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Effects of Irrigation Practices on Some Soil Chemical Properties on OMI Irrigation Scheme

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ABSTRACT
Irrigation practices have been observed to impact scheme soil properties and other parameters negatively. These could be as a result of irrigation water quality, method of application and nature of scheme soil. This study was therefore conducted to study the effects of irrigation practices on the soils of Omi irrigation scheme Kogi state, Nigeria after 13years of operation. Soil samples were taken at depths 0 – 20 cm (A1), 20 – 80 cm (A2) and 80 – 120 cm (A3) from two operating lands (OL); OL 5 and OL 18 of the study area. The samples were analysed for chemical parameters (pH, CEC, ESP, Mg^{2+}, Ca^{2+}, OM, and OC). The soil pH which was in the neutral range (pH=6.65 to 7.00) at inception of scheme, has become slightly acidic (pH=6.53 to 6.60). Cation exchange capacity (CEC) levels have also increased from 10cmol$_{+}$kg^{-1} to 35cmol$_{+}$kg$^{-1.}$ While Organic matter (OM) and Organic carbon (OC) also have marked increase in their levels (baseline as 0.93 to 1.08; for year 2013 as 9.52 to 9.79). Generally, the analysis indicated a need for proper monitoring of the scheme soil to prevent further deterioration.
Keywords-irrigation, impacts, salinity, ground water, chemical properties

I. Introduction

Irrigation is defined as the application of water to the soil for the purpose of supplying moisture essential for plant growth. Globally approximate, 1,260 million hectares of land are under rain fed agriculture, which corresponds to 80% of the world's total cultivated land and supplies 60% of the world's food; while the 277 million hectares under irrigation, (20% of cultivated land), contributes the other 40% of the food supplies and on the average ([1]). It was also observed that on the average irrigated crop yield is 2.3 times higher than those from rainfed. Several researchers have also reported similar trends of increased productivity as a result of irrigation practices ([1], [2], [4]). This therefore demonstrates that irrigated agriculture will continue to play an important role as a significant contributor to the world's food and fibre production. Increase in the world population, and the need to expand agricultural land under cultivation and irrigation. The threat of climate change therefore arises.

However, it has been estimated that up to 20% of irrigated lands in the world are affected adversely by different levels of salinity and sodium contents. In Iran, about 15% of lands, which is about 25 million hectares, are suffering from salinity, including 0.32 million hectare of lands in Isfahan province ([2]). Others reported that high concentrations of soluble salts in the root zone are detrimental to plant growth particularly because water availability is reduced ([3], [4], [5], [6] [7]). Meanwhile, some soil properties are good indicators of soil quality as they contribute to the biological, physical and chemical properties of the soil. These include 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) mineral nutrients.

It therefore becomes necessary that, since soils of various schemes have been observed to be adversely affected by irrigation practices, the soil of Omi Irrigation Scheme needs to be monitored to ensure sustainability and deal with fluctuations in the scheme soil quality. This study was thus conducted to monitor the soil conditions with particular focus on the chemical properties under basin method of irrigation practice to guides against destruction and deterioration of the scheme soil from 2000 (baseline) to 2013 as the years under consideration. The method of irrigation commonly used on this scheme is the Basin surface irrigation for the production of maize, pepper, okro and garden egg.

II. Materials and Methodology

2.1 Location of Study Area

Omi Irrigation Scheme is located in Yagba West Local Government Area of Kogi State, Nigeria. It is about one hundred and forty six kilometres (146 km) from Ilorin, the capital of Kwara State (longitudes 6^{o} 37^{1}and 6^{o}42^{1} East and latitudes 8^{o} 34^{1} and 8^{o} 38^{1}North).The irrigation network consists of a main canal and about 300 km length of feeder canals and complimentary drainage lines. The slope of the land is gentle, thus enhancing water flow by gravity to various fields for irrigation purposes. Although, the dam was designed to serve purposes such as irrigation of farmlands, generation of hydropower and its supply, but its use had been restricted to the irrigation of farmlands ([8]).

