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*Full Length Research Paper*

# Physicochemical characteristics of the Kalimbeza Rice project soil, Katima Mulilo Namibia

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**As part of efforts towards improving the productive capacity of the Kalimbeza rice project soil, the main objective of this study was to establish the physicochemical characteristics of the rice soil. During the 2014 to 2015 cropping season, a total of 68 soil samples (consisting of 34 each) were randomly collected within top (0-15cm) and sub (15- 30cm) in the pre- and post-rice cultivation soil for laboratory analysis. The laboratory results revealed that the rice soil has a predominant sandy loam textural characteristic and moderate acidity with average pH levels of 5.47 (pre-cultivation) and 5.39 (post-cultivation). The mean levels of electrical conductivity of the pre- and post-rice cultivation soil were 61.60dS/m and 58.50dS/m respectively and these suggest saline soils characteristic. Very low mean levels of nitrogen (0.1% and 0.09%), phosphorus (1.30ppm and 3.68ppm), potassium (35.60ppm and 45.50ppm) and organic carbon (0.81% and 0.72%) were recorded in the pre- and post-rice cultivation soil analyses respectively. High mean level of cation exchange capacity (12.26meq/100g) was recorded in the pre-rice cultivation soil analysis while a low mean level of 7.37meq/100g was recorded in the post-rice cultivation soil. Under rice mono-cropping system such as currently practiced at the Kalimbeza rice project, the observed physicochemical properties of the rice project soil require proper soil management strategy in order to enhance its long-term productivity.**

**Keywords:** Rice productivity, soil properties, pre- and post-rice cultivation, Kalimbeza rice project

## INTRODUCTION

Globally, rice forms a significant part of the household food security of about 50% of the world's population (Fageria et al., 2003; Calpe, 2006). Rice crop is broadly grown under two main ecosystems: upland and lowland. In both ecosystems however, the soil physicochemical characteristics affecting rice productivity and yield vary considerably according to the local soil and climatic factors. Moreover, optimum rice productivity is often threatened by the frequent alteration of soil physicochemical properties which constitute critical component of rice agro-ecosystem. Changes in soil properties caused by cultivation and management and their consequences to soil productivity have generated significant research concern for many years (Zhou et al., 2014). Research evidence has indicated that the degradation of soil quality is a key factor for the observed declining yield of most crops (Ladha et al., 2003).

In most sub-Saharan countries, agricultural production is under threat due to declining soil fertility (Sanchez, 2002).

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This is particularly a serious problem in developing nations where climate change and low soil fertility are primary constraints to rice production. In the assessment of soil nutrient depletion in sub-Saharan Africa, it was reported that soil nutrient depletion is quite severe in Africa with estimated net loss of the order of 10 kg N/ha, 4 kg $P_2O_5$/ha and 19 kg $K_2O$/ha per year (Stoorvol and Smaling, 1990). In another report, it was noted that inherently low fertility status, inappropriate land use, poor management, erosion and salinization are major constraints to crop productivity in most areas (Bationo et al., 2006). However, such nutrient balances cannot be used to indicate soil sustainability without consideration to site-specific nutrient characteristics of a given agricultural soil.

The Kalimbeza sub-rice zone is an annual floodplain in the northeastern Namibia and currently, the major rice producing area of the country but there is dearth of documented information on the farm soils' physicochemical properties. This could present challenge for proper planning and long term management of the cultivable land. Soil fertility assessment is effective in increasing crop productivities (Ilagan et al., 2014) and hence, considered as the first important step to managing soil fertility (McKenzie, 1998) and productive capacity. The quantity of available nutrient in the soil sample determines recommended fertilizer application for the optimum crop growth and production (Rashid and Rafiq, 1998). With the increasing site-specific researches and managements being implemented in many farms today, there is a growing need to characterize the variability in important physicochemical properties of the soil across all rice fields. The main objective of this study was to provide a comprehensive data of the physicochemical characteristics of the Kalimbeza rice project soil and compare with standard response data. The information will provide useful guide necessary for future monitoring, proper planning and long term management of the paddy soil.

## MATERIALS AND METHODS

### Study area

The Kalimbeza rice project field is a floodplain ecosystem located in Kalimbeza village; about 40 km east of Katima Mulilo, latitude 17o30'00"S and longitude 24o16'00"E based on the World Geodetic System (WGS) 84 coordinate reference system (Abah et al., 2014). The rice project field receives annual rainfall of 500mm to 600mm, summer temperature of 23°C to 30°C and winter temperature of 15°C to 18°C (CPPN, 2005). According to the report of Caprivi freedom (2011), Kalimbeza rice project was first realized in 1987 by the then Ministry of Agriculture during the colonial government (Government of National Unity) but never took off the ground. The project started large scale rice cultivation in 2007 on 4 hectares of land when the University of Namibia joined the rice trial project (Caprivi vision, 2011). Since then, the rice project has been witnessing land expansion on yearly basis but no comprehensive study was carried out to document the physicochemical properties of the rice soil to enable review and proper soil fertility management planning.

### Soil samples collection and pre-treatment

Soil samples were collected in two phases for laboratory analyses. 1). Prior to rice cultivation (May to July 2014), and 2), after rice harvest (July to September, 2015). A total of 34 sampling grids measuring 2.5 acres each were mapped out within the cultivated land area. Then, 16 samples (consisting of 8 soil samples within topsoil [0-15cm] and another 8 soil samples within subsoil [15-30cm]) were randomly collected at 8 different points in each sampling grid. The International Plant Nutrition Institute (IPNI) has noted that grid sampling method helps to minimize field pattern bias, yet provides an organized sampling scheme to represent the entire field (IPNI 2013). For each soil depth (0 – 15cm and 15 – 30cm), all the 8 soil samples collected within each sampling grids were pooled together, properly homogenized and one representative subsample taken. Thus, a total of 68 representative soil samples (made up of 34 samples within 0-15cm and another 34 samples within 15 – 30cm) were collected for laboratory analysis.

