Original Research Article

Impact of Irrigation Practices on Soil Physicochemical Properties of Josepdam Irrigation Scheme

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ABSTRACT

The importance of irrigation practice in food production cannot be over-emphasised, however irrigation practices impact soils and other environmental parameters negatively. This necessitates the need for continuous monitoring of the impacts of irrigation on soils and the general environment. A study was carried out on the Josepdam Irrigation Scheme (JIS) located in Bacita, Ilorin, Nigeria. This study was limited to the impact assessment of irrigation practices on the soil physical and chemical properties. Soil samples were collected from irrigated lands at depths 0-20, 20-80 and 80-120 cm from 8 OLs on JIS using soil auger. During each season of collection, samples were kept in polyethylene bags and transported within 24 hours to the laboratory for analyses. The samples were analysed immediately according to ISRIC-FAO procedures for pH, Cation Exchange Capacity (CEC), Exchangeable Sodium Percent (ESP), Mg^{2+}, Ca^{2+}, Na^{+} and Sodium Adsorption Ratio (SAR). The results indicated that the soil texture was sandy loam and sandy clay loam, In JIS, the pH of 7.2 at inception reduced to 4.6; SAR increased from 0.4 to 2.14 $meq^{1/2}$ and CEC increased from 18 to 26 $cmolkg^{-1}$. The impacts of irrigation on the soil was determined. The results of these evaluations were compared with FAO standards and past research results.

Keywords: Soil properties; irrigation; Josepdam Irrigation Scheme; soil samples

1. INTRODUCTION

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[1]. Some of the reported adverse impacts include salinity, water logging, human health and decrease in crop yield which may be due to inadequate drainage facilities or poor water management consequently giving rise to soil infertility and reduced crop yield[2]. Also, improper use of fertilizer and poor irrigation water quality have resulted in loss of nutrient and cation exchange capacity of the soil[3], [4].

The implementation of irrigation practices in large-scale projects can be associated with adverse impacts on environmental conditions, which may affect the sustainability of the projects[5]. Though irrigation practices help in improving food production, they may also contribute to environmental degradation. If not well managed, it could cause damage to the soil (in terms of biological, physical and chemical properties), water and human health. Eventually, this makes the soil unsuitable for farming operation resulting in decreased crop yield in the long run [6].

In an experiment conducted by [7] who studied the post-irrigation problems in the Harran Plain; it was concluded that excessive irrigations could raise groundwater levels above critical thresholds, thereby increasing sediment losses, and soil degradation with salinity. Environmental degradation in Nigeria has become an issue of growing concern in recent years especially as regards irrigation development and practice. This study is aimed at auditing the environmental effects of irrigation practices on soil physiochemical properties of Josepdam irrigation scheme soil (JIS) formerly known as Nigerian Sugar Company (NISUCO) Bacita. This was last monitored in 1995. These are presented and discussed in charts and graphs in the subsequent sections.

2. MATERIAL AND METHODS

2.1 Study Area

JosepdamIrrigation Scheme (JIS) is located in Bacita, a town 120 km north of Ilorin, the Kwara State capital and on the south bank of River Niger in Edu Local Government Area of Kwara State. The town lies in the Guinea Savannah region, Latitude 09°5' N and Longitude 04°56' E at an altitude 76 m above sea level and with a population of about 50,000 people. The monthly mean minimum and maximum air temperatures are 20.1°C and 33.6°C, respectively. Rainfall occurs from April to October. The monthly mean rainfall is 93.5 mm and the peak of rainfall is normally witnessed in September. The sunshine in the area is high between December and March. The project area is affected by two principal wind currents North East Trade wind (from November to March) and the South-West wind (April to May) [8].

Generally, the terrain of the irrigation scheme is relatively flat with gentle slope in some areas. The farm irrigated areas are divided into eight namely; Egbungi, Oshin, Belle, Fanagun, Nebung, Brung, Shigo and Gebung which sum up to 5,600 ha. The soil is predominantly heavy clay and sandy loam. This topography makes it possible for the practice of both surface and sprinkler irrigation.

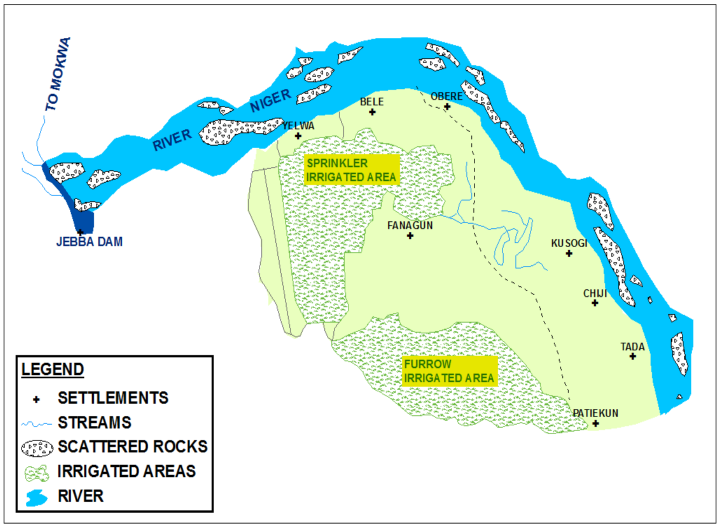


Fig. 1. Irrigation Areas on the Josepdam Sugar Company Limited, Bacita (Adapted from Nwa, 2003)

