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ASSESSMENT OF SOIL CHEMICAL PROPERTIES OF OKE-OYI IRRIGATION SCHEME FOR SUITABILITY OF AGRICULTURAL PRODUCTION

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ABSTRACT

Irrigation applications have impacts on soil properties and these impacts may be negative on soil, crop and groundwater quality. This could be as a result of the quality of water used, method of application and the nature of the soil viz the chemical composition of the soil. Soil quality analysis at phase 1I of Oke-Oyi irrigation scheme was carried out in the study. Twelve soil sampling points were considered from different locations around the irrigation scheme. Soil samples were collected at the rooting depths (0-20, 20-60 and 60-100cm) of the crops planted making a total 36 samples. The soil samples were collected in October, 2020 through September, 2021 using soil auger. A random sampling method was used to sample soil and the soil samples were taken to the laboratory for chemical analysis. The chemical analysis results revealed that the soil pH of the baseline data (2013) and the field data were moderately acidic to neutral. The pH of both baseline (2013) and field data ranged from 5.30 to 6.87 and 5.12 to 6.81, respectively. The average organic carbon (OC) for both baseline and field data ranged from 0.14 to 0.27% and 0.12 to 0.20% of the entire soil nutrients relating to soil fertility. There is a little decrease in the level of organic carbon compared with the baseline data. Available phosphorous content of the soil is high and larger from 20.276 to 28.342mg/l for the baseline data (2013) and for the field data, it ranged from 18.20 to 22.01mg/l. Sodium, which determines the sodicity status of a soil is generally low for both baseline and field data, and ranged from 0.15 to 0.65me/l and 0.12 to 0.47me/l, respectively. The exchangeable sodium percentage (ESP) value of both baseline and field data ranged from 5.90 to 10.0% and 2.63 to 9.06%, slightly decreased for both data. The calcium in the soils is generally moderate and ranged from 4.36 to 6.22me/l and 2.86 to 4.16me/l for both baseline and field data, respectively. Magnesium which has been the dominant cation in the study ranged from 1.16 to 2.26me/l and 1.09 to 2.11me/l for both baseline and field data. The organic matter of the soil is moderate for both baseline and field data, ranging from 0.13 to 0.17% and 0.11 to 0.16%, respectively, due to rapid rate of organic matter decomposition as a result of available moisture during irrigation. The cation exchange capacity (CEC) of the soil for both data ranged from 4.76 to 5.52me/l. The sodium adsorption ratio (SAR) ranged from 0.10 to 0.32 meg/l. In 2011, rice yield decreased from 85,000 kg to 77,000 kg in 2012 and subsequently, decreased to 70,000 kg in 2013. Therefore, the study concluded that there is a need for proper monitoring of the soil condition in the irrigation scheme to prevent further deterioration of the soils since some changes have been observed compared to the baseline data.

Keywords: Practice, Chemical Properties, Soil Samples, Crop Yields, Soil Sampling

1.0 INTRODUCTION

Irrigation, if done in an environmentally sustainable way, not only helps to overcome the problems of rainfall shortage and variability, but also plays a vital role in combating nutrition insecurity (Domènech, 2015). Applying water to the soil to provide the moisture necessary for plant growth is known as irrigation. Nigeria's irrigation schemes are growing quickly as a result of the country's growing population and consequent demand for more food. The introduction of irrigation schemes was prompted by the need to feed and raise the standard of living for the growing human population. This has raised the farmer's economic standard of living and made it easier to cultivate the same area twice or more in a year (Maina *et al.*, 2012). Irrigation development and practices were observed variously to bring about changes in soil of schemes, ecology, humans and the environment. Some of these changes were positive, while others were adverse and have led to deterioration or even degradation of such schemes (Adejumobi *et al.*, 2022). The adverse impacts of salinization, which includes potential salt accumulation in the soil, are frequently caused by the use of irrigation water for agricultural cultivation. Potential physical degradation of the soil, such as a decrease in the amount of organic matter and a loss of soil structure. Overuse of inorganic fertilizers on the field may be the cause of an increase in the salinity and alkalinity levels of irrigation soil. A soil's fertility can be strongly inferred from its chemical characteristics (Dikko *et al.,* 2010).

Certain soil attributes are useful markers of soil quality such as; Cation exchange capacity (CEC), soil organic matter (OM) and organic carbon (OC), exchangeable sodium percentage (ESP), electrical conductivity (EC), salinity and sodicity status, calcium (Ca), and magnesium (Mg) (Adejumobi *et al.*, 2014). The continuous use of soil for irrigation activity without careful quality assessment and monitoring will rise to accumulation of salts on the soil and consequently affects the crops potential yield. The establishment of irrigated agriculture in the study area is vital to enhance crop productivity to attain food sufficiency. But, in a long run, may have adverse effect on the soil physical and chemical properties, fertility and sustainable productivity since it has not been well monitored. The study therefore focus on monitoring the soil conditions under irrigation practice at Oke-Oyi phase II Irrigation Scheme with particular emphasis on some chemical properties to guide against soil fertility deterioration between previous (baseline; 2013) and current data (2021).