### Samples preparation and analyses

The soil samples were air-dried at room temperature. Then, each sample was crushed and sieved using a 2 mm size mesh and laboratory analyses of the soil parameters were carried out on the < 2.00mm fractions using standard laboratory procedures. All laboratory preparations and analyses were carried out at the Agricultural Laboratory of the Ministry of Agriculture, Water and Forestry, Windhoek, Namibia.

Particle sizes were determined using the hydrometer method (Gee and Bauder, 1986), pH was measured in 1:2.5 suspensions in water and organic carbon was determined by the potassium dichromate oxidation method (Gelma et al., 2011). The soil exchangeable cations: calcium, (Ca), magnesium (Mg), potassium (K) and sodium (Na) were extracted using 1N ammonium acetate at pH 7.0 (USDA, 2004) and their levels in the soil extracts were determined using Atomic Absorption Spectrophotometer (AAS). Thereafter, the cation exchange capacity (CEC) of the soil was determined by summation method (IITA, 1979). The electrical conductivity (EC) was determined by measurement in the supernatant of 1:2.5 soil:water suspensions using conductivity meter (Gee and Bauder, 1986). Available phosphorus was determined by the Olsen method (USDA, 2004). Total nitrogen was determined following Kjeldahl digestion method (Bremmer and Mulvaney, 1982)

### Soil C:N ratio

The soil C:N ratio in this study was calculated by dividing the soil organic matter (%) by total nitrogen(%) (Swangjang, 2015).

### Statistical analysis

GenStat Discovery Edition 4 was used for the data analysis. Box plots were applied to analyse the soil data based on the effect of rice cultivation and soil depths on the different physicochemical parameters. Mean values of the soil parameters were compared with their corresponding standard reference values (Appendix 1) based on which informed decisions on the site's nutrient characteristics were taken. Furthermore, ANOVA was performed to assess the effects of cultivation (EC), soil depth (SD) and their interactions (EC x SD) on the significance of data variations ($p < 0.01$ and $P < 0.05$) between the soil parameters. Correlation matrix was also computed for the soil parameters to assess their degree of associations.

## RESULTS AND DISCUSSION

### Characteristics of the Kalimbeza Rice Project Soil

In the results and discussion that follow, pre-cultivated soil refers to soil samples collected from the Kalimbeza rice project soil prior to rice cultivation in the 2014-2015 cropping season while post-cultivated soil refers to soil samples collected from the same site after rice harvest in 2015.

### Soil texture

Figure 1 is a box plot showing the effects of rice cultivation and soil depths on the particle size distributions of the of the Kalimbeza rice project soil (n =34). In the pre-cultivated soil, the rice project soil has mean particle size distributions of 62.60% sand, 19.20% clay and 18.20% silt while in the post-cultivated soil, the mean particle size distributions were: 68.30% sand, 15.30% clay and 16.40% silt. The particle size distributions within the 0-15cm and 15 – 30cm soil depths revealed 66.20% sand, 16.30% clay, 17.50% silt and 64.64% sand, 18.22% clay and 17.14% silt respectively. Based on the United States Department of Agriculture [USDA]'s index for soil texture classification (USDA, 2004), the results of the particle size distributions of both the pre- and post-cultivated soil of the Kalimbeza rice project revealed sandy loam textural class. Apart from the mean variation of sand particles which was statistically significant ($p < 0.05$) when compared under the effect of cultivation, there was no statistical difference between the variation of the mean particulate sizes recorded under the soil depths as well as the interaction between the cultivation and soil depths.

Soil texture is a permanent soil feature and not easily changed by human activity (Crouse, 2016). Soil texture relates most specifically to the overall porosity of the soil including its macro and micropores, long term drain ability and compressibility (Ponnamperuma and Deturk, 1993). Soils that have high sandy characteristic possess high drainage and poor nutrients retention abilities. Thus, the textural class of the Kalimbeza rice project soil may require proper soil fertility management strategy in order to optimize rice yields. The knowledge of the proportions of different-sized particles in soils is critical to understand soil behaviour and their management (UK Essay, 2013).

### pH of the rice project soil

The box plot (Figure 2) shows that in the pre-cultivated soil analysis (n =34), the Kalimbeza rice project soil recorded a mean pH of 5.47 and 5.39 in the post-cultivated soil. Within the 0-15cm and 15-30cm soil depths, the mean values of the pH were 5.39 and 5.46 respectively. These pH values represent a moderately acidic soil and fall outside the reported ideal soil pH range of 5.5 to 7.0 suitable for rice productivity (Sangatanan and Sangatanan, 1990). Soil pH can affects many physical, chemical and biological properties of soil, which in turn affect the growth of rice plants directly or indirectly (Yu, 1991). The analysis of variance of the pH levels under both the effect of cultivations and soil depths as well as their interactions was statistically not significant ($p < 0.05$) (Table 1). This finding suggests that the Kalimbeza rice project soil has a characteristically moderate acidity at the time of this study. However, the present soil pH level may not require liming for correcting soil acidity and hence, simple flooding or field submergence may be employed (Serchan and Jones, 2009) in the rice cultivation.