2.2Sample Collection

Soil samples were collected from the different designated points in the irrigation scheme. The entire JIS consists of 5,600 ha and was divided into surface irrigation area of 2,670 ha and 2,930 ha for sprinkler irrigation and eight soil groups (units). Within these areas, plots were selected for sampling in each soil unit namely; Egbungi, Oshin, Belle, Fanagun, Nebung, Brung, Shigo and Gebung plots to ensure coverage of all known soil groups and irrigation methods used on the scheme. Soils from each of the selected schemes were sampled for both textural and chemical analysis according to [9]. Different sampling points and depths were selected to correspond as much as possible with those in the available baseline data and also in accordance with rooting depth of crops planted on each scheme. JIS, where sugarcane was the main crop, sampling depths of 0 – 30 cm, 30 – 60 cm and 60 – 120 cm were used in line with the maximum rooting depth of 1.2m for sugarcane. Three samples were also collected from each sampling point for textural and chemical analysis. A total of 127 soil samples were collected from 3 profiles. These constituted 45samples from topsoil, 41 samples from the subsurface and 41 samples from subsoil depth by augering.

2.3Soil Sample Analysis

Analyses of samples were carried out in the Lower Niger River Basin laboratory, Ilorin, where chemical, physical and microbial properties of the soil samples collected were determined using [9] laboratory soil standards. The physical property of interest in soil analyses wastexture, while chemical properties of concern include pH, Electrical Conductivity (ECe), Exchangeable Sodium Percentage (ESP), Sodium Adsorption Ratio (SAR) and micro and macronutrients.

3. RESULTS AND DISCUSSION

Soils of the eight (8) operating lands (OL), on the JIS scheme wereanalysed for textural and chemical properties.

3.1 Soil Textural Classification

The soil on the operating lands were pre-named according to the location of the farms. However, for this study, these were duly classified using the USDA textural classification for ease of identification as shown in Table 1

Table 1. Dominant Soil Classification in Josepdam Irrigation Scheme

Operating Land	Textural Class (1995)	Textural Class (2019)
Egbungi	Clay	Clay
Oshin	Silty Loam	Sandy Loam
Belle	Clay loam	Clay Loam
Fanagun	Red sand	Silty Loam
Gebungi.	Sandy Loam	Sandy Loam
Brung,	Clay	Silty Clay
Shingo,	CoarseSand	Sandy Loam
Nebung	SandyLoam	SandyLoam

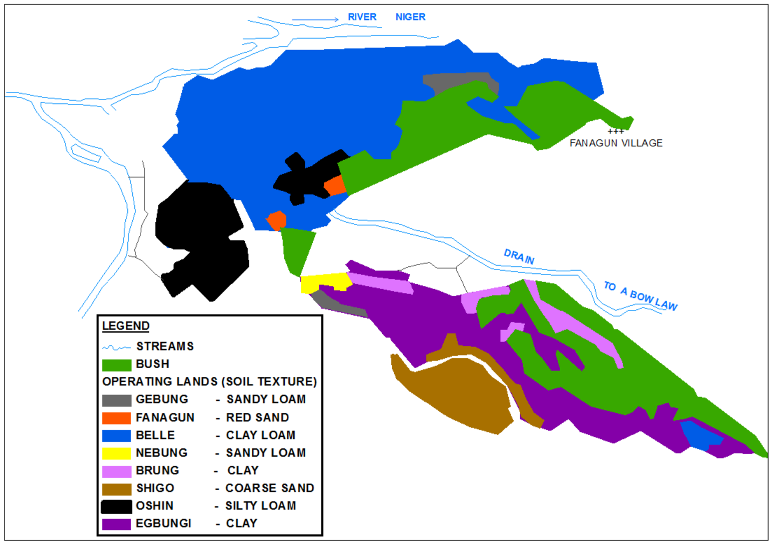


Fig. 2. Soils Textural Class distribution on Josepdam Irrigation Scheme,Bacita Nigeria Source: [Ojediran, (1997)]

Soil Texture

The baseline soil texture data obtained [8]are shown in Table 1 and the areal distribution of each textural class is also shown in Figure 2. The current result of the textural analysis of the eight operating lands on the scheme is also shown in Table 2 and Figure3 for ease of comparison. A close comparison of the 1995 and 2019 soil textural analysis for this scheme indicated that there were no major changes in the classification. It can therefore be safely concluded that irrigation practices on this scheme have not had any major significant impacts on the soil texture.

