http://dx.doi.org/10.22161/ijeab/3.5.39 ISSN: 2456-1878

# Characterization, classification and suitability ratings of soils for rainfed rice production in Rukubi, Doma, Nasarawa State, Nigeria

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***Abstract*— *Rice is an important annual crop in Nigeria. It is one of the major staples, which can provide a nation's population with the nationally required food. The objectives of this study were to characterize, classify and determine the suitability ratings of some soils of Rukubi for rainfed rice production. All the soil units were deep (150 – 199 cm), unit III soils were well drained, while units I and II soils were somewhat poorly drained. The soils had textures ranging between sandy clay loam and clay loam. The soils were well structured (strong coarse sub-angular blocky). Soil reactions were slightly acid (pH 5.12 – 7.15 in $H_2O$). The organic carbon content of the soils were moderately low to high (1.03 – 1.62 %) in the surfaces, while low in the sub-surface horizons (0.50 – 1.60 %). The total nitrogen was low at the surface horizons and ranged between 0.01 and 0.16 %. The soils were dominated by Ca and Mg with values varying from 1.10 – 4.021 cmol/kg and 0.05 – 3.89 cmol/kg respectively. The available phosphorus was relatively high in the surfaces (4.10 – 11.8 mg/kg), but, much lower in the sub-surfaces (14.15 – 9.85 mg/kg). The percentage base saturation of the soil ranged from 47 % to 98 %. Based on the physical and chemical characteristics, the soils of unit I 1were classified as TypicEndoaquepts/ AndicFluvisols; unit II was classified as EutricEndoaquepts/ AndicCambisols and unit III as ArenicEndoaquepts/ EutricFluvisols. The characteristics of the soil units were compared with the land requirements for rice production. On suitability rating, all of the soil units highly suitable for rainfed rice production.*

***Keywords*— Rainfed rice, suitability ratings, soils.**

## I. INTRODUCTION

Cereals are one of the important foods for growing population of human. Approximately 50% of consumed calories by the whole population of humans depend on wheat, Rice and maize (Gnanamanickam, 2009). Although rice has the second place because of planted area but it serves as the most important food source for Asian countries mainly in south-east parts where it is an economic crop for farmers and workers who grow it on millions of hectares throughout the region (Gomez 2001). Historically, rice was cultivated 10000 years ago in the river valleys of South and Southeast Asia and China since it served as the most important food for people. Although Asia is the main place of rice cultivation but it was harvested in other continents like Latin America, Europe, some parts of Africa and even USA (Gnanamanickam, 2009).

The rice sector in Nigeria is one of the most important remarkable agricultural developments over the decades. It is the most consumed staple food by Nigeria's over 174 million people across states and geo-political zones. There is lopsidedness in the level of production of rice in Nigeria as compared to its consumption pattern. The implication is that, to meet up with the high demand for its consumption, the rice has to be imported and these have been on the high side and it is inelastic.

In the light of this, Frederic *et al*. (2003) observed that, with rice now being the structural component of the Nigerian diet, and rice imports making up an important share of Nigeria's agricultural imports, there is considerable political interest in increasing the consumption of local rice. This has made rice a highly political commodity.

Akpokodje*et al.* (2001) maintained that, a comprehensive and up to date picture of rice sector in Nigeria in general and rice production, processing and consumption in particular is lacking. It can be seemingly noticed that, despite its agricultural potentials, Nigeria is yet to harness its vastland resources suitable for agriculture, to not only improve its export on rice, but even to cater for its domestic consumption which will invariably serve for sufficient food security. This is evident from the fact that, rice consumption in Nigeria increases over decades and in alarming rates.

*http://dx.doi.org/10.22161/ijeab/3.5.39* *ISSN: 2456-1878*

Although, the total rice production is increasing recently due to high demands; the recorded increase however, have not been sufficient to meet the increasing demand from the rapidly growing population; estimated at over 174 million people.

Osagie (2014) observed that Nigeria currently spends about a billion Naira daily importing rice. The Nigerian government recently came up with a policy decision to ban rice importation completely by 2015. The question is how prepared is the Nigerian government towards ensuring that, this policy intentions are actualized? Considering the fact that, the United States Department of Agriculture reveals that, Nigeria's rice imports in 2012 to 2013 alone were estimated to reach about 3 million tones. This is mainly because, the projected increase in rice production in 2012 to 2013 falls short of consumption requirements.