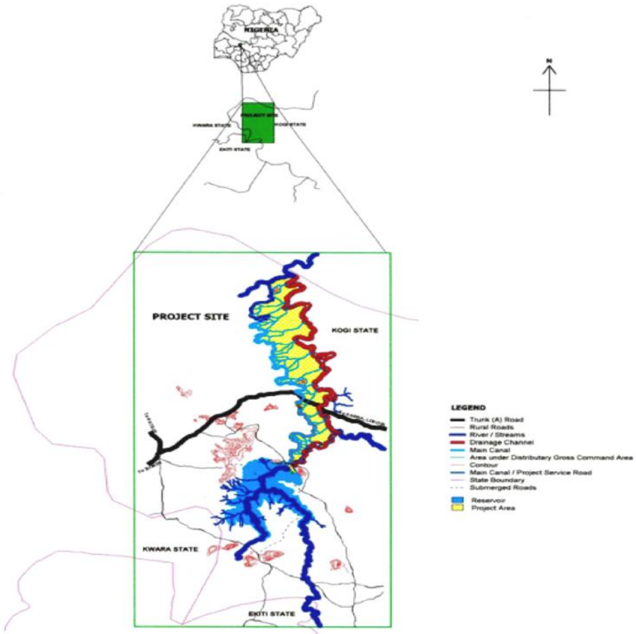

Figure 1: Location map of Omi irrigation scheme. Source:[8]

Soil sampling

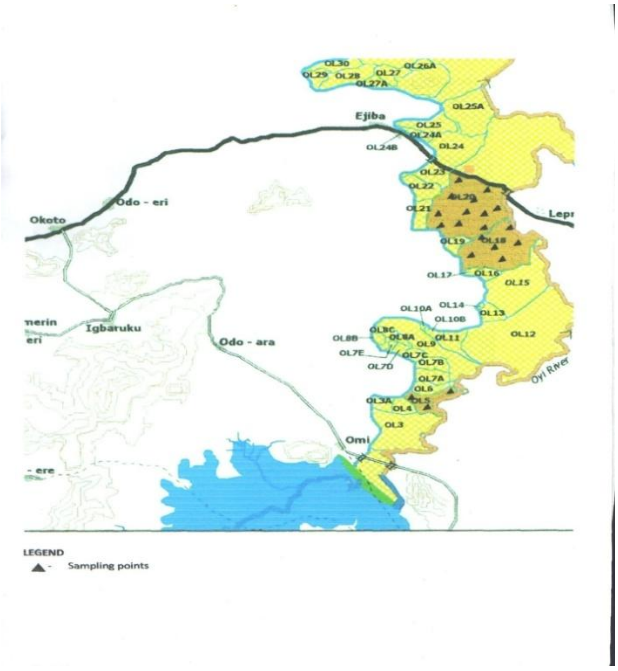

Figure 2: Soil sampling points on OL5 and OL18 at the Omi Irrigation scheme

Soil samples were collected scheme from two operating lands (OL); OL 5 and OL 18 of the study area. Samples were taken at depths 0 – 20 cm (A1), 20 – 80 cm (A2) and 80 – 120 cm (A3) which correspond with the depths in the available baseline data and the rooting depth of crops in the field. OL 5 was used as the control area, since there was no irrigation practice on it while on OL 18 was used as experimental site since this is continuously irrigated. Random sampling approach by following a zig-zag pattern across the field was used in collecting soil samples at different sampling points at the required depths. Thirty – three (33) samples were collected from the scheme in labelled polythene bags. These samples were taken to the Lower Niger River Basin Authority, Ilorin, Kwara State laboratory for analysis.

The chemical properties analysed include; pH, CEC, ESP, OM, OC, Ca, and Mg. Soil pH which is probably the most commonly measured soil chemical property indicates acidity or alkalinity of the soil. It is also an excellent indicator of a soil's suitability for plant growth which in turn affects the availability of nutrients to the crop. However crops vary in their acidity tolerance, growing best in a narrow pH range, while the desirable pH range for optimum plant growth also varies among crops.

Cation exchange capacity (CEC) is an estimate of the capacity of soil to hold or adsorb positively charged nutrients known as cations. The major soil cations include: calcium (Ca^{2+}), potassium (K^{+}), sodium (Na^{+}), magnesium (Mg^{2+}), hydrogen (H^{+}) and aluminum (Al^{3+}). It is primarily influenced by soil type, pH levels and amounts of organic matter, hence, the higher the CEC, the more the clay and organic matter content present in the soil.

Exchangeable sodium percentage (ESP) gives a measure of the percentage of sodium ions out of the total base cations. It is recognized in scientific literature as one of the indices of salinity with a reported threshold of 15% ([9]). When ESP=15 the critical values of ESP above which most crops are affected, causing changes in soil slow infiltration which in negative to crop growth ([10]).

