34.2	121	69.5	27.8	12.36	4.5	22.85

pH

FAO guidelines recommend a pH range for irrigation water of 6.5 to 8.5 (FAO, 2021). In this study, the pH was between 6.3 and 7.3 for all blocks sampled and within the average recommended normal range. Therefore, the study recommended no adjustments.

Salinity

Electrical conductivity (EC) is the measure of salinity. FAO guidelines recommend an EC of up to 700 µS/cm (FAO, 2021). All the water samples tested had salinity within the normal range.

Total Suspended Solids

The danger with suspended solids is that they cause clogging of the water emitting system. This is in the piped irrigation system, but in Doho,

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where this study was carried out, which uses a flooding system in the rice fields, total suspended solids may not be a serious problem unless a lot of woody and leafy materials are deposited, causing blockage of the water supply canals.

Total Hardness

This is an indicator of the amount of Calcium and magnesium present in water. Water contains salts of Calcium and magnesium, which lead to hardness much as other elements like iron, manganese, aluminium, and zinc can also contribute to the hardness. Both Calcium and magnesium are essential elements for crop growth. A total hardness of up to 500 mg/L is permissible (Selvaraj et al., 1999). The total hardness for all the water samples that were tested was within the normal range.

Calcium Hardness

Calcium is a crop nutrient and therefore, it is desirable for the irrigation water to contain this element. However, its salts could be in concentrations that lead to hardness. The permissible calcium hardness in irrigation water ranges from 40 to 100 mg/L (Selvaraj et al., 1999). Calcium hardness for all the water samples tested was within the normal range.

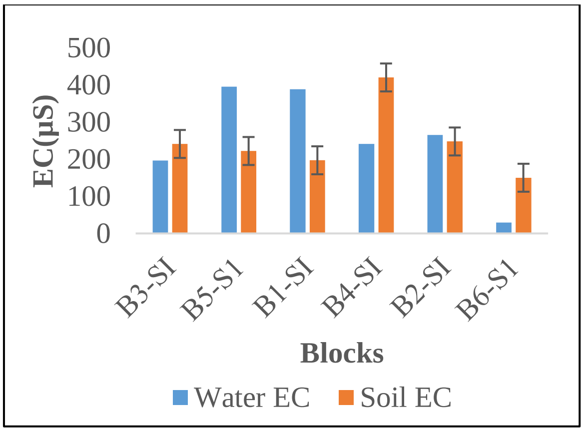
Ca, Mg, K and Na Content

Normal ranges of Calcium, magnesium, Potassium, and sodium are 0-20 me/L, 0-5 me/L, 0-2 me/L and 0-40 me/L respectively (Selvaraj et al., 1999). For all the parameters in all the water samples, the levels were within the normal ranges. Findings showed that the equipment used to construct these schemes is often heavy, hence compacting the soil. More so, resulting oil spills affect the chemical and physical properties of both soil and water at the scheme. The study done by Ahamefule (2015) noted that the major problems facing irrigated land are salinity and sodicity; these cause poor water and nutrient uptake by a plant, which is usually wrongly interpreted as a lack of adequate irrigation or fertilisation. Moreover, Saline conditions reduce the osmotic ability of crops, which inhibits their water absorption abilities, leading to low yields. Oil contains hydrocarbons whose presence directly affects water quality parameters like Biochemical Oxygen Demand (BOD), PH, Turbidity, Electro conductivity, leading to salinity and sodicity (Uhegbu, Elekwa, Iweala, & Kanu, 2011). The BOD refers to the measure of the amount of oxygen required to remove waste organic matter from water in the process of decomposition by aerobic bacteria that live only in environments containing oxygen (USGS, 2018). However, the BOD experiments could not be done because of the lack of some apparatus versus the time factor.

Comparisons of the Soil and Water Parameters within the Doho Irrigation Scheme

Results revealed variations in the soil and water parameters. The concentration of chemicals was very high in the water as compared to that in the soils, as observed in *Figures 2-4*.