## II. MATERIALS AND METHODS

The study area is Rukubi, located at about 81 km South-west of Lafia and 40 km North-west of Makurdi town. The area lies between Latitudes $7^{0}19^{1}28^{11}$ and $7^{0}55^{1}45^{11}$N, Longitudes $8^{0}30^{1}56^{11}$ and $8^{0}18^{1}20^{11}$E, and the altitude of 252 m above sea level (asl). The area experiences distinct wet and dry seasons with the mean annual rainfall of about 1307 mm falling between April and October of most years. The mean average temperature is about $27.4^{0}$C.The monthly minimum temperature is between $16.2^{0}$C - $17.2^{0}$C.

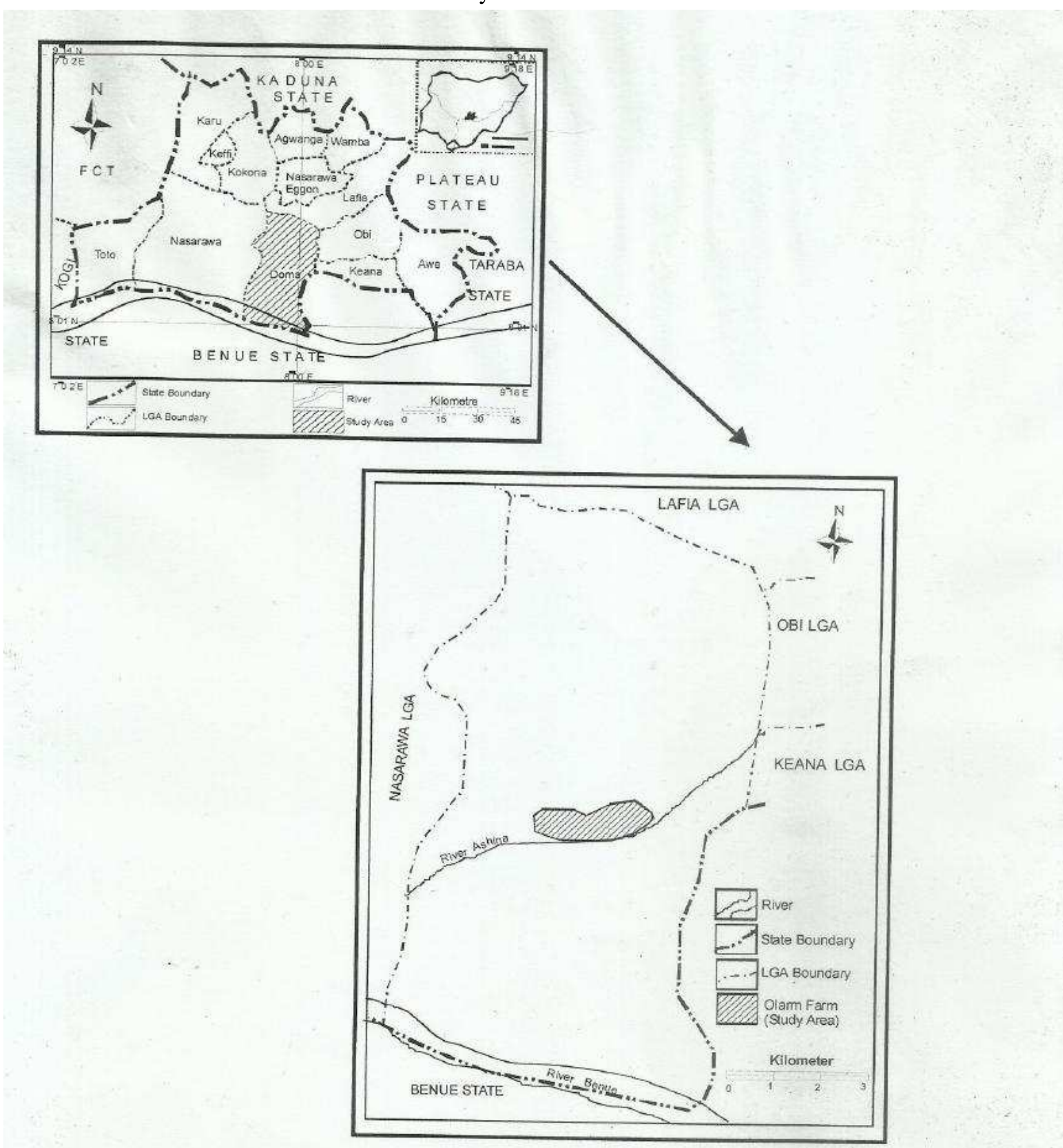


*Fig.1: Map of Nasarawa State showing the study area*

*http://dx.doi.org/10.22161/ijeab/3.5.39* *ISSN: 2456-1878*

The geomorphology of the area shows that the rock types are making up the components of Nigerian geology (Basement, Younger Granites and Sedimentary rocks). The basement complex cover up to 60% of the total area of the area, while the remaining 40% is made of sedimentary rocks of the middle Benue Trough.The area is composed of undulating lowlands and network topography with little or no rock outcrops (Nyagba, 1995).