### Electrical conductivity of the rice project soil

The box plot of the electrical conductivity (also in Figure 2) revealed that in the pre-cultivated soil, the Kalimbeza rice project soil recorded a mean level of 61.60µS/cm while the post-cultivated soil recorded 58.50µS/cm. Within the topsoil (0-15cm) and subsoil (15-30cm), the results were: 62.60µS/cm and 57.40µS/cm respectively. The analysis of variance between the electrical conductivity levels under the effect of cultivations as well as soil depths and their interactions was statistically not significant ($p < 0.05$) (Table 1). Based on the standard reference values for interpreting soil properties (Appendix 1), these levels of soil electrical conductivity characteristically fall within the reported soil saline levels (Sonon et al., (2015). Although,

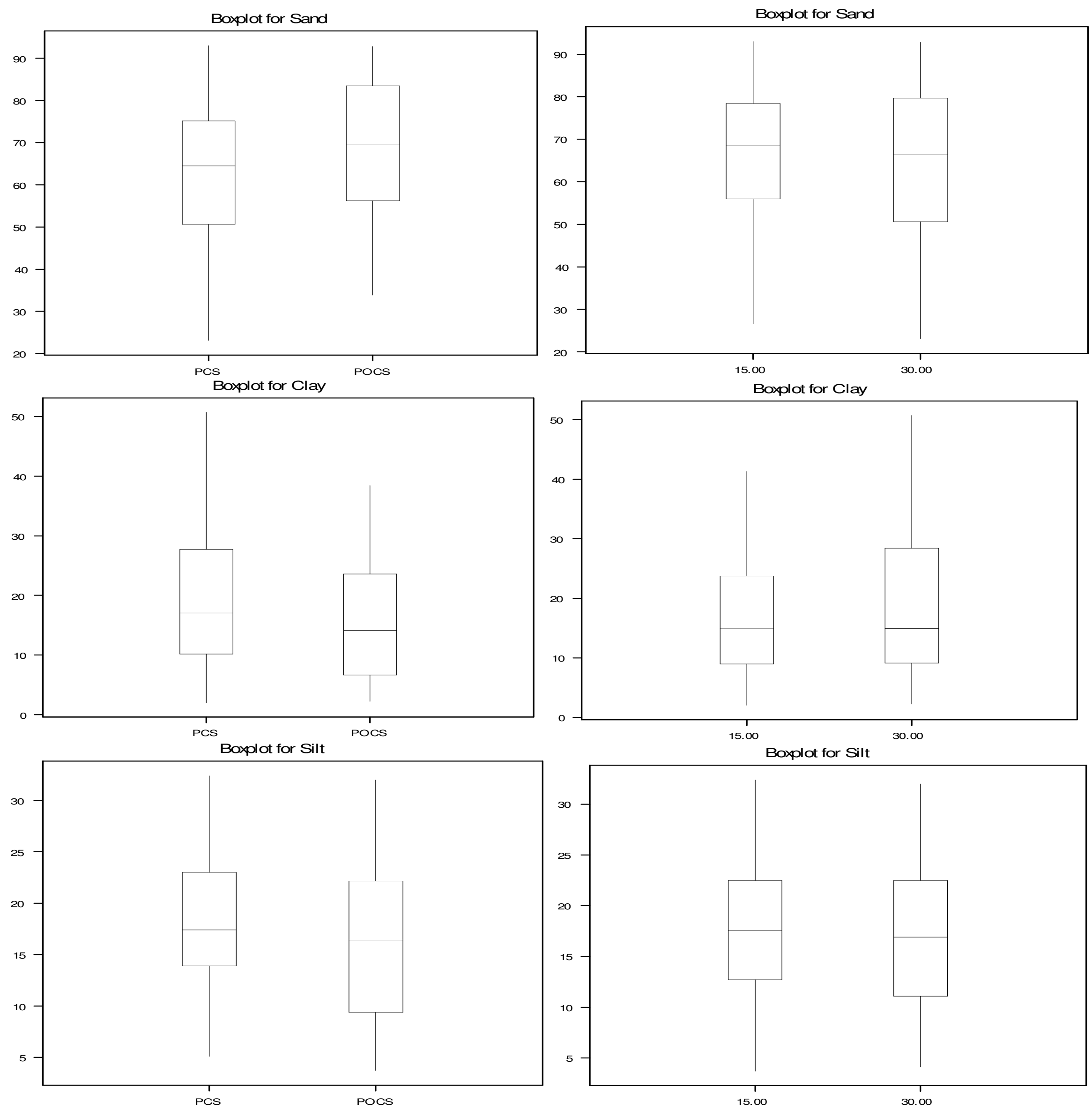


**Figure 1.** Boxplot showing the effects of cultivation (left) and soil depth (right) on the soil particle size distributions in the Kalimbeza rice project soil, PCS = pre-cultivated soil, POCS = post-cultivated soil, 15.00 = 0-15cm soil depth, 30.00 = 15 – 30cm soil depth

rice shows variability in its sensitivity to excessive salinity at different stages of growth (Morales et al., 2012), it is considered a relatively saline-tolerant species at the germination stage, whereas the vegetative and early reproduction stages are the most sensitive to salinity, directly affecting yield (Zeng, 2004). Soil salinity is caused by several factors and soils may become saline as a result of land use, including the use of irrigation water with high levels of salt (Sonon et al., 2015). This is important for consideration in further study as the Kalimbeza rice project is supported by flood irrigation.

## Organic carbon

In the pre-cultivated soil analysis, the box plot (Figure 2 above) also revealed that the rice soil recorded a mean organic carbon level of 0.81% while 0.72% was recorded in the post-cultivated soil (n = 34). Within the two soil depths (0-15cm and 15-30cm), the mean organic carbon levels