Soil organic matter (OM) is the organic fraction of the soil that is made up of decomposed plant and animal materials as well as microbial organisms, without involving fresh and un-decomposed plant materials, such as straw and litter, lying on the soil surface ([11]). The decomposition makes certain nutrients such as nitrogen, phosphorus and a range of other nutrients available for plant growth. Organic Matter also acts as buffer against toxic and harmful substances (i.e.) lessen their effects. Soil organic carbon (OC) is the carbon associated with soil organic matter. It promotes soil structure by holding the soil particles together as stable aggregates and improves soil physical properties such as water holding capacity, water infiltration, gaseous exchange, root growth and ease of cultivation. The actual amount of OC present in the soil is a function of a number of factors; rainfall, temperature, vegetation and soil type.

Calcium (Ca^{2+}) is a secondary macronutrient required by plants, important for cell nutrition, improving plant absorption of other nutrients and making plants respond better to environmental and disease stresses. It was stated the beneficial use of calcium in the soil; soil structure stabilization and combating of soil acidity ([12]). It is also observed that soils that are acidic are usually deficient in calcium. Calcium availability is closely related to soil pH. Magnesium (Mg^{2+}) is another secondary macronutrient required by plants, vital for chlorophyll production or plant photosynthesis. It helps legume nodules fix nitrogen; moves phosphorus within the plant and in important for enzyme reactions. Magnesium deficiencies in different plants are shown by different symptoms ([12]).

The methods used in determining the chemical properties include: pH was determined with pH meter E520 using 1: 25 (soil to water ratio) as described by ([13]).CEC was determined titrimetrically, following sequential leaching with ammonium acetate (saturation solution), 95% ethanol and potassium chloride; and distillate collected over 2% ([14]). Exchangeable sodium percentage (ESP %) was obtained by dividing total exchangeable sodium by the cation exchange capacity (CEC) multiplied by 100 ([15]). Organic carbon (OC) expressed in percentage was determined using the Walkley-Black wet digestion method ([15]) and organic matter (OM) in percentage was done by calculating ([16]);

$$OM = OC \times 1.723$$

Atomic Absorption Spectrophotometer (AAS) was used in determining calcium (Ca) and magnesium (Mg) as detailed by ([17], [18]).

The baseline data of 2000 were obtained from Afremedev consultant services, Abuja, Nigeria for comparison with the current data (2013) from this research.

III. Results and Discussions

The following results were obtained from the analysis carried out.

The pH in the control field (OL5) indicates a general decrease at all depths between the current and baseline data. Decrease at an A1 and A2 being greater than A3 **(**Fig 1a). However results of soil pH on irrigated land indicate a decrease in A1, an increase in A2 and an almost will change at A3. However all results of pH at all level indicate acidity symptom, calling for careful management and close monitoring. The pH in the irrigated field(OL18) Fig 1b, the depth A2 is in the neutral range while depths A1 and A3 falls within the moderate and slightly acidic range. This, therefore makes the soil pH range for the operating lands to be in the slightly acidic and neutral range as given by ([19]) and thus suitable for crop growth. United State Department of Agriculture (USDA) also concluded that too high or too low pH leads to deficiency of many nutrients, decline in microbial activities, decrease in crop yield, and deterioration of soil health.