**Field Studies**

About 300 ha of the extensive farmland at Olam were soil-surveyed using grid method with traverses cut at 200m perpendicular to the baseline. Auger point investigations were conducted at 200 m interval. Different soil types were identified using morphological characteristics such as colour, texture, structures, topography, consistence, and surface characteristics as differentiating features for delineating soil boundaries. Two pits will sunk in each soil unit, described using the guidelines of soil profile descriptions (soil survey staff, 2014). Sampling were done for each identified horizon

The soil samples from each representative soil unit were collected into polythene bags, neatly labeled and taken to the laboratory for physical and chemical analysis. Based on the data obtained from the soil survey, the soils at Rukubi were subsequently characterized, classified and mapped.

The soil samples were air-dried, gently crushed and sieved to obtain the fine earth fraction (<2 mm). Soil bulk density were determined by the undisturbed core sampling method after drying the soil samples in an oven at 105 $^{0}$C to constant weights, while particle density were measured by the pycnometer method (Black, 1965). Percentage pore space was computed from the values of bulk density and particle density (Brady and Weil, 2002) as total pore space (percentage) = (1-BD/PD) x 100.

The laboratory analysis was carried out included particle size distribution using hydrometer method as described by Day (1965). Soil pH was determined by electrometer method as described by Hesse (1971). Soil organic carbon was determined by Walkey Black method based on the oxidation of organic matter by potassium dichromate (Hesse, 1971). Total nitrogen was determined using macro Kjeldahl procedures. Available phosphorus determined using Bray 1 method (IITA, 1979). The exchangeable bases were extracted using neutral $NH_4OAC$ as displacing solution. Calcium and Magnesium were read on atomic absorption spectrophotometer, while Potassium and sodium were read on flame photometer. Exchange acidity was determined using Barium Chloride Triethanolamine as described by Peech (1965). Effective cation exchange capacity was calculated as the sum of exchange acidity and exchangeable bases. The percentage base saturation was calculated as total exchangeable bases divided by effective cation exchange capacity multiplied by 100.