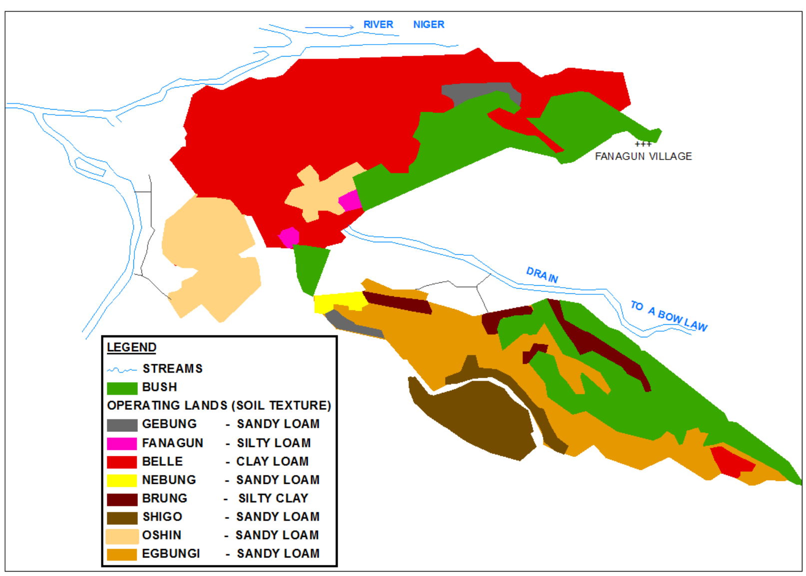
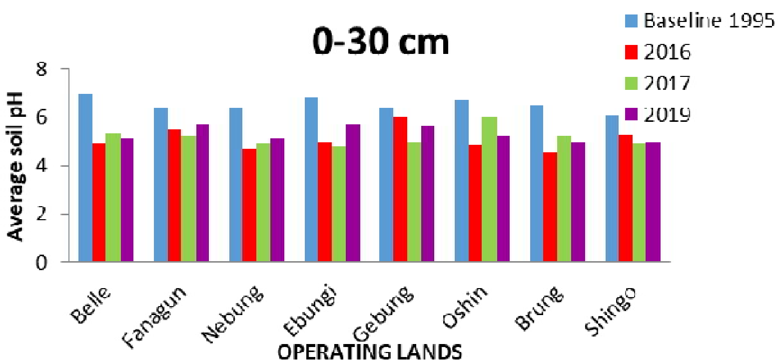


Fig. 3. Soils Textural Class distribution on Josepdam 2019

3.2Soil pH

The analyses of the soil samples for pH of this scheme for three years (2016-2019) and the 1995 baseline values for each layer and operating land are shown in Figures 4a, b and c. The results showed that there were decreases in the soil pH of the sampled soils from JIS when compared with the1995 baseline data indicating a general tendency toward acidity. Considering current study (2019) on this scheme, it was observed that all the operating land at depth 0 – 30 cm were having pH between 5- 5.7, indicating moderately acidic. Figure 4b showed that most of the lands which were neutral in 1995 were becoming moderately acidic, except for Fanagun (pH of 4.7) that is strongly acidic.

Figure 4c also showed that for all the operating lands, at depth 60–120 cm which were slightly acidic and becoming moderately acidic except obviously for Belle and Oshin. This confirms that the twenty four (24) years of irrigation have contributed negatively to the soil pH. This general decrease in pH, notwithstanding, the current soil pH is still within the range of 5-8.5 that can be tolerated for sugarcane cultivation [10].Therefore, this study showed that precautions should be taken to prevent further decrease in the soil pH, preventing soil from becoming too acidic for the production of sugarcane as a drastic effect on the yield may result. The study further shows the need for constant scheme auditing/monitoring.



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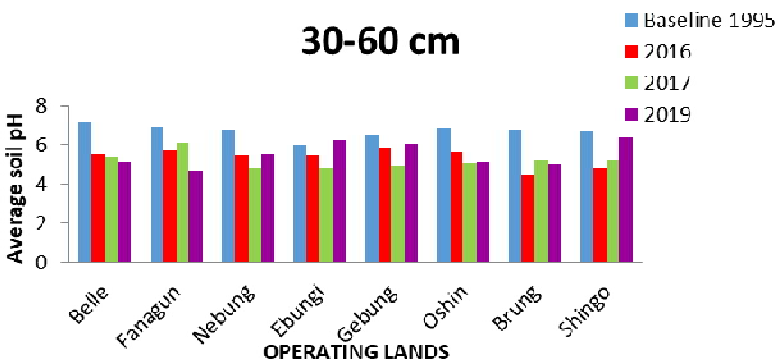