2.0 METHODOLOGY

2.1 Description of the Study Area

Oke-Oyi Irrigation Scheme of the Lower Niger River Basin Development Authority (LNRBDA) is situated at Ilorin-East LGA of Kwara State, Nigeria. Oke-Oyi is the head quarter of Ilorin East Local Government Area of Kwara State, which is around 25 km away from Ilorin town along old Ilorin-Jebba Road. The irrigation project location is situated between Greenwich Meridian latitudes 8^o 37.322' N and 8^o 37.781' N and longitudes 4^o 45.893' E and 4^o 46.027' E (LNRBDA, 2012). The 50 hectares of land that make up the irrigation project site were split into Phase II (30 ha) and Phase III (20 ha). Arable crops with surface areas of 12.5ha, 10ha, and 7.5ha were cultivated in Phase II, including rice, maize, and okra. As seen in Figure 1, this small-medium irrigation scheme used a basin irrigation system to feed water to the field from the rectangular weir on the scheme's opposite side.

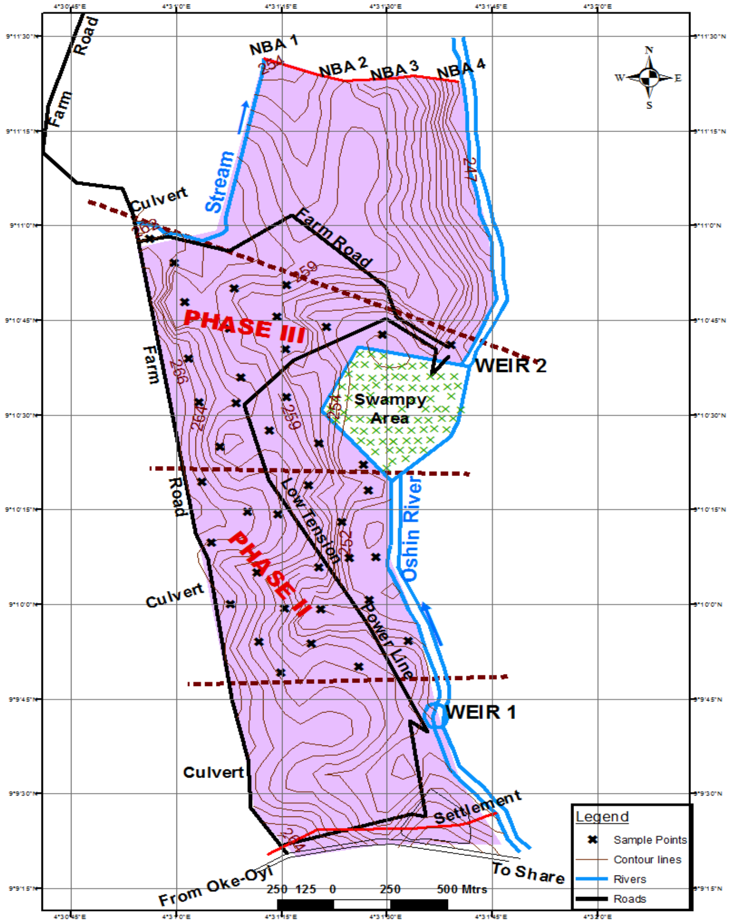

Figure 1: Map of Oke-Oyi Irrigation Scheme Showing the Soil Sampling Points. *Source: LNRBDA, 2012*

2.2 Soil Sampling Method

Twelve soil sampling points were considered from different locations around the irrigation scheme. Soil samples were collected at the rooting depths (0-20, 20-60 and 60-100cm) of the crops planted on the field making a total 36 samples. The soil samples were collected in October, 2020 through September, 2021 using soil auger. A random sampling method was used to sample soil and the soil samples were taken to the laboratory for analysis.

2.3 Soil Analysis Methods

For chemical analysis, the following techniques were used:

(i) A pH meter was used to measure the pH of the soil in soil-water and soil-KCL filtrates.

(ii) Total exchangeable sodium was divided by the cation exchange capacity and multiplied by 100 to determine the exchangeable sodium percentage (ESP).

(iii) The Walkley-Black wet digestion method was used to calculate the proportion of organic carbon (OC).

(iv) The organic matter (OM) was calculated using the formula OM = OC x 1.723.

(v) Following extraction with neutral ammonium acetate, the exchangeable cations (Ca, Na, and Mg) were measured using a flame analyzer.
(vi) The Bray I method was used to determine available phosphorus.
(vii) After successive leaching with ammonium acetate, 95% ethanol, and potassium chloride, and distillate collected over 2%, CEC was measured titrimetrically.

2.4 Statistical Analysis Method

A two-factor (basin irrigation system and crop rooting depth) factorial with a spatial covariance structure was used to analyze nine response variables (pH, Mg^{2+}, Ca^{2+}, Na^{+}, OC, OM, P, ESP and CEC) recorded at the three levels of crop rooting depths (0-20, 20-60, and 60-100 cm). Because the soil samples from the three crop rooting depths were expected to be correlated, the analysis requires a spatial covariance structure. This means that if a response measurement is high on the surface at a particular sampling location, it is also expected to be relatively high in the subsurface soil. A normal distribution with constant variance was the independence assumption on the error terms in such measurements (Montgomery, 2017).