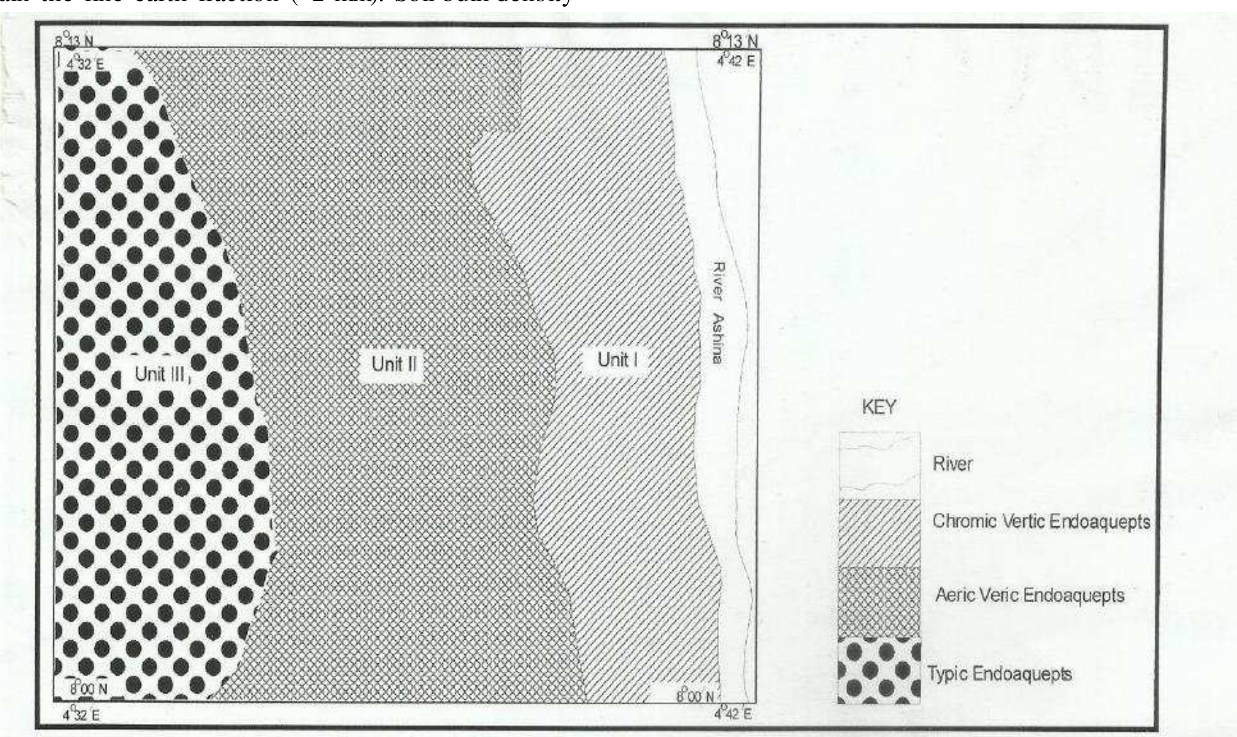


*Fig.2: Soil Map of Rukubi*

http://dx.doi.org/10.22161/ijeab/3.5.39 ISSN: 2456-1878

## III. RESULTS AND DISCUSSIONS

### Soil morphological characteristics

Figure 1 shows distribution of the three mapping units. The soils were generally poorly drained. They were fine textured with clay content ranging from 10.7 % and 40.0 %, this could be as result of the shale parent material. The clay and sand content distribution was irregular across the horizons except for sand in unit III were the sand content decreased with increase in depth. This could be as result of intense disturbances caused heavy machinery used in farming by Olam rice farm. More so, the irregular pattern in most of the units could be due to different types of sediment with varying textures deposited annually in accordance to their source. The structure of the surface horizon in all the soil units was strong coarse sub- angular blocky possibly as a result of high organic and clay contents.

### Soil chemical properties

The pH value of the soils of the study area as shown in Table 1 indicates that the soils were slightly acid in reaction. Soil pH of surface horizon ranged 5.12 and 7.1. These figures mostly decreased with depth probably due to the effect of nutrient biocycling (Ogunwale *et al.,* 2002) the percentage organic carbon was highest 1.62% in pedon 3 probably due to incorporation of the crop residues to the soil. The total nitrogen values of the soils ranged between 0.01 to 0.70 %. These nitrogen levels are very low for surface horizons of soils as rated by (IRRI, 1995) and probably due to release from plant tissues, gaseous loss and volatilization (De Datta, *et al.,* 1991).

The available phosphorus values were relatively high (11.8 cmol/kg). The values decrease with increasing depth. This is perhaps due to the relationship of organic carbon with phosphorus (Miura *et al.,* 1997).

Exchangeable Ca and Mg dominated over K and Na in the exchange complex. This is in agreement with earlier finding of Fagbami and Akamigbo, (1986). The values of exchange acidity were generally low and ranged between 0.88 to 1.80 cmol/kg. Effective cation exchange capacity values were low and ranged between 3.39 cmol/kg and 9.70 cmol/kg of soil, which is rated as low to moderate (FAO, 1983). This may probably be due to the contribution of clay (Idoga and Azagaku, 2005). The percentage base saturation was rated from moderate to high, ranging from 47 % to 98 %. This could be linked to the active plant litter decomposition process, which incorporates cations from the litter into the soil surface (Malgwi, 1979).

The USDA soil taxonomy (soil survey staff, 2014) and the WRB, (2006) were used in classifying the soils of the area. Both field and laboratory studies of the soils of the area indicate an increasing trend in the amount of clay with depth (especially unit III) and also high degree of aggregation. The clay distribution pattern shows that there is argillic horizon in all the profiles studied. This clay distribution pattern corresponds with the high base saturation status of the soils therefore qualifying them as Alfisols. The presence of mottles mostly near the soil surface, a chroma of 2 in some horizons qualifies the soils as Aqualfs. Soil units II and III show evidence of episaturation by the presence of mottles at or near the soil surface and the dominant hue of 10YR and 2.5Y; they therefore qualify as Epiaqualfs. They further qualify as AericVerticEndoaqualfs and ChromicVerticEndoaqualfs because of the presence of cracks narrower than 2 cm and shallower than 50 cm, as well as the dominance of hue of 7.5YR, and 10YR. All the soil units showed irregular but decreasing clay content with depth. They therefore classified as *Inceptisols*. This inferred ustic soil moisture regime of the area places these soils into the suborder ustept. The clay distribution pattern of the soils places them in the great group Haplustepts. They further classified as AquicHaplustepts because of aquic soil moisture regime within 70 cm of soil surface.