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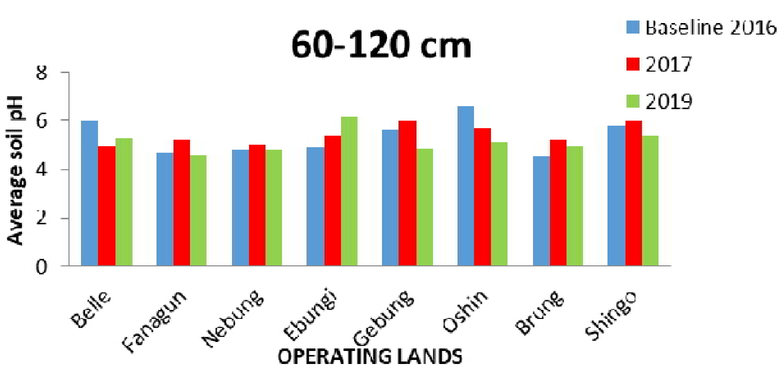

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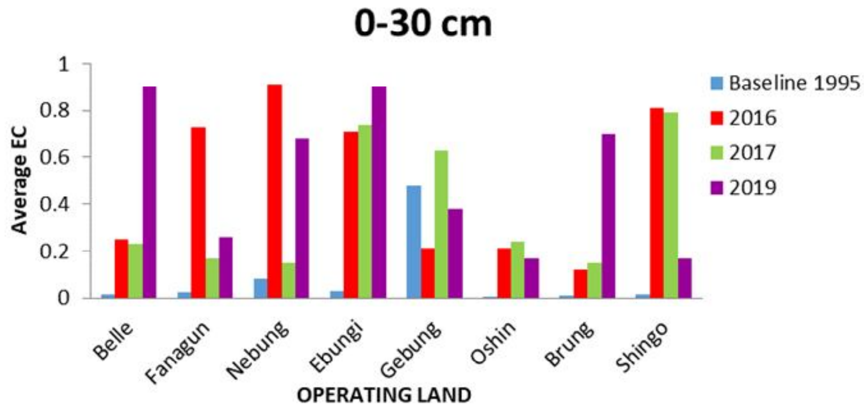
Fig. 4. Variation of pH on JIS Soil Layers

3.3Electrical Conductivity

Electrical Conductivity of 1.7dS/m has been observed as the standard above which a decline in crop yield may be experienced [11]. The analyses carried out in this study as illustrated in Figures 5 a,b and c showed a general increase in EC from 0.084dS/m baseline in 1995 to 1.5dS/m in 2019 over the three years examined at all soil depths. This observation which is in the range of 0-1.5 and less than 1.7dS/m showed the EC as being within the acceptable range for adequate crop yield.

An overview of the results, however, indicated that highest EC value of 1.5dS/m was obtained in Belle at depth 60 cm while the lowest value of 0.15 dS/m was obtained at depth 0 – 30cm in Brung. Baseline data was not available for 60 – 120cm soil depth, this research values will, therefore, serve as baseline for this soil depth. The results obtained for the electrical conductivity values of all the soil samples fall below 1.7dS/m, which implies that the soil of the scheme is fit for the production of sugarcane. However, the results indicated that the scheme soils has been impacted by the consistent irrigation practices of the past 24 years on this scheme. The level of increase to 1.5dS/m indicated an average annual increase of 0.08dS/m, which calls for consistent monitoring considering the current level attained, especially at Belle with the current average of 1.5dS/m.



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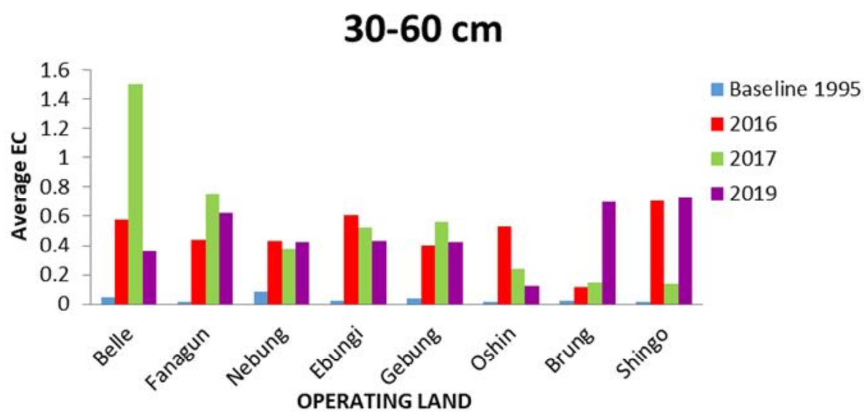

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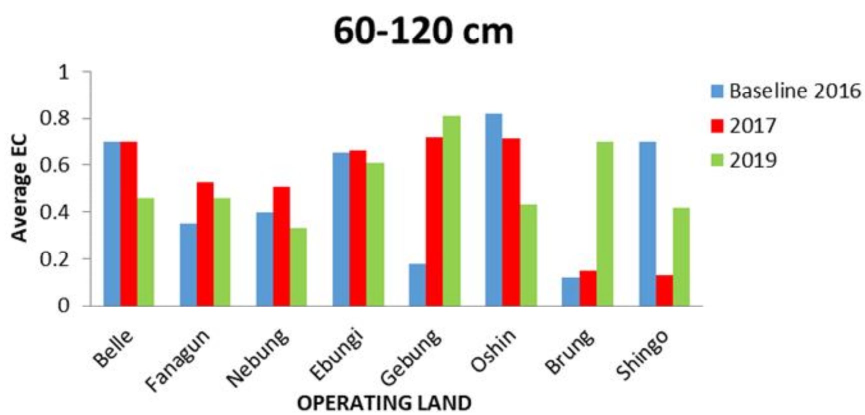