3.0 RESULTS AND DISCUSSION

3.1 Results of Soil Chemical Analysis

The results of the average soil chemical analysis for the study from October 2020 through to September, 2021 and the baseline data (2013) are presented in Table 1 and 2.

Table 1: Results of the Average Chemical Analysis of the Field Soil Samples

S/N	Parameter	0-20cm	20-60cm	60-100cm
1	pH	6.34	5.12	6.81
2	Mg^{++} (me/l)	1.24	1.09	2.11
3	Ca^{++} (me/l)	3.21	2.86	4.16
4	Na^{+} (me/l)	0.21	0.12	0.47
5	OC (%)	0.20	0.12	0.19
6	OM (%)	0.12	0.16	0.11
7	P (mg/l)	20.21	22.01	18.20
8	ESP (%)	9.06	5.86	2.63
9	CEC (me/l)	5.23	3.62	4.56

Table 2: Results of the Average Chemical Analysis of the Baseline Data

S/N	Parameter	0-20cm	20-60cm	60-100cm
1	pH	6.52	5.30	6.87
2	Mg^{++} (me/l)	1.36	1.16	2.26
3	Ca^{++} (me/l)	5.25	4.36	6.22
4	Na^{+} (me/l)	0.25	0.16	0.65
5	OC (%)	0.23	0.14	0.27
6	OM (%)	0.17	0.16	0.13
7	P (mg/l)	28.34	26.06	20.28
8	ESP (%)	10.00	9.11	5.90
9	CEC (me/l)	5.34	4.76	5.52

The soil pH is a measure of soil acidity and alkalinity. Soil pH of the baseline data (2013) and the field data were moderately acidic to neutral as given by Hart *et al.,* (1999) in Table 3. The pH of both baseline (2013) and field data ranged from 5.30 to 6.87 and 5.12 to 6.81, respectively;

indicating a decrease from 0 to 20cm to 20 to 60cm soil depth and subsequently tending towards neutral.

Table 3: Soil pH ranges

S/N	Ranges	pH
1	Strongly acidic	Below 5.1
2	Moderately acidic	5.2-6.0
3	Slightly acidic	6.1-6.5
4	Neutral	6.6-7.3
5	Moderately alkaline	7.4-8.4
6	Strongly alkaline	Above 8.5

Source: Hart *et al.*, 1999

As shown in Figure 2, the minimum and maximum soil pH values for baseline and field data are; 5.30 and 5.12, and 6.87 and 6.81, respectively. However, both results of soil pH are not far from each other at all depths and indicate moderate to slightly acidic symptom, calling for careful management and monitoring. According to United State Department of Agriculture (USDA), too high or too low soil pH leads to deficiency of many nutrients, decline in microbial activities, decrease in crop yield, and deterioration of soil health. Therefore, the soil is thus suitable for crop growth.

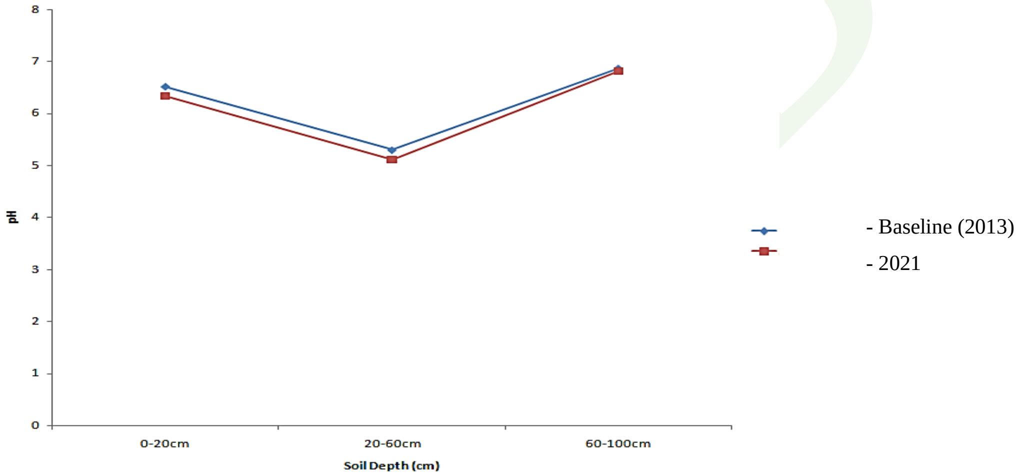

Figure 2: The Soil Available pH at Three Soil Depths

The average organic carbon (OC) for both baseline and field data ranged from 0.14 to 0.27% and 0.12 to 0.20% of the entire soil nutrients relating to soil fertility. According to Velayutham (2006) the organic carbon for the soil is considered high if it is within the range of 0.96 to 1.08 %. It is observed from Figure 3 that the level of organic carbon has decreased from surface depth (0 – 20cm) to the second depth (20-60cm) and sharply increased from second depth (20 – 60cm) to third depth (60 – 100cm) of the soil depths at both baseline (2013) and field data for year 2021. In the year 2021, there is a little decrease in the level of organic carbon compared with the baseline data. However, irrigation has positive effect corresponding to increase in the organic carbon levels of the current soil status.