In the WRB (2006), the soils have high clay content in the subsoil than in the topsoil as a result of pedogenic processes (elluviation and Illuviation) leading to an Argic subsoil horizon. All soil units have evidence of redoximorphic features caused by subsurface water, which periodically wet both the topsoil and the subsoil over a considerably period of time leading to the formation of mottles. For these reasons, they are classified as Luvisols (WRB, 2006). They further qualify as VerticLuvisols because of vertic properties within 100 cm of soil surface and higher clay content of the subsoil as well as the high base status of the soils.

*Table.1: Physical and Chemical Characteristics of the Soils*

| Horizon | Depth | Bulk Density | Particle size analysis | | | Textural Class | pH (1:1) | | Organic Carbon (%) | Avail. P (mg/kg p) | Total N (%) | Exchangeable Cations | | | | Exch. Acidity | ECEC | BS (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sand | Silt | Clay | | KCl | $H_2O$ | | | | Ca | Mg | K | Na | | | |
| | | | → % ← | | | | | | | | | → Cmol/kg ← | | | | | | |
| **Soil Unit I: Pedon 1 Chromic VerticEndoaqualfs/ AndicLuvisols** | | | | | | | | | | | | | | | | | | |
| A | 0-15 | 2.73 | 69.2 | 2.60 | 28.2 | SCL | 4.58 | 5.63 | 1.60 | 4.10 | 0.70 | 3.80 | 3.40 | 0.34 | 0.36 | 1.08 | 8.63 | 92 |
| B | 15-30 | 2.82 | 25.5 | 40.6 | 33.9 | CL | 4.50 | 5.76 | 1.10 | 4.50 | 0.56 | 3.76 | 3.30 | 0.34 | 0.38 | 1.03 | 8.97 | 89 |
| $B_1$ | 30-87 | 2.87 | 39.1 | 42.0 | 18.9 | L | 4.40 | 5.74 | 1.10 | 4.40 | 0.56 | 3.63 | 3.20 | 0.32 | 0.34 | 1.02 | 8.51 | 88 |
| $B_2$ | 87-130 | 2.79 | 40.8 | 32.0 | 27.2 | L | 4.87 | 5.84 | 0.87 | 4.20 | 0.56 | 3.61 | 3.18 | 0.32 | 0.34 | 0.99 | 8.44 | 89 |
| C | 130-150 | 2.90 | 41.3 | 29.9 | 28.8 | CL | 4.53 | 5.92 | | 4.15 | 0.49 | 3.52 | 3.06 | 0.29 | 0.33 | 0.72 | 7.92 | 91 |
| **Soil Unit I: Pedon 2 Chromic VerticEndoaqualfs/ AndicLuvisols** | | | | | | | | | | | | | | | | | | |
| A | 0-30 | 2.93 | 73.5 | 15.7 | 10.7 | SCL | 5.07 | 7.15 | 1.44 | 4.80 | 0.56 | 4.10 | 3.60 | 0.36 | 0.40 | 1.12 | 9.52 | 88 |
| $A_1$ | 30-70 | 2.74 | 31.5 | 37.7 | 30.8 | L | 5.04 | 6.40 | 1.32 | 4.65 | 0.56 | 4.00 | 3.89 | 0.34 | 0.37 | 1.10 | 9.70 | 89 |
| B | 70-116 | 2.82 | 64.2 | 18.3 | 17.5 | SL | 4.93 | 6.38 | 1.00 | 4.65 | 0.49 | 3.92 | 3.37 | 0.33 | 0.34 | 0.98 | 8.94 | 89 |
| C | 116-199 | 2.84 | 61.3 | 25.0 | 13.5 | SL | 4.65 | 5.93 | 0.84 | 4.20 | 0.49 | 4.00 | 3.50 | 0.35 | 0.38 | 0.88 | 9.11 | 90 |
| **Soil Unit II: Pedon 3AericVerticEndoaqualfs/ VerticLuvisols** | | | | | | | | | | | | | | | | | | |
| A | 0-10 | 2.74 | 33.5 | 36.0 | 30.5 | CL | 4.49 | 5.91 | 1.62 | 4.40 | 0.59 | 3.86 | 3.30 | 0.30 | 0.34 | 1.13 | 8.93 | 87 |
| AB | 10-49 | 2.79 | 21.5 | 41.3 | 37.2 | CL | 4.41 | 5.86 | 1.60 | 4.50 | 0.56 | 3.88 | 3.17 | 0.31 | 0.35 | 1.10 | 8.81 | 88 |
| B | 49-99 | 2.94 | 35.1 | 36.4 | 28.5 | CL | 4.54 | 5.92 | 0.87 | 4.40 | 0.56 | 3.51 | 3.00 | 0.30 | 0.34 | 1.06 | 8.21 | 71 |
| $Bt_2$ | 99-140 | 3.02 | 44.8 | 35.0 | 20.2 | L | 4.54 | 5.88 | 0.68 | 4.30 | 0.59 | 3.40 | 3.10 | 0.28 | 0.32 | 0.98 | 8.08 | 88 |
| C | 140-154 | 3.11 | 28.9 | 40.0 | 31.1 | CL | 4.56 | 5.78 | 0.60 | 4.25 | 0.70 | 3.31 | 3.00 | 0.28 | 0.29 | 0.81 | 7.69 | 90 |
| **Soil Unit II: Pedon 4AericVerticEndoaqualfs/ VerticLuvisols** | | | | | | | | | | | | | | | | | | |
| $A_1$ | 0-13 | 2.70 | 37.1 | 38.4 | 24.5 | L | 4.69 | 6.69 | 1.12 | 4.65 | 0.56 | 3.84 | 3.40 | 0.34 | 0.56 | 1.14 | 8.28 | 98 |
| $B_2$ | 13-57 | 2.98 | 34.8 | 42.0 | 23.2 | L | 5.60 | 6.62 | 1.07 | 4.50 | 0.56 | 3.74 | 3.18 | 0.32 | 0.36 | 1.04 | 8.64 | 88 |