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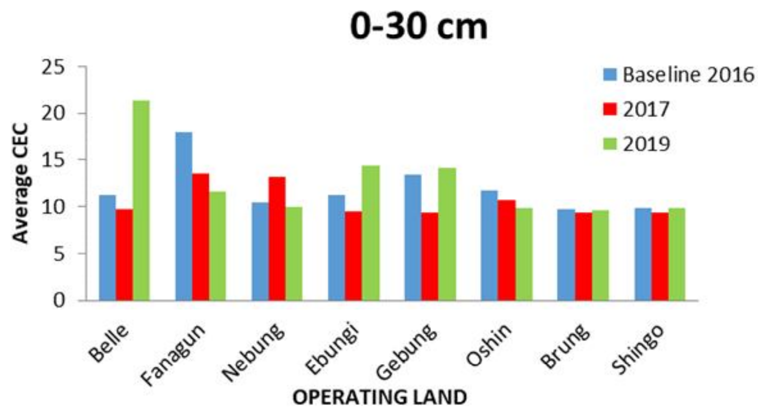
Fig. 5. Variation of Electrical Conductivity (EC) on JIS soil Layers

3.4Cation Exchange Capacity (CEC)

The CEC is the maximum quantity of total cations that a soil is capable of holding at a given pH value, available for exchange with the soil solution. CEC is used as a measure of fertility, nutrient retention, and the capacity to protect groundwater from cation contamination.[8]noted that there were no baseline CEC data for this scheme, hence the current CEC status was determined to serve as baseline data for future studies. The results of the analysis of the soil samples of this scheme for CEC for the current study are as presented in Figures 6a, b and c.

Observably, the CEC values in all the soil depths sampled ranged from 16 mol/kg in 2016 to 26 mol/kg in 2019 indicating an increase within the three-year study, with Belle having the highest values (26 mol/kg) in all soil depths.

The recorded high CEC levels for all the operating lands in this study were still within the acceptable range of CEC (2 – 40 mol/kg) reported by [12] as desirable, when combined with other measures of soil fertility. CEC is a good indicator of soil quality and productivity because soils with high CEC are considered fertile. Comparing these current results with the typical CEC values for different soils outlined by [13], the soil of the irrigation scheme currently fall within the medium to high CEC level. The three years of irrigation practice has therefore contributed to the increased level of CEC (16mol/kg in 2016 – 26 mol/kg in 2019) in all the operating lands. Since there were no baseline data to compare the present study with, therefore, this will serve as baseline for future monitoring.



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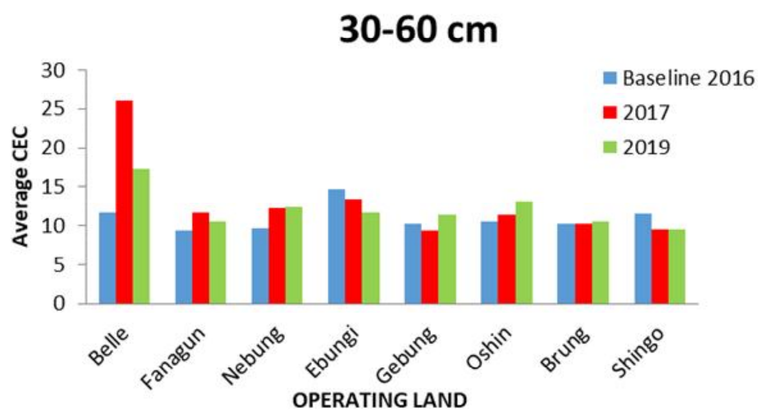

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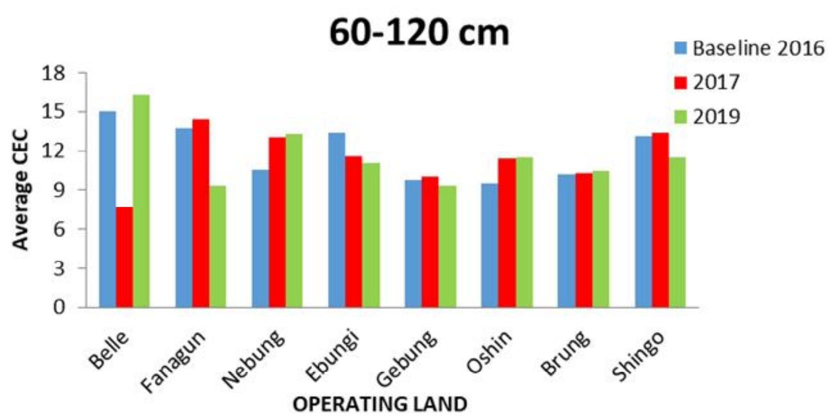