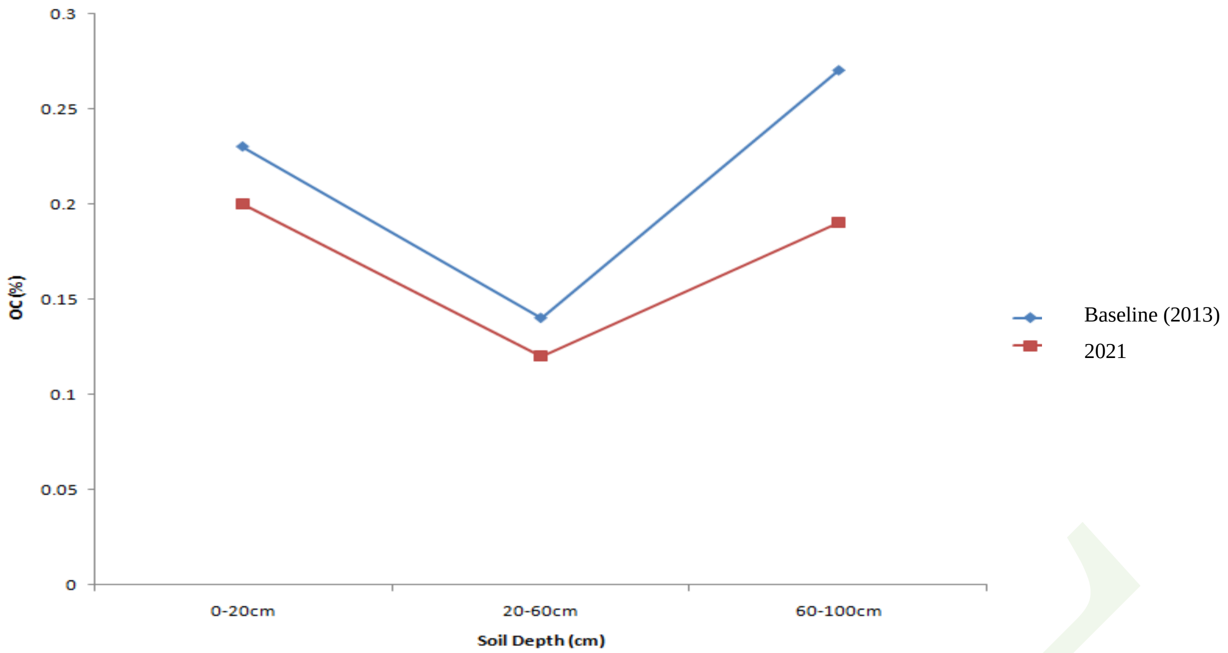

Figure 3: The Soil Available Organic Carbon at Three Soil Depths

Phosphorus is an essential macro-nutrient which is relatively needed by crops in large quantity for proper growth and development. The different levels of the soil phosphorous at both baseline and year 2021 on the soil at three depths are shown in Figure 4. Available phosphorous content of the soil is high and larger from 20.276 to 28.342mg/l for the baseline data (2013) and for the field data, it ranged from 18.20 to 22.01mg/l. In the year 2021, there is a little decrease in the level of phosphorus compared with the baseline data. However, the soil will be good for crop that required much phosphorus.