http://dx.doi.org/10.22161/ijeab/3.5.39 ISSN: 2456-1878

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $B_3$ | 57-96 | 2.84 | 40.8 | 40.0 | 19.2 | L | 6.03 | 6.54 | 0.87 | 4.30 | 0.70 | 4.02 | 3.60 | 0.37 | 0.40 | 1.00 | 9.39 | 89 |
| C | 96-156 | 2.88 | 73.1 | 10.9 | 16.2 | SL | 5.62 | 6.92 | 0.62 | 4.75 | 0.63 | 3.86 | 3.60 | 0.36 | 0.40 | 0.94 | 9.32 | 88 |
| **Soil Unit III: Pedon 5 Chromic VerticEndoaqualfs/ VerticLuvisols** | | | | | | | | | | | | | | | | | | |
| A | 0-28 | 2.52 | 40.8 | 18.2 | 40.0 | SC | 4.50 | 5.98 | 1.56 | 11.8 | 0.59 | 2.22 | 1.47 | 0.31 | 0.17 | 1.50 | 5.67 | 74 |
| B | 28-49 | 2.67 | 45.2 | 19.2 | 35.6 | CL | 4.42 | 5.96 | 1.06 | 9.85 | 0.52 | 1.14 | 1.61 | 1.36 | 0.12 | 1.50 | 5.73 | 73 |
| $Bt_1$ | 40-70 | 3.00 | 44.6 | 23.2 | 33.2 | CL | 4.33 | 5.68 | 0.92 | 9.12 | 0.51 | 1.10 | 1.54 | 0.84 | 0.10 | 1.35 | 4.37 | 81 |
| $Bt_2$ | 70-93 | 3.03 | 46.8 | 20.0 | 33.2 | CL | 4.00 | 6.51 | 0.56 | 8.22 | 0.43 | 1.07 | 1.46 | 0.44 | 0.05 | 1.20 | 4.22 | 72 |
| $Bt_3$ | 93-150 | 3.09 | 48.8 | 20.0 | 31.2 | SCL | 4.12 | 5.12 | 0.62 | 8.0 | 0.04 | 1.05 | 1.33 | 0.48 | 0.02 | 0.88 | 3.76 | 77 |
| **Soil Unit III: Pedon 6 Chromic VerticEndoaqualfs/ VerticLuvisols** | | | | | | | | | | | | | | | | | | |
| A | 0-22 | 2.78 | 48.5 | 15.5 | 36.0 | SC | 4.88 | 5.99 | 1.03 | 10.5 | 0.10 | 2.81 | 2.53 | 0.30 | 0.16 | 1.50 | 7.30 | 79 |
| B | 22-67 | 2.77 | 44.6 | 21.0 | 34.4 | CL | 4.62 | 5.88 | 1.00 | 9.01 | 0.09 | 1.92 | 1.29 | 0.28 | 0.12 | 1.65 | 5.26 | 69 |
| $Bt_1$ | 67-93 | 3.20 | 48.2 | 20.8 | 31.0 | SCL | 4.81 | 5.91 | 0.67 | 8.51 | 0.07 | 1.74 | 1.04 | 0.27 | 0.15 | 1.60 | 4.30 | 74 |
| $Bt_2$ | 93-138 | 3.38 | 50.0 | 20.0 | 30.0 | L | 4.72 | 5.82 | 0.58 | 8.50 | 0.05 | 1.53 | 0.89 | 0.24 | 0.10 | 1.80 | 4.36 | 63 |
| $Bt_3$ | 138-160 | 3.40 | 39.7 | 22.3 | 38.0 | L | 4.91 | 5.82 | 0.50 | 7.00 | 0.01 | 1.23 | 0.05 | 0.21 | 0.10 | 1.80 | 3.39 | 47 |