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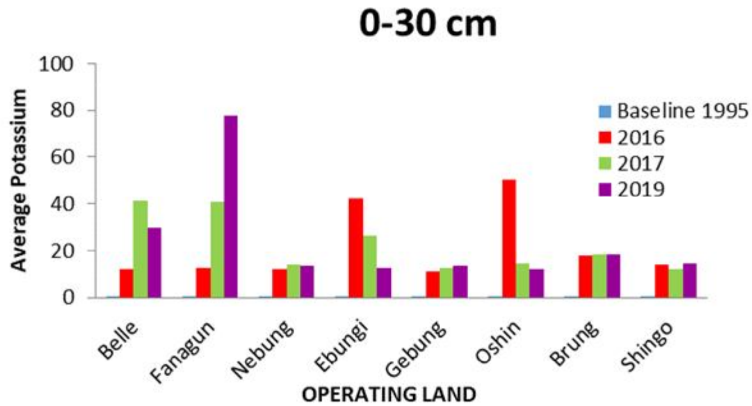
Fig. 6. Variation of Cation Exchange Capacity (CEC) on JIS soils Layers

3.5Potassium

Potassium K^+ is one of the three major macronutrients desirable for plant as it promotes general vigour, disease resistance and growth. Stunted growth with chisel leaves are symbols of potassium deficiency[12]. From Figures 7 a, b and c, all the operating lands showed high contents of potassium, as compared with the 1995 baseline data, Fanagun showed a marked increase of 77 mol/kg within the top soil layer in 2019, while at 60cm depth, Ebungi and Brung operating lands had higher values than the rest of the operating lands with 33 mol/kg and 26 mol/kg, respectively. At 60 – 120 cm soil depth, all the operating lands had increased in potassium contents with Ebungi having the highest value (30 mol/kg) in 2019, followed by Gebung (27 mol/kg) and Brung (27 mol/kg). Irrigation practices on JIS had positive effects on soil potassium level because soil depths of the operating lands showed increase Potassium contents which may help in boosting crop yield without application of fertilizer [11].



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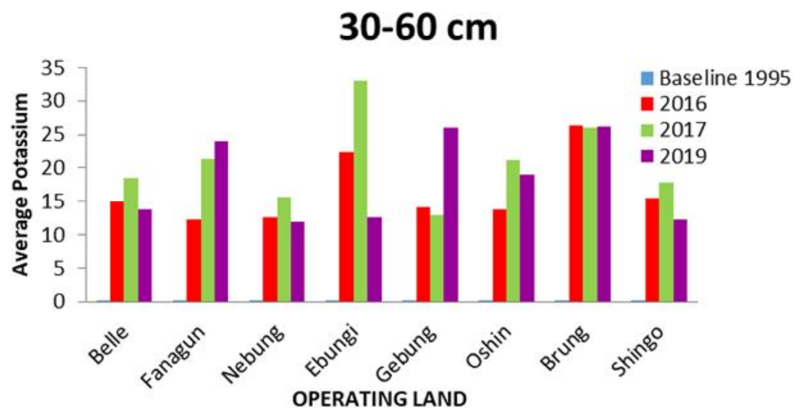

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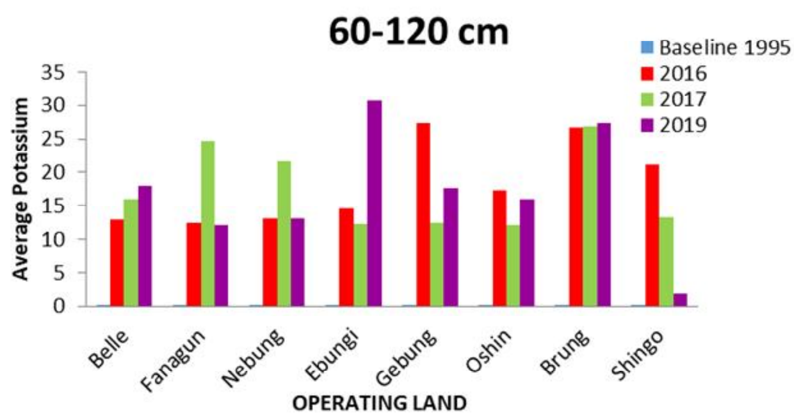