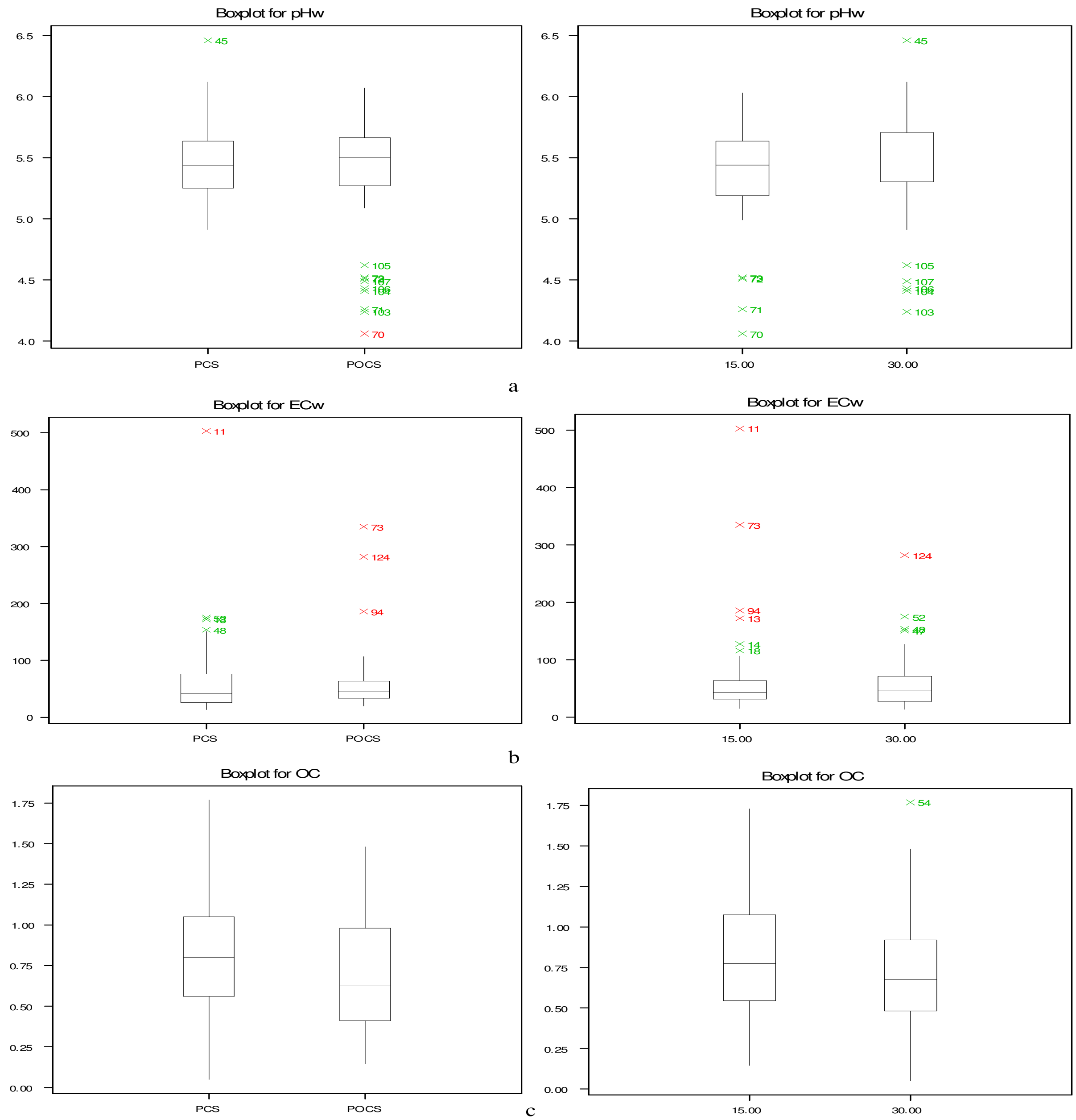


**Figure 2.** Boxplot showing the effects of cultivation (left) and soil depth (right) on the pH (a), electrical conductivity (b) and organic carbon (c) of the Kalimbeza rice project soil, pHw = pH in water (1:2.5), PCS = precultivated soil, POCS = post cultivated soil, 15.00 = 0-15cm soil depth, 30.00 = 15 – 30cm soil depth

were 0.80% and 0.73% respectively. The analysis of variance between the organic carbon contents under both the effect of cultivations and soil depths as well as their interactions was statistically not significant ($p < 0.05$) (Table 1). Based on the standard reference values (Appendix 1), these levels of soil organic carbon fall within the very low status characteristic. This has direct implication for the fertility health and nutrient binding ability of the soil. Soil organic carbon plays a key role not only in plant productivity by mediating nutrient supply (Manlay et al., 2007; Pan et al., 2009) but also in ecosystem functioning by improving biophysical environment and biodiversity (Mader et al., 2000; Anil et al., 2014). In fact, the size and dynamics of soil organic carbon pool is

**Table 1.** Analysis of variance of the effect of cultivations as well as soil depths and their interactions on the soil physicochemical parameters

| Parameter | Source of variation | p-value |
|---|---|---|
| pH | Effect of cultivation (E.C) | 0.257$^{ns}$ |
| | Soil depth (S.D) | 0.296$^{ns}$ |
| | Interaction (E.C x S.D) | 0.370$^{ns}$ |
| Electrical conductivity | Effect of cultivation (E.C) | 0.767$^{ns}$ |
| | Soil depth (S.D) | 0.613$^{ns}$ |
| | Interaction (E.C x S.D) | 0.793$^{ns}$ |
| Organic carbon | Effect of cultivation (E.C) | 0.127$^{ns}$ |
| | Soil depth (S.D) | 0.205$^{ns}$ |
| | Interaction (E.C x S.D) | 0.633$^{ns}$ |
| Cation exchange capacity | Effect of cultivation (E.C) | *** |
| | Soil depth (S.D) | 0.716$^{ns}$ |
| | Interaction (E.C x S.D) | 0.926$^{ns}$ |
| Nitrogen | Effect of cultivation (E.C) | 0.022$^{ns}$ |
| | Soil depth (S.D) | 0.997$^{ns}$ |
| | Interaction (E.C x S.D) | 0.812$^{ns}$ |
| Phosphorus | Effect of cultivation (E.C) | *** |
| | Soil depth (S.D) | 0.444$^{ns}$ |
| | Interaction (E.C x S.D) | 0.602$^{ns}$ |
| Potassium | Effect of cultivation (E.C) | 0.003$^{ns}$ |
| | Soil depth (S.D) | 0.413$^{ns}$ |
| | Interaction (E.C x S.D) | 0.816$^{ns}$ |
| Mg | Effect of cultivation (E.C) | *** |
| | Soil depth (S.D) | 0.589$^{ns}$ |
| | Interaction (E.C x S.D) | 0.497$^{ns}$ |
| Na | Effect of cultivation (E.C) | *** |
| | Soil depth (S.D) | 0.139$^{ns}$ |
| | Interaction (E.C x S.D) | 0.135$^{ns}$ |
| Sand | Effect of cultivation (E.C) | ** |
| | Soil depth (S.D) | 0.558$^{ns}$ |
| | Interaction (E.C x S.D) | 0.653$^{ns}$ |
| Silt | Effect of cultivation (E.C) | 0.140$^{ns}$ |
| | Soil depth (S.D) | 0.750$^{ns}$ |
| | Interaction (E.C x S.D) | 0.504$^{ns}$ |
| Clay | Effect of cultivation (E.C) | 0.038$^{ns}$ |
| | Soil depth (S.D) | 0.303$^{ns}$ |
| | Interaction (E.C x S.D) | 0.261$^{ns}$ |