**Source :**Field Studies

*Table.3: Summary of Soil of Soil Type and Their Suitability Ratings*

| Soil Units | Pedons | Taxonomic classes | Suitability ratings |
|---|---|---|---|
| I | 1 and 2 | Chromic VerticEndoaqualfs/ AndicLuvisols | $S_2$ |
| II | 3 and 4 | AericVerticEndoaqualfs/ VerticLuvisols | $S_2$ |
| III | 5 and 6 | Chromic VerticEndoaqualfs/ VerticLuvisols | $S_2$ |

**Where $S_2$- moderately Suitable**

http://dx.doi.org/10.22161/ijeab/3.5.39 ISSN: 2456-1878

**Suitability ratings for rainfed rice production**

Suitability ratings derived from the results of soil survey work (Fagbemi and Akamigbo, 1986). The interpretation of soil survey work itself is a statement of prediction of performance. Suitability ratings is therefore, carried out by comparing the characteristics of the soils with the requirements of the crop in this case, rice. The chemical characteristics of the soils such as pH, organic matter, exchangeable bases, effective cation exchange capacity, and exchange acidity are found to be conducive to rice production or can be mended by individual farmers and therefore cannot be permanent limitations.

All mapping units were very deep (>120cm) and all are considered suitable for the production of rice. However, all the pedons have characteristic mottling at the subsurface through to the last horizon. This probably accounted for the observed redoximorphic condition in all the soil units indicated by the presence of few fine medium to coarse and distinct to prominent mottles occurring within the horizons. However, the soil may not have been under permanent water saturation for a period longer than few weeks as indicated by soil colour which ranged from the texture of the soils ranged from clay loam to sandy clay loam. According to Sys (1991, 1993), rice require loamy clay to sandy loam clay for optimum yield. Thus, the soils in pedon unit I and III present a very slight limitation to rice yield, while soil unit II seems to possess no textural limitation to rice production, hence, it is highly suitable. The structure of the soils ranged between fine sub angular blocky to coarse sub angular blocky. Coarse sub angular blocky is regarded as highly suitable for rice production (Sys, 1991). The structures of all the mapping units were considered highly suitable for rice production. The soil chemical properties, which could affect their suitability for rainfed, rice production are acidity, salinity, and fertility. The reactions of the soils ranged from slightly acidic to neutral (pH 5.12 to 7.15). Although this pH level may not pose serious problem for P uptake, pH above 6.0 may limit the availability of micronutrients such as Fe, Zn, Mn and Cu which form metallic cations that precipitate into low solubility compounds at high pH levels. Total exchangeable acidity ($H^+$ + $Al^+$) ranged between 0.72 cmol/kg and 1.80 cmol/kgindicating that the level of exchangeable aluminium was below toxic range (Tanaka and Yoshida 1970). The soils have low to medium levels of exchangeable Ca, Mg, K, Na and of N and medium to high levels of Bray-1 P. All with the exception P, the major nutrient content in the soil were lower than the critical requirement for rice production (De Datta, 1989). The result of the survey revealed that the levels of organic matter, nitrogen, exchangeable cations and Mn were below the critical requirements for rice production (Adeoye, 2002).