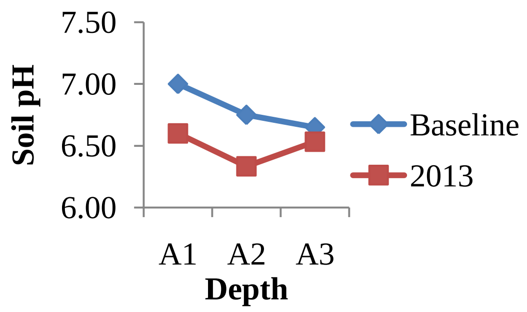

Figure 1a: Chart of pH with depth for OL 5

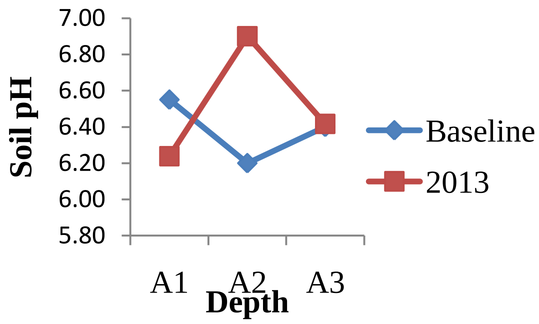

Figure 1b: Chart of pH with depth for OL 18

CEC: The CEC results obtained are as indicated in fig 2a and 2b, for OL5 depths A1 and A3 had an increase in CEC levels but a wide increase of up to 28.39 $cmol_+kg^{-1}$occurred in depths A1 and A3 with depth A2 still with a difference of 1.42$cmol_+kg^{-1}$ for the current data (2013). Meanwhile, from Fig 2b, It was observed that CEC increases with depth in the irrigated land, marked increase occurs at depth A2. These indicate that irrigation has contributed to CEC level of the operating land.

However, these high CEC levels for the operating lands are still within the range as reported by ([12]), CEC is a good indicator of soil quality and productivity, thus the soil of the irrigation scheme currently falls within the medium to high level as outlined by[20]).

Moreso, high CEC soils (clay) are less susceptible to leaching and has a greater water holding capacity compared to low CEC soils (sandy) which are more likely to develop potassium and magnesium (and other cations) deficiencies. OL5 and OL18 whose textural classes are mainly clayey is seen to have shown a higher CEC level (Fig 2b).

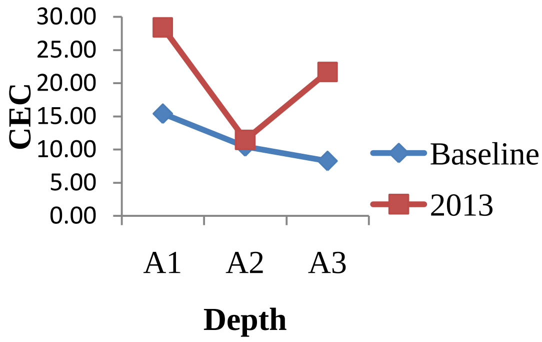

Figure 2a: Chart of CEC values with depth for OL 5

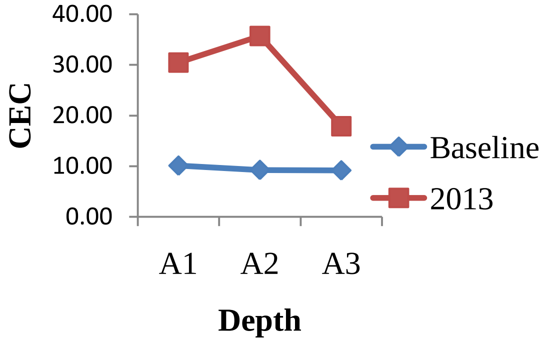

Figure 2b: Chart of CEC values with depth for OL 18

ESP: From Fig 3a, the ESP values of the current data decreased from A1 and A2 and a slight increase for depth A3 while the baseline data increased but in OL 18, the depths A2 and A3 have always shown a greater increase while depth A1 has slightly increased compared to the baseline data (Fig 3b), though the current data had much increase but still within the range as suggested above. The implication of a high ESP value on the soil is soil deterioration or damage and unhealthy soil condition as stated by ([21]).This implies that irrigation has had adverse effect on the soil, deterioration and damage are on or imminent. However it also implies that lack of irrigation is best since fig 3a shows a decrease in ESP.

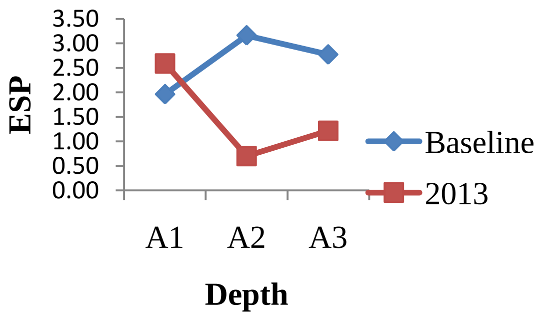

Figure 3a: Chart of ESP with depth for OL 5

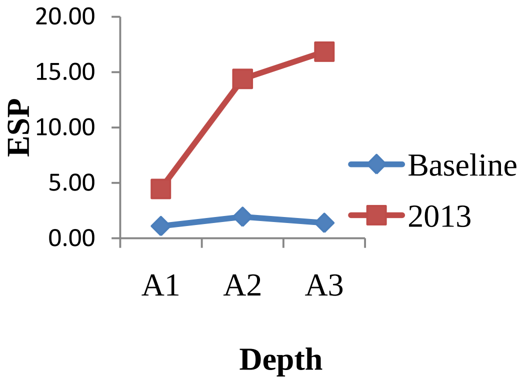

Figure 3b: Chart of ESP with depth for OL 18

Organic matter (OM): Using the Walkley – Black scale, the ideal soil organic matter level from the nutrient cycling and fertility standpoint is generally considered as 5 – 8%. Thus, considering the current state of the soil for the both operating lands either for the irrigated or unirrigated at all depths, there is increase in organic matter levels compared to the baseline data as presented in Fig 4a - b. these indicate that irrigation has contributed to organic matter level of the operating land.