Key: Statistically significant: *** = $p < 0.01$, ** = $p < 0.05$, ns = not statistically significant

recognized as a major determinant of the capacity of soil to provide nutrient for plant growth and to deliver the ecosystem services (Victoria et al., 2012).

### 3.1.5 NPK status

Figure 3 is the box plots showing the effects of cultivation on the major nutrient elements (NPK) of the Kalimbeza rice project soil. Very low levels of N (0.10% and 0.09%), P (1.30ppm and 3.68ppm) and K (35.60ppm and 45.50ppm) were recorded respectively in the pre- and post-cultivated soils (n = 34). Within the 0-15cm and 15-30cm soil depths, the results were N (0.10% and 0.10%), P (2.67ppm and 2.31ppm) and K (41.90ppm and 39.20ppm) respectively. The analysis of variance between the nitrogen levels under both the effect of cultivations and soil depths as well as

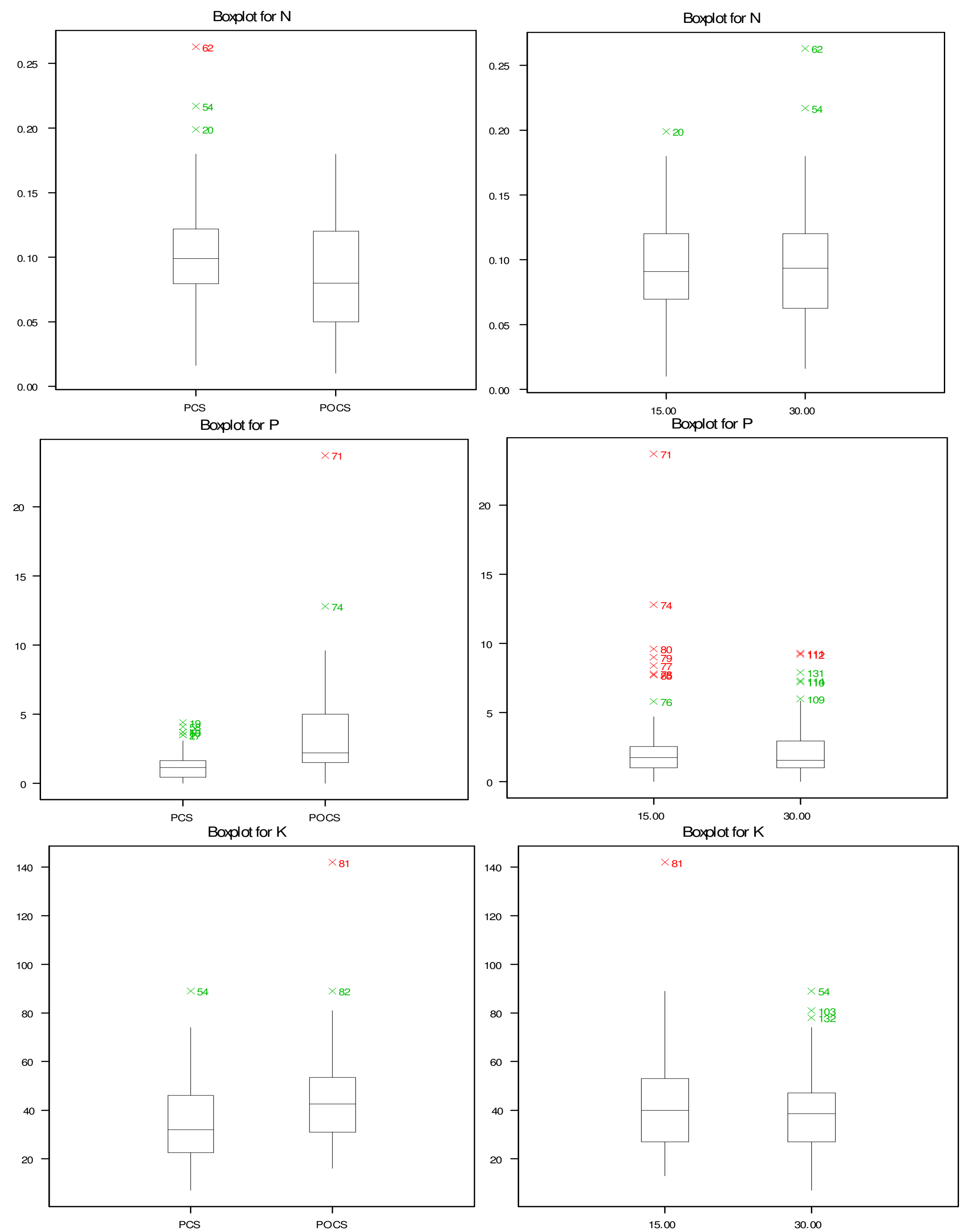


**Figure 3.** Boxplot showing the effects of cultivation (left) and soil depth (right) on the nitrogen (N), phosphorus (P) and potassium (K) of the Kalimbeza rice project soil, PCS = pre-cultivated soil, POCS = post-cultivated soil, 15.00 = 0-15cm soil depth, 30.00 = 15 – 30cm soil depth