*Appendix A: Land Requirement for Suitability Classes For rain-fed Rice Production*

| Land Qualities | $S1_1$ | $S1_2$ | S2 | S3 | N1 | N2 |
|---|---|---|---|---|---|---|
| **CLIMATE** | | | | | | |
| Annual Rainfall | >1000 | 900-1000 | 800-900 | 600-800 | 600-500 | <500 |
| Mean annual temperature($^{O}$C) | >25 | 22-25 | 20-22 | 18-20 | 16-18 | <16 |
| Relative Humidity (%) | >75 | 70-75 | 65-70 | 60-65 | <60 | |
| Topography: Slope (%) | <2 | 3-4 | 5-6 | 7-8 | 9-10 | >10 |
| **DRAINAGE (s):** | | | | | | |
| Wetness | WD (ID) † | MWD (ID) † | MD | ID (WD) † | PD (WD) † | PD (WD) † |
| Flooding | Fo | Fo | F1 | F1 | F2 | F3 |
| **SOIL PHYSICAL PROPERTIES** | | | | | | |
| Texture | L (LC) † | Lfs (SLC) † | LS (SL) † | S | S | S |
| Structure | Cr (SAB) † | C (SAB) † | SAB (Cr) † | SAB (Cr) † | Col (Cr) † | Col (Cr) † |
| Coarse fragment (%) (0-45cm) | <3 | 3-5 | 5-10 | 10-15 | >15 | |
| Soil Depth (cm) | >75 | 65-70 | 50-65 | 35-50 | 30-35 | <30 |
| **FERTILITY (F)** | | | | | | |
| pH | 5.5-6.5 | 5.0-5.5 | 4.5-5.0 | 4.0 | 4.5 | <4.0 |
| Base Saturation | >80 | 70-80 | 50-70 | 40-50 | 25-35 | <25 |

http://dx.doi.org/10.22161/ijeab/3.5.39 ISSN: 2456-1878

| | | | | | | |
|---|---|---|---|---|---|---|
| Organic Carbon (%) (0-30cm) | >2.0 | 2.0-1.5 | 1.2-1.5 | 1.0-1.2 | 1.0 | <1.0 |
| **MACRO-NUTRIENTS** | | | | | | |
| Nitrogen (%) | >2.0 | 1.5-2.0 | 1.0-1.5 | 0.5-1.0 | <0.5 | |
| Phosphorus (mg $kg^{-1}$) | >20 | 15-20 | 8-15 | 5-8 | 3-5 | <3 |
| Potassium (cmol $kg^{-1}$) | >0.5 | 0.3-0.5 | 0.2-0.3 | 0.1-0.2 | <0.1 | |
| **MICRO-NUTRIENTS** | | | | | | |
| Iron (Fe) (mg $kg^{-1}$) | >4.5 | 3.5-4.5 | 2.5-3.5 | 1.5-2.5 | 1.0-1.5 | <1.0 |
| Zinc (Zn) (mg $kg^{-1}$ ) | 2.0-2.5 | 1.5-2.0 | 1.0-1.5 | 0.8-1.0 | 0.6-0.8 | <0.6 |
| Manganese (Mn) (mg $kg^{-1}$) | 1.5-1.7 | 1.0-1.5 | 0.8-1.o | 0.6-0.8 | 0.5-0.6 | <0.5 |

***Source:* Sys *et al., (*1991, 1993*);* De Datta (1989)**

†= ratings for lowland rice production; SAB= Sub-Angular Blocky; Col= Columnar; Cr= Crumb; WD= Well Drained; MWD= Moderately Well Drained; ID= Imperfectly Drained; PD= Poorly Drained; L= Loamy; SL= Sandy Loam; LS= Loamy Sand; Lfs= Loamy fine sand; SCL= Sandy Clay Loam; Fo= Rarely flooded; F1= Flooding expected; F2= Irregularly Flooded; F3= Regularly Flooded

The climate of the studied area is quite favourable for the production of rice. The mean annual temperature ($27^0$C-$30^0$C), average sunshine hours (>5 hours), total annual rainfall and distribution pattern (>1000) and relative humidity during cropping season (>75%) are all adequate by the standard of Sys (1993). The topography of the toposequence is also considered adequate (Slope between <1-2%).

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