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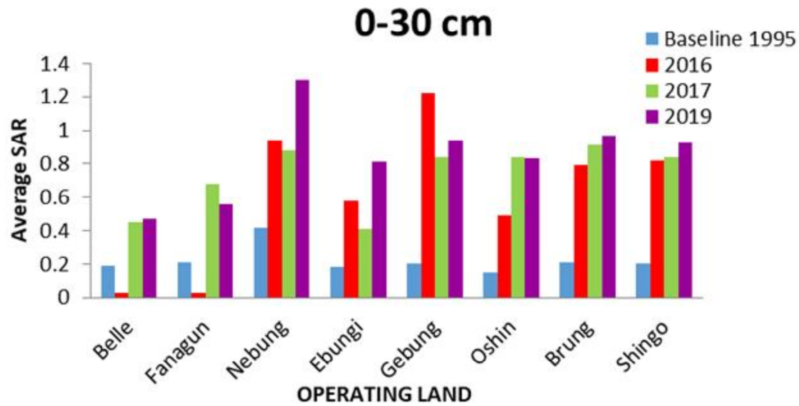
Fig. 7. Variation of Potassium in JIS soils Layers

3.6Sodium Adsorption Ratio (SAR)

The 1995 baseline data indicated relatively low SAR values compared with those obtained for the three years examined in this study for all the operating lands. Computation of SAR values of the operating lands on this scheme shown in Figure 8 a, indicated that SAR values increased in all the operating lands for the top soil layer (0 – 30 cm), except on Belle and Fanagun soils which showed sharp decreased in SAR values (0.028 and 0.026) in 2016. At the 30 – 60 cm soil depth (Figure 8b), Nebung showed the highest value of SAR (1.62) in 2017, the operating lands showed increases in SAR values in comparison with the baseline data. The higher the sodium adsorption ratio, the higher the displacement of calcium and magnesium in the soil which lead to a decrease in the ability of the soil to form stable aggregates and a loss of soil structure and tilth which could affect infiltration and consequently the growth of sugarcane. The SAR values obtained for the operating lands were generally below 13 meq/l$^{1/2}$ which indicated that the soil of the lands are normal for the growth of sugarcane and the soil structure was in good condition for proper yield. However, the general increases observed in these values indicated a negative impact of irrigation practices on SAR, and called for constant monitoring/auditing of SAR values to avoid the irreversible effects of high SAR, a situation that can be easily aggravated by irrigation practices.



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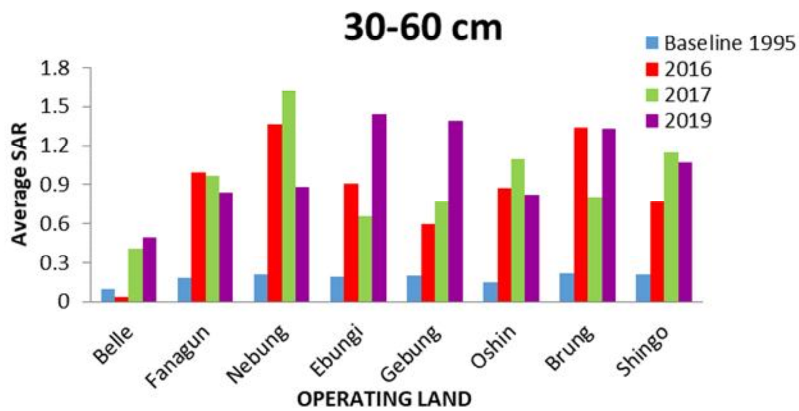

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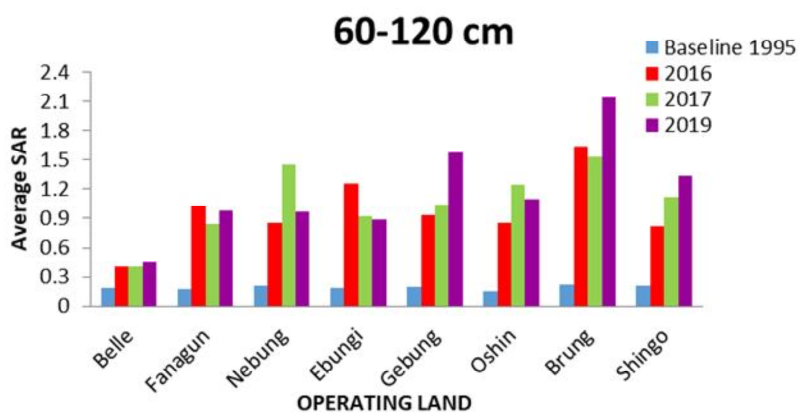

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Fig. 8. Variation of SAR on JIS Soils Layers

3.7Exchange Sodium Percentage (ESP)

Earlier studies on this scheme did not give any record of ESP for all operating lands, hence the current study was carried out to serve as the baseline for future studies and monitoring. Soils with Exchangeable Sodium Percentage (ESP) greater than 15 are considered as sodic soils. From Figure 9a at depth 0-30 cm, Gebung had the highest average of ESP in all the operating lands and for all the three research years, these values were within the threshold of 15. Likewise in Figure 9b, Brung had the highest ESP (0.58 - 0.61) value in 30 – 60 cm soil depth in all the years, operating lands and for all the three research years, these values were within the threshold of 15. Likewise in Figure 8b, Brung had the highest ESP (0.58 - 0.61) value in 30 – 60 cm soil depth in all the years, all the operating lands have appreciable values. Also considering Figure 9c (60 -120 cm), there are increases in the ESP values in all the operating land with Egbungi having the highest value (0.83) in the year 2017. ESP values in all the operating lands increased as the depth increases, this showed the leaching effect of irrigation practices, and more Exchangeable sodium are deposited at the sub-soil layer and made available for the root as nutrients. Therefore three years of irrigation practice had contributed to increased level of ESP in all the soil depth.