their interactions was statistically not significant ($p < 0.05$) (Table 1). However, the variation between the mean levels of potassium under the effect of cultivation was statistically significant ($p < 0.05$), while phosphorus mean variation was statistically significant ($p < 0.01$). When compared under the effects of soil depths as well as the interaction between cultivation and soil depths, there was no significant difference. The NPK levels recorded at the time of this

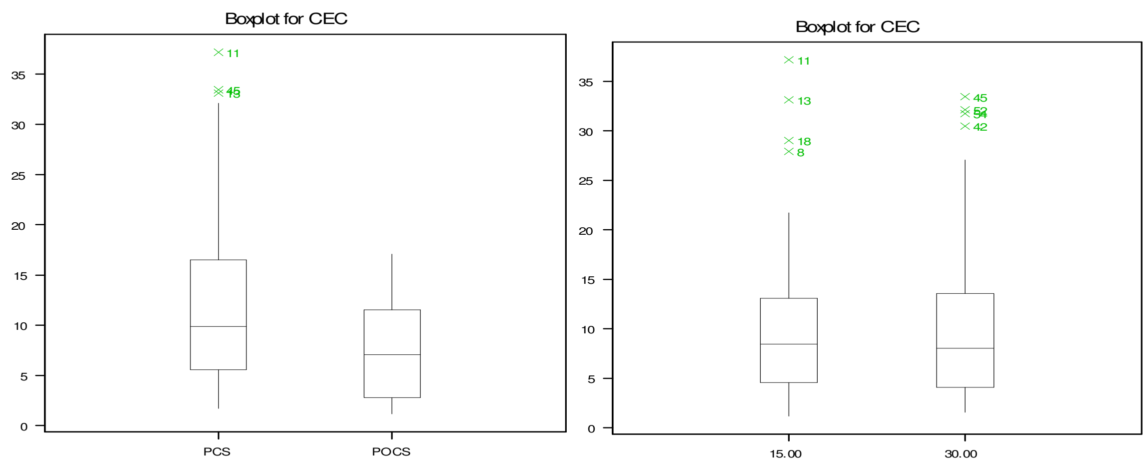


**Figure 4**. Boxplot showing the effects of cultivation (left) and soil depth (right) on the cation exchange capacity (CEC) of the Kalimbeza rice project soil, PCS = pre-cultivated soil, POCS = post-cultivated soil, 15.00 = 0-15cm soil depth, 30.00 = 15 – 30cm soil depth

study suggest that the Kalimbeza rice project soil is characteristically a very low NPK soil. This might be occasioned by the effect of continuous rice cultivation under mono-cropping system. Research finding indicated that mono-cropping has negative impact on soil fertility and soil productivity (Shukla et al., 2005), and rice cultivation is known for depleting soil nutrients particularly nitrogen (Hepute and Abah, 2017). Furthermore, the soil textural class being predominantly sandy loam in nature is a high draining and poor nutrients retention ecosystem. The implication of free drainage in sandy soil is that soil nutrients are easily washed down into the soil and become inaccessible for use by plants (Brady and Weil, 2002). Nitrogen in particular, has been described as a mobile nutrient (Buchholz, 1983) and hence, may be easily leached in the Kalimbeza rice project soil with high percentage of sand fraction. Research report has shown that low soil fertility and the often unfavourable climate conditions create intense pressure on land, even at relatively low population densities (Haefele, 2013). This is also a likely concern for the long term productivity of the Kalimbeza rice project soil as the host country, Namibia, is highly vulnerable to drought and climate change effect.

## Cation exchange capacity of the rice project soil

The box plot (Figure 4) shows the cation exchange capacity (CEC) of the pre- and post-cultivated soil of the Kalimbeza rice project soil (n =34). The results revealed a high CEC mean level of 12.26meq/100g in the pre-cultivated soil while a low mean level of 7.37meq/100g was recorded in the post-cultivated soil. Within the two soil depths, the topsoil (0-15cm) recorded a mean CEC level of 9.73meq/100g while the subsoil (15-30cm) recorded 10.20meq/100g. The CEC level of the post-cultivated soil samples suggest that the rice soil is prone to leaching of soil nutrients. The higher the CEC of a soil, the more nutrients it is likely to hold and the higher will be its fertility level (Fullen and Catt, 2004). It has been reported that the lower the soil CEC level, the faster the soil pH will decrease with time (Souleymane et al., 2015) and this could result into acidic soil with negative implication for nutrient availability and hence, rice productivity. Low soil CEC may be a concern in the rice project field which has sandy loam characteristics with poor binding and nutrient retention ability.