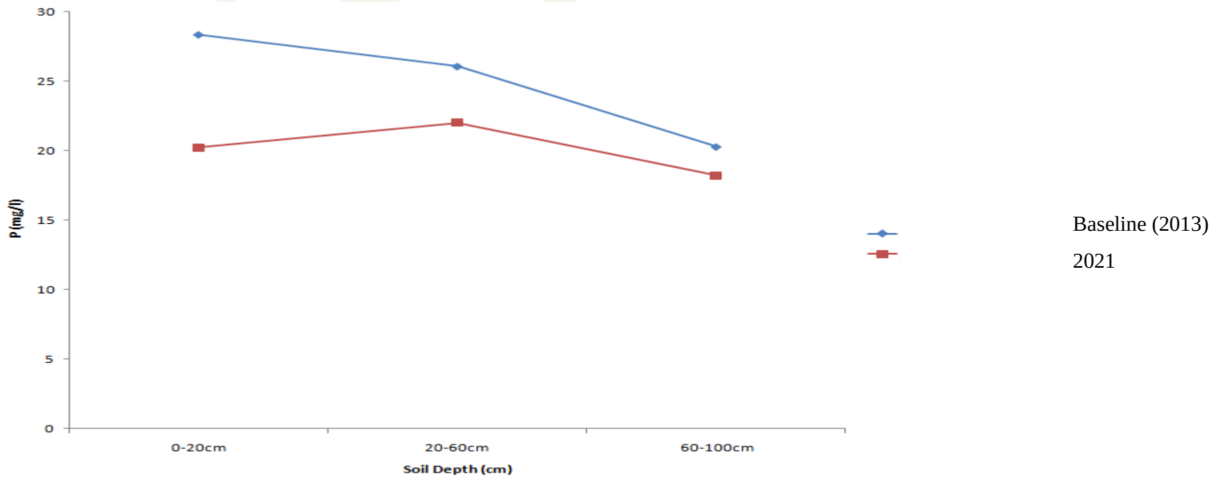

Figure 4: The Soil Available Phosphorous at Three Soil Depths

Sodium, which determines the sodicity status of a soil is generally low for both baseline and field data, and ranged from 0.15 to 0.65me/l and 0.12 to 0.47me/l, respectively. It is observed from Figure 5 that the level of sodium in both baseline and field data slightly decreased from soil surface depth (0 – 20cm) downward to the second depth (20-60cm) and also slightly increased to the third depth (60 – 100cm). In the year 2021, there is a little decrease in the level of sodium compared with the baseline data. The low sodium level trends in the soils indicates a non-sodic status of the soils and thus good for irrigation (Joseph *et al.*, 2014).

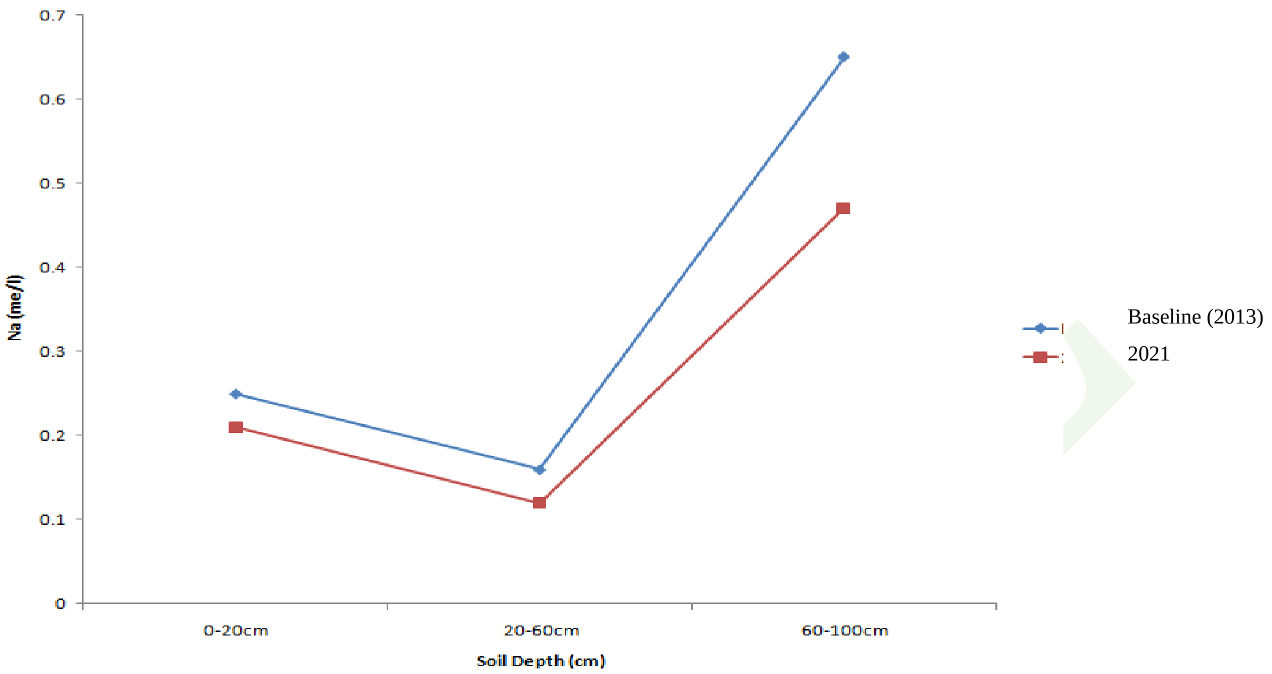

Figure 5: The Soil Sodium at Three Soil Depths

Exchangeable sodium percentage (ESP) gives the measure of the potential sodium problem and is the percentage of sodium ions out of the total base cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) (Marx *et al.*, 1997). ESP value of both baseline and field data ranged from 5.90 to 10.0% and 2.63 to 9.06%. It slightly decreased for both data from soil surface depth (0-20cm) to the second depth (20-60cm) and decreased sharply to the third depth (60 – 100cm) as shown in Figure 6. In the year 2021, there is a sharp decrease in the level of ESP towards the second and third soil depths compared with the baseline data. ESP has not exceeded 10% which could result to problem on the soil. The implication of a high ESP value on the soil is soil deterioration or damage and unhealthy soil condition as stated by Marx *et al.* (1997). The excessive sodium levels that occurred in the soils may be due to irrigation water with high sodium content.

