CHARACTERIZATION AND SUITABILITY RATING OF SOME SELECTED WETLAND SOILS FOR RAINFED RICE PRODUCTION IN KWANDE LOCAL GOVERNMENT AREA, BENUE STATE

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ABSTRACT

This study was carried out to characterize and determine the suitability of selected soils of Kwande for rainfed rice production. The study area was Adagi, Ikyurav-ya Council Ward, Kwande Local Government Area of Benue State (05º35' and 05º47' N and longitudes and 07º55' and 07º39' E). The soils were characterized, classified and mapped out according to their morphological, physical and chemical properties. They were also mapped according to their topographic positions in relation to the level of soil moisture. Six varieties of rice (Faro 62, Faro 61, Faro 57, Faro 44, OM2386 and a local {Gborogidi}) were tested across three topographic positions. Field trials were carried out on three slope levels (middle, lower and toe) with the view to compare the performance among six varieties of rice and to ascertain the best variety for each of the slope levels. The study revealed that the soils were deep (107 – 167 cm), somewhat poorly drained, having 40.80 % to 76.80 % of sand, 08.00 % to 29.00 % of silt and 12.20 % to 40.92 % of clay. Unit I soils occupied the middle slope and were well drained while the other units were somewhat poorly drained as a result of their topographical positions and their texture and structure (moderate to strong sub-angular blocky). The soils in the study area were structurally strong coarse subangular blocky to strong fine subangular blocky in most of the horizons. The soils were rated as strongly acid to slightly alkaline in reaction ranging from 4.5 – 7.5. The soils had low organic carbon (0.17 to 2.51 gkg-1), very low total nitrogen (