## Carbon: Nitrogen (C:N) of the rice project soil

Figure 5 presents the results of the C:N ratio obtained in the pre-cultivated and post-cultivated soil of the rice project. In the pre-cultivated soil, C:N ratio range of 2:1 to 15:1 (mean = 8.82, n = 34) was recorded within the topsoil (0-15cm) while a range of 0:1 to 38:1 (mean = 8.56, n = 34) was recorded in the subsoil (15-30cm). In the post-cultivated the C:N ratio was 7:1 to 61:1 (mean = 9.84, n = 34) within the topsoil and 5:1 to 9:1 (mean = 8.12, n = 34) within the subsoil. The ratio of C to N in a soil illustrates its appropriateness to supply the nutrients and the capability

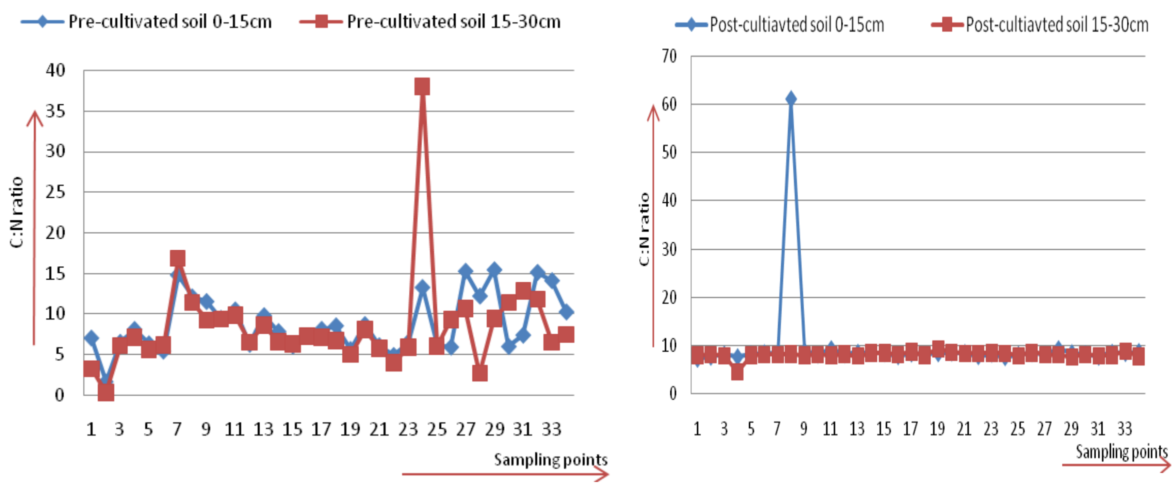


**Figure 5.** C:N ratio of the Kalimbeza rice project soil

of carbon storage and for agricultural soil, low C:N ratio (20:1 or less) is sufficient (Swangjang, 2015). The ratio of C:N indicates the rate of decomposition of organic matter and this results in the release (mineralization) or immobilization of soil nitrogen (Swangjang, 2015). In the current study, the mean levels of the C:N ratio of the rice project soil suggest the soil's suitability to supply nutrients under appropriate agronomic practices. The change of soil C:N could lead to significant declines in carbon storage (Aitkenhead and McDowell, 2000) and hence, the soil health. However, many factors including land use, climate, topography and some basic soil properties (Zhang et al., 2007), influence the biogeochemical cycle in soil which further the change of C and N storage (Swangjang, 2015). Among these factors, land use is the most importance (Yang et al., 2010).

## Correlation analysis between the physicochemical properties of the rice project soil

The correlation analysis was performed in order to assess the degree of associations between the physicochemical characteristics of the pre- and post-cultivated rice soil. The results obtained (Table 2) revealed mostly both very weak positive and negative correlations ($0.00 < r \leq \pm0.19$), both weak positive and negative correlations ($0.20 \leq r \leq \pm0.39$), both moderate positive and negative correlations ($0.40 \leq r \leq \pm0.59$), both strong positive and negative correlations ($0.60 \leq r \leq \pm0.79$) and both very positive and negative correlations ($0.80 \leq r \leq \pm0.99$). In the pre-cultivated soil, the correlation coefficients (r) between the soil nutrients binding properties and nutrient elements revealed that organic carbon is strongly positively correlated with exchangeable K (r = 0.6829), exchangeable Ca(r = 0.6651), exchangeable Mg (r = 0.7591) and N (r = 0.6162). Silt also recorded strong positive correlations with the nutrient elements: exchangeable K (r = 0.6681), exchangeable Ca (r = 0.7414); moderate positive correlation with N (r = 0.5972) and very strong positive correlation with exchangeable Mg (r = 0.8010). Similarly, clay recorded strong positive correlation with exchangeable K (r = 0.6566); very strong positive correlations with exchangeable Ca (r = 0.9442) and Mg (r = 0.9246) as well as moderate positive correlation with N (r = 0.4605). Organic carbon, silt and clay showed very weak positive correlations with available phosphorus. However, sand recorded strong negative correlation with exchangeable K (r = - 0.7052); very strong negative correlations with exchangeable Ca (r = -0.9225) and Mg (r = -0.9350) as well as moderate negative correlation with N (r = -0.5474). Similar pattern of the correlation coefficients were obtained between the soil nutrients binding properties and nutrient elements of the post-rice cultivation soil analysis. Because the Kalimbeza rice project has a predominant sandy loam textural characteristic with higher sand fraction, the moderate to very strong negative correlation coefficients