The soils of the scheme fall in the medium level ([20]). These increased levels are beneficial in improving crop nutrition, aggregate stability (soil structure), water retention, ease of cultivation and seedbed preparation, soil aeration, aiding in the resistance of a soil to compaction and enhancing soil biodiversity.

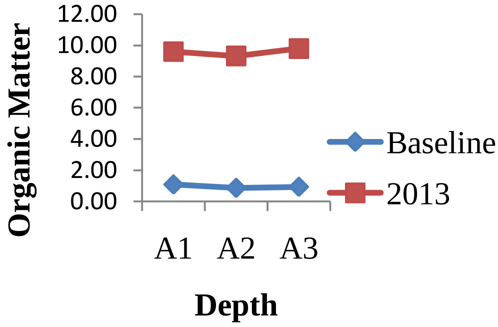

Figure 4a: Chart of OM with depth for OL 5

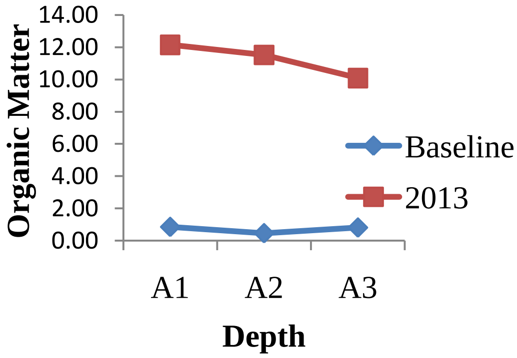

Figure 4b: Chart of OM with depth for OL 18

Organic carbon (OC): It is observed from Fig 5a and5b that the level of organic carbon has largely increased compared to the baseline data and year 2013 for both operating lands at the three depths monitored. However it shows that irrigation has positive effect on the soil organic carbon.

Due to increase in organic matter levels, there is a corresponding increase in the organic carbon level of the current soil status.

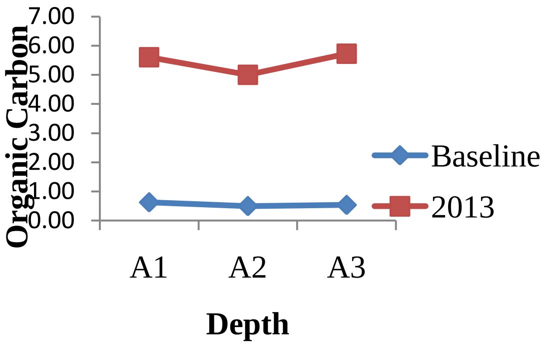

Figure 5a: Chart of OC with depth for OL 5

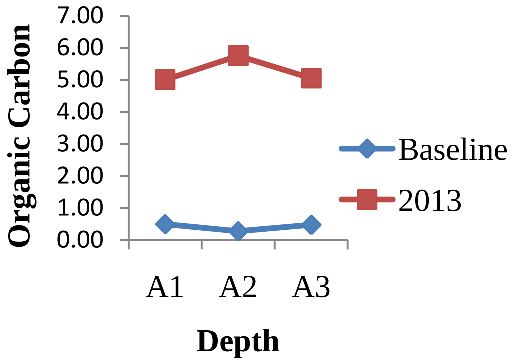

Figure 5b: Chart of OC with depth for OL 18

Calcium:, it can be deduced from the results showed in fig 6a and 6b that there is an appreciable decrease in the calcium levels of the current state of the soil compared to the baseline data and years 2013 for both operating lands. This decrease could be related to the decrease in pH observed pH which is tending towards acidity. It indicates that irrigation has lead to decrease in calcium level for both operating land.