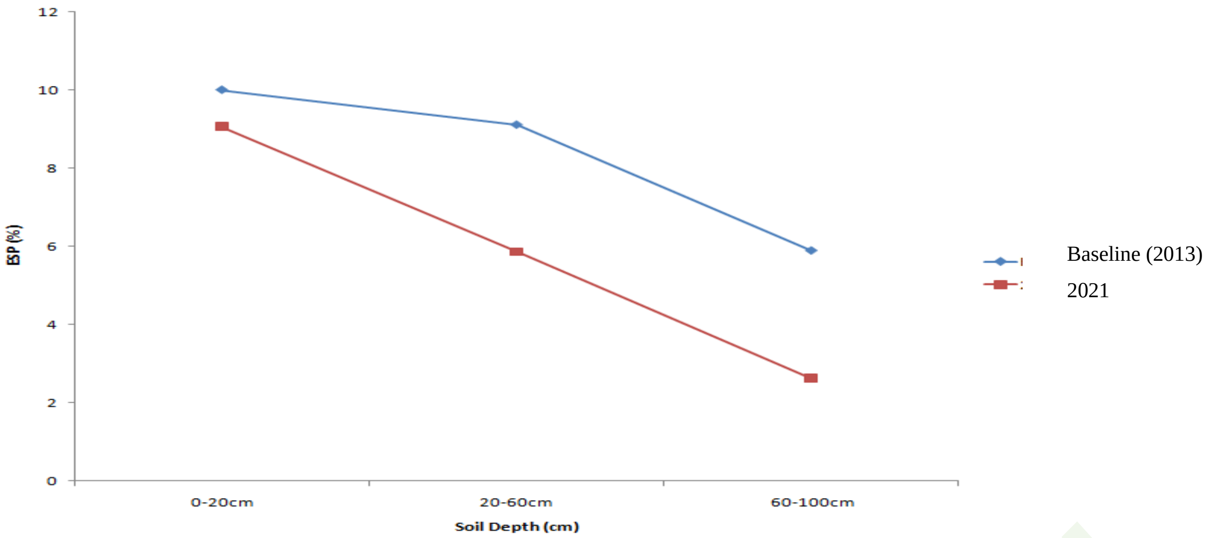

Figure 6: The soil ESP at Three Soil Depths

The calcium in the soils is generally moderate and ranged from 4.36 to 6.22me/l and 2.86 to 4.16me/l for both baseline and field data, respectively. It can be deduced from Figure 7 that there is a decrease in the calcium levels from the soil surface depth to the second depth (20 – 60cm) and subsequently increased to the third depth (60 – 100cm) for both data. In the year 2021, there is a sharp decrease in the level of calcium at all soil depths compared with the baseline data. The decrease may be as a result of leaching of such element during irrigation. This increase could be related to the increase in pH observed which tending towards moderate to slightly acidic. It indicates that irrigation has led to increase in calcium level of the soil.

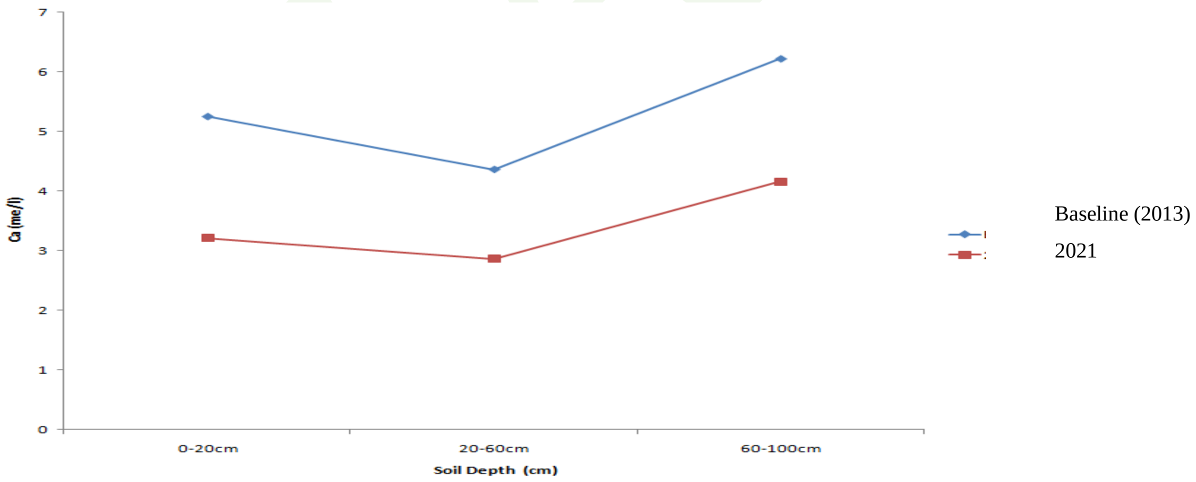

Figure 7: The soil Calcium at three soil depth

Magnesium which has been the dominant cation in the study ranged from 1.16 to 2.26me/l and 1.09 to 2.11me/l for both baseline and field data. In Figure 8, magnesium levels for both data slightly decreases from soil surface depth (0 – 20cm) to the second depth (20 - 60cm) and increased sharply from the second depth to the third depth (60 – 100cm). In the year 2021, there is a little decrease in the level of magnesium compared with the baseline data. Magnesium is one of the secondary macronutrient required by plant, it deficiency causes leaf yellowing with brilliant tints (Yin, 2008).