Figure 2: Comparisons in water and soil EC and pH, respectively



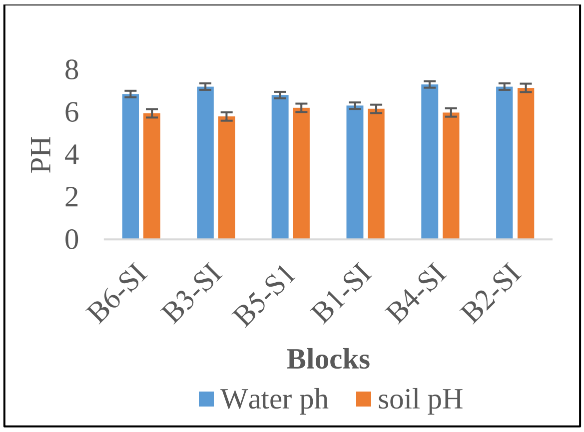
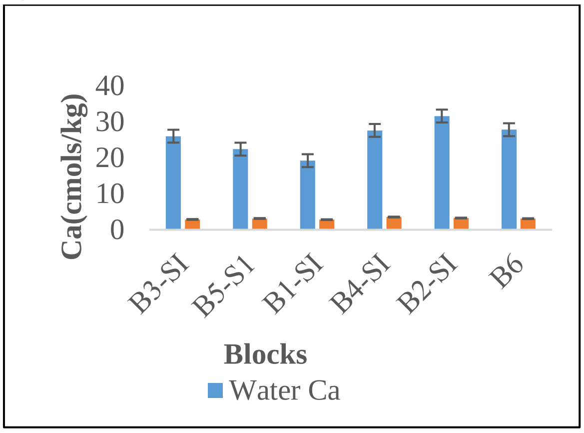


Figure 3: Comparisons in Water and Soil Ca and K Contents



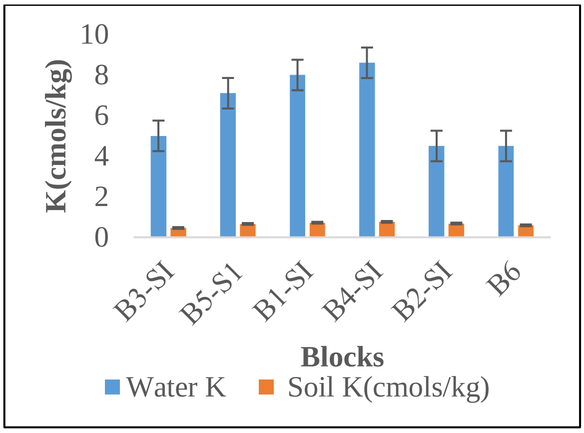
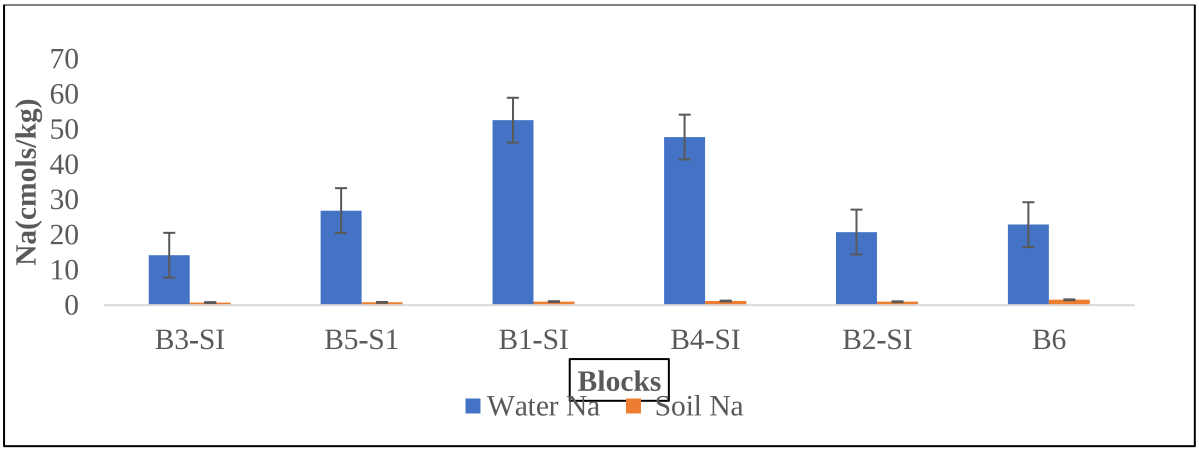


Figure 4: Comparisons in Water and Soil Na, respectively



These variations were attributed to rehabilitation activities that were recently conducted that involved the use of heavy machinery that comes with large oil deposits, hence the higher concentrations in water than in soils.

CONCLUSION

The data indicated variations between water and soil parameters in the irrigation scheme. This was attributed to the rehabilitations that were done on the scheme with the resultant deposition of oil by the heavy mechanisation used. This is in agreement with a study done by (Selvaraj, Pal, Raja-y, & Rawal, 1999; and Uhegbu et al., 2011), which showed that hydrocarbons have an effect on both sodicity and salinity of water. These are often a result of the oil deposits due to heavy machinery used during the rehabilitation of irrigation schemes (Ite, Harry, Obadimu, Asuaiko, & Inim, 2018). At the Doho irrigation scheme, the salinity levels were in line with the required levels for proper rice growth (less than 3 dSm^{-1}), which is ideal for rice growing. Therefore, there is a need to maintain the salinity levels to realise increased rice yields at the scheme.

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