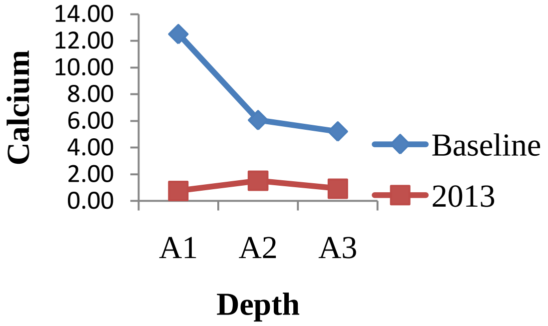

Figure 6a: Chart of Ca^{2+} with depth for OL 5

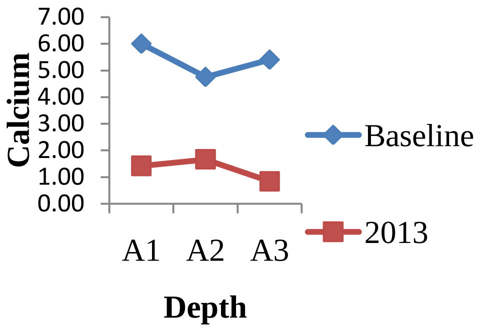

Figure 6b: Chart of Ca^{2+} with depth for OL 18

Magnesium (Mg^{2+}): From Fig 7a, magnesium levels decreases with depth for the operating land (OL 5), while in OL 18 fig 7b magnesium levels increases with depth but A3 shows the same value with baseline. This increase with depth could be as a result of decrease on Calcium leaching. Magnesium is one of the secondary macronutrient required by plant, its deficiency causes leaf yellowing with brilliant tints ([11]). Irrigation has reduced magnesium levels in both operating land.

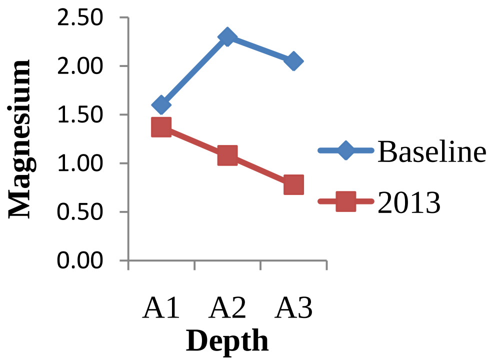

Figure 7a: Chart of Mg^{2+} with depth for OL 5

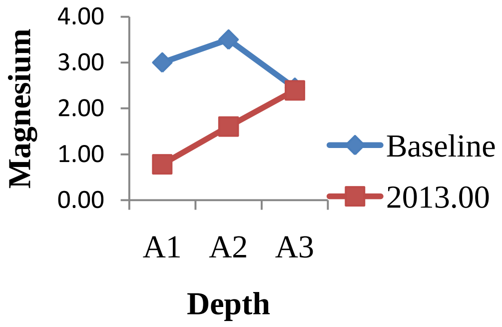

Figure 7b: Chart of Mg^{2+} with depth for OL 18

IV. Conclusion

The analysis carried out revealed that the soil of the scheme has been affected due to changes in some chemical characteristics measured in the field compared to its baseline, thus the following conclusions were drawn from the studies:

- The soil pH which was in the neutral range at the inception of the scheme has reduced to being slightly acidic and this could pose the problem of salinity if proper management is not enforced.
- The cation exchange capacity (CEC) levels is presently increased which favours the high potential for retaining of plant nutrients. Organic matter (OM) and organic carbon (OC) also have increase in their levels which serve an importance in indicating the health status or quality of the soil as it contributes to its biological, chemical and physical properties.
- Macronutrients such as $Ca^{2+}$and Mg^{2+} required by crops have reduced compared to the baseline and this in turn could reduce the fertility of the soil due to the deficiencies.
- Generally, the analysis indicated that a need for proper monitoring of the soil condition in the irrigation scheme in order to prevent further deterioration is highly encouraged since some changes have been observed compared to the baseline data.

The following are the recommendations based on the study; frequent monitoring and analysis of soil samples should be carried out to determine the soil's present state since some soil nutrients change quickly and which serves as a pointer to efficient fertility evaluation. Also, proper irrigation scheduling should be encouraged, since soil water content is critical to supply the water needs of the crop and to dissolve nutrients which make them available to the plant. Excess water in the soil, however, depletes oxygen (O_2) and builds up carbon dioxide (CO_2) levels. While O_2 is needed by roots to grow and take up nutrients, high CO_2 levels are toxic.

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