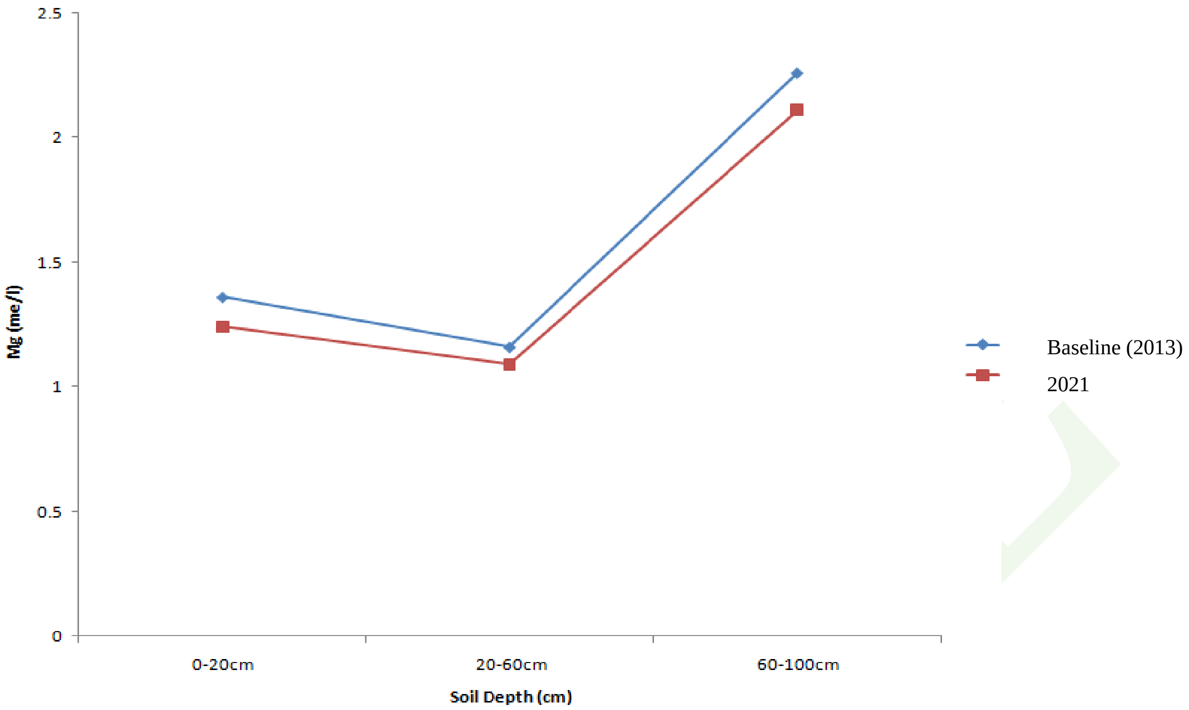

Figure 8: The Soil Magnesium at Three Soil Depths

The organic matter of the soil is moderate for both baseline and field data, ranging from 0.13 to 0.17% and 0.11 to 0.16%, respectively, due to rapid rate of organic matter decomposition as a result of available moisture during irrigation. However, in considering the current state of the soil for the field data at all the soil depths, there is decrease in organic matter levels compared to the baseline data except at the second soil depth (20 - 60cm) which equates to the baseline data as shown in Figure 9. This indicates that continuous irrigation practices have contributed to decline in organic matter level of the soil.

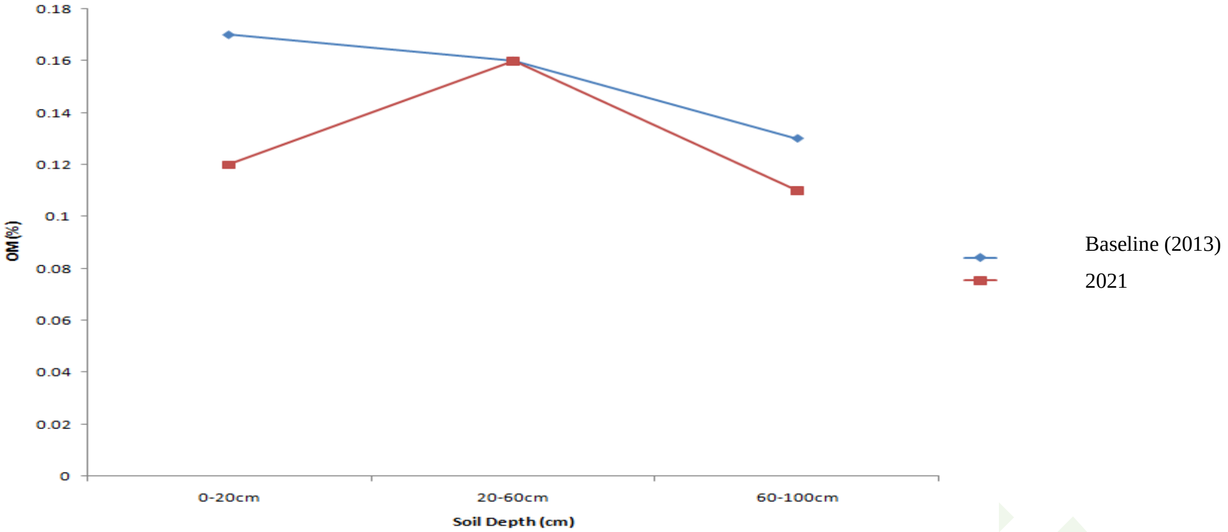

Figure 9: The Soil Organic Matter at Three Soil Depths

Cation exchange capacity (CEC) is a measure of soil capacity to retain and release element such as Ca, K, Mg, and Na (Marx *et al.,* 1999). It is used as one way of estimating soil fertility and a good indicator of soil quality and productivity. It is observed that the CEC value has increased from the soil surface depth (0 – 20cm) to the second depth (20 – 60cm) and a rapid decrease occurred from second depth to the third depth (60 – 100cm) as shown in Figure 10. It ranged from 4.76 to 5.52me/l. In the year 2021, there is a sharp decrease in the level of magnesium from first depth to the third depth compared with the baseline data. The marked decrease indicates that irrigation has contributed to decrease level of CEC.

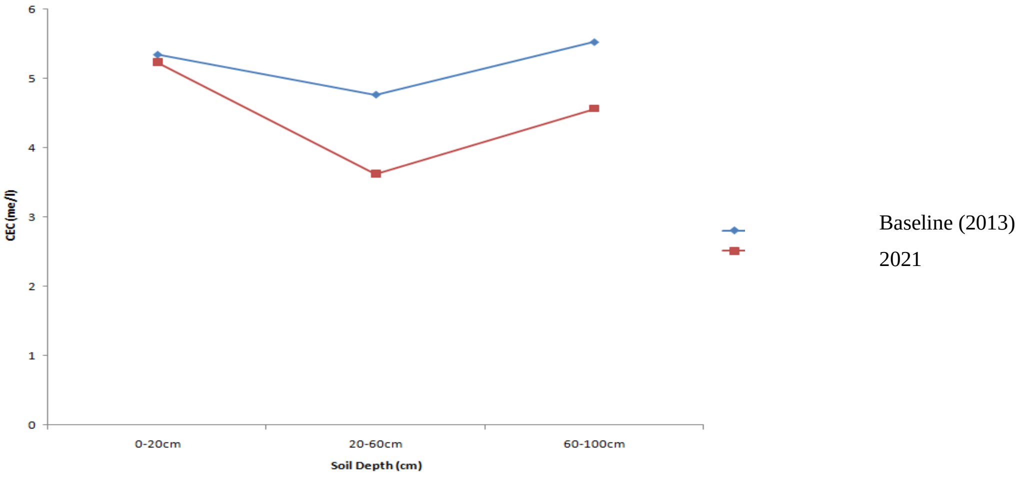

Figure 10: The soil CEC at Three Soil Depths

3.2 Comparison of Irrigation System and Crop Rooting Depths

Table 4 illustrates the significance of the interaction effects between crop rooting depths and irrigation system on the nine response values.

Table 4: P-Values for the Interaction Effect of Irrigation System and Crop Rooting Depths

Effect	pH	Na^+	Ca^{2+}	Mg^{2+}	OM	OC	CEC	P	ESP
Irrigation	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Depth	0.004	0.023	0.012	0.016	0.020	0.031	0.011	0.024	0.018

There was a significant interaction effect on pH (p-value = 0.004), Na^+ (p-value = 0.023), Ca^{2+} (p-value = 0.012), Mg^{2+} (p-value = 0.016), OM (p-value = 0.020), OC (p-value = 0.031), CEC (p-value = 0.011), P (p-value = 0.024) and ESP (p-value = 0.018), indicating that crop rooting depths and irrigation system variations were inconsistent at both surface and subterranean depths.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The study has assessed the effect of soil properties for sustainable agricultural production for proper monitoring of the soil conditions under irrigation practice with particular emphasis on chemical properties to guide against soil fertility deterioration between previous (baseline; 2013) and current data (2021). There exists a considerable variation between the average soil chemical analysis in the study and baseline data. The test of significance shown that all the nine response variables were significantly affected by either irrigation system or crop rooting depths with p-values < 0.1.Generally, the analysis indicated that there is a need for proper monitoring of the soil condition in the irrigation scheme to prevent further deterioration of the soils since some changes have been observed compared to the baseline data.

4.2 Recommendations

Frequent soil monitoring and analysis should be carried out in about five year's interval; since some soil parameters change quickly and will serve as a pointer to efficient fertility evaluation.

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