**Table 2.** Correlation analysis of the soil physicochemical properties

| | | pH | EC | OC | P | K | Ca | Mg | Na | N | Sand | Silt | Clay | CEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pre-rice cultivation soil analysis | pH | 1.0000 | | | | | | | | | | | | |
| | EC | 0.2696 | 1.0000 | | | | | | | | | | | |
| | OC | -0.2542 | 0.2849 | 1.0000 | | | | | | | | | | |
| | P | 0.1770 | 0.0506 | -0.0580 | 1.0000 | | | | | | | | | |
| | K | -0.1092 | 0.2624 | 0.6829 | 0.1162 | 1.0000 | | | | | | | | |
| | Ca | 0.0172 | 0.4656 | 0.6665 | 0.0238 | 0.7352 | 1.0000 | | | | | | | |
| | Mg | -0.1103 | 0.5194 | 0.7591 | 0.0651 | 0.7692 | 0.9220 | 1.0000 | | | | | | |
| | Na | 0.4208 | 0.8719 | 0.3077 | 0.0316 | 0.3471 | 0.5853 | 0.5786 | 1.0000 | | | | | |
| | N | -0.3057 | 0.1745 | 0.6162 | -0.0386 | 0.6403 | 0.4497 | 0.5403 | 0.0494 | 1.0000 | | | | |
| | Sand | 0.2213 | -0.4824 | -0.7625 | 0.0186 | -0.7052 | -0.9224 | -0.9350 | -0.5482 | -0.5474 | 1.0000 | | | |
| | Silt | -0.4012 | 0.3945 | 0.7206 | 0.0457 | 0.6681 | 0.7414 | 0.8010 | 0.3963 | 0.5972 | -0.9009 | 1.0000 | | |
| | Clay | -0.0807 | 0.4878 | 0.7117 | -0.0573 | 0.6566 | 0.9442 | 0.9246 | 0.5881 | 0.4605 | -0.9613 | 0.7467 | 1.0000 | |
| | CEC | 0.1793 | 0.7372 | 0.5214 | 0.0084 | 0.5875 | 0.8388 | 0.7783 | 0.7821 | 0.3430 | -0.7827 | 0.6314 | 0.7985 | 1.0000 |
| Post-rice cultivation soil analysis | pH | 1.0000 | | | | | | | | | | | | |
| | EC | -0.2188 | 1.0000 | | | | | | | | | | | |
| | OC | 0.0119 | 0.4157 | 1.0000 | | | | | | | | | | |
| | P | -0.4442 | -0.1386 | 0.1778 | 1.0000 | | | | | | | | | |
| | K | -0.1521 | 0.1452 | 0.5060 | 0.2500 | 1.0000 | | | | | | | | |
| | Ca | 0.1340 | 0.1294 | 0.5786 | 0.1451 | 0.5799 | 1.0000 | | | | | | | |
| | Mg | 0.0307 | 0.1635 | 0.5782 | 0.1873 | 0.6434 | 0.9379 | 1.0000 | | | | | | |
| | Na | 0.1714 | 0.1135 | 0.3483 | 0.1347 | 0.2710 | 0.7828 | 0.6700 | 1.0000 | | | | | |
| | N | 0.0167 | 0.4217 | 0.9688 | 0.1547 | 0.4610 | 0.5217 | 0.5139 | 0.3345 | 1.0000 | | | | |
| | Sand | 0.0445 | -0.0939 | -0.7843 | -0.3401 | -0.5831 | -0.7093 | -0.7436 | -0.3262 | -0.7138 | 1.0000 | | | |
| | Silt | 0.0301 | 0.0153 | 0.7489 | 0.3529 | 0.5576 | 0.6273 | 0.6436 | 0.2789 | 0.6897 | -0.9550 | 1.0000 | | |
| | Clay | -0.1020 | 0.1458 | 0.7559 | 0.3139 | 0.5674 | 0.7286 | 0.7750 | 0.3418 | 0.6814 | -0.9754 | 0.8670 | 1.0000 | |
| | CEC | -0.0058 | 0.1644 | 0.7820 | 0.2533 | 0.5056 | 0.7211 | 0.7014 | 0.3648 | 0.7299 | -0.9541 | 0.8739 | 0.9577 | 1.0000 |

between the nutrient elements and sand particles suggest poor nutrient holding potential of the rice soil.

## CONCLUSION

The results of this study revealed that the Kalimbeza rice project soil has a characteristically sandy loam textural class, moderate acidity, very low status of NPK and organic carbon contents. It was also found that the soil electrical conductivity characteristically fall within saline soils level while the post-cultivated soil analyses results gave low CEC. The low CEC particularly suggests that the rice soil is prone to leaching of soil nutrients. Furthermore, the moderate to very strong negative correlations between nutrient elements and sand particles of the rice project soil suggest poor nutrient holding potential. However, the present mean levels of C:N ratio of the rice project soil suggest soil's suitability to supply nutrients under appropriate agronomic practices. Therefore, a systematic management of chemical fertilizer based on immediate soil test result will be needed to optimize long term productive capacity of the Kalimbeza rice project soil.

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**Appendix 1**. Standard reference values for soil pH, EC, N, P, K, CEC, OC tests interpretation

| Soil pH | Level | EC (uS/cm) | | Fertility index | N | P | K | CEC (meq/100g) | OC (%) |
|---|---|---|---|---|---|---|---|---|---|
| < 4.5 | Very strongly acidic | < 0.40 | No salinity effects | Very Low | < 0.05 | 0 - 3 | < 70 | < 6 | < 2 |
| 4.5 - 5.2 | Strongly acidic | 0.40 - 0.80 | Very slightly saline | Low | 0.05 – 0.15 | 4 - 7 | 70 - 150 | 6 -12 | 2 – 4 |
| 5.3 - 6.0 | Moderately acidic | 0.81 - 1.20 | Moderately saline | Moderate | 0.15 – 0.25 | 8 - 13 | 150 - 250 | 12 - 25 | 4 – 10 |
| 6.1 - 6.9 | Slightly acidic | 1.21 - 1.60 | Saline soil | High | 0.25 – 0.50 | 14 - 22 | 250 - 350 | 25 - 40 | 10 – 20 |
| 7.0 - 7.5 | Slightly alkaline | 1.61 - 3.20 | Strongly saline | very high | > 0.5 | > 23 | > 350 | > 40 | > 20 |
| 7.6 - 8.2 | Moderately alkaline | > 3.2 | Very strongly saline | | | | | | |
| 8.6 - 9.0 | Strongly alkaline | | | | | | | | |
| > 9.0 | Very strongly alkaline | | | | | | | | |

Sources: Apal Agricultural Laboratory, Australia; Hill Agricultural Laboratories, New Zealand
EC = Electrical conductivity, CEC = Cation exchange capacity, OC = Organic carbon