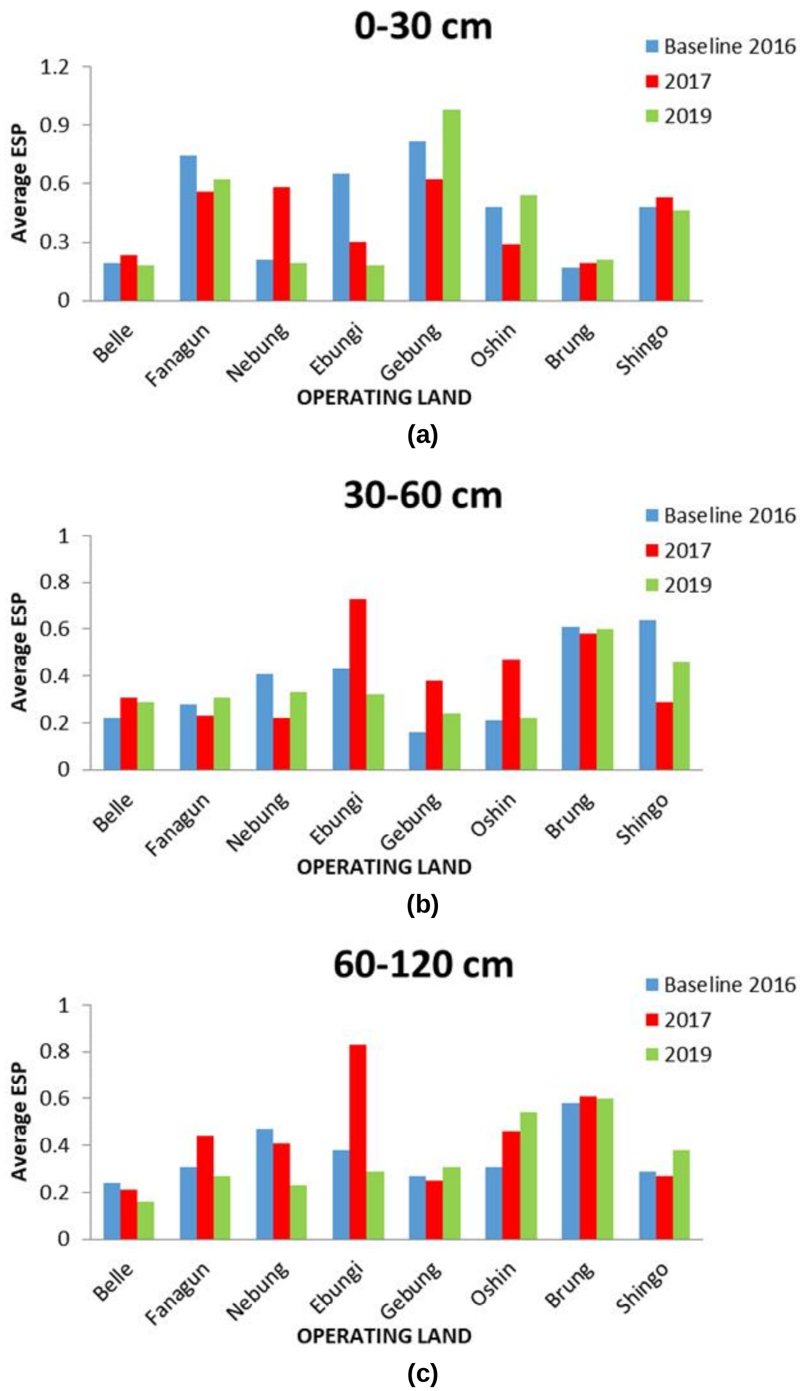

Fig. 9. Variation of ESP on JIS Soils Layers

4. CONCLUSION

The impact of irrigation practice on soil of the selected irrigation scheme in the Southern Guinea Savannah zone of Nigeria, Josepdam Irrigation Scheme (JIS), Bacita in the Lower Niger River Basin were reviewed and analysed after twenty-four years of active irrigation practices on the selected scheme. Observably, JIS was last assessed in 1995. The analysis carried out revealed that soils of the scheme had been affected due to some observed changes in some chemical parameters compared to the baseline data. Based on the findings of the research work,the soils at JIS have become moderately acidic. Although the acidity level is within tolerable range for sugarcane production at JIS, care must be taken to avoid further increase in the acidity. Presently, there is no problem of salinity in the soils of the scheme though increase in the salinity indices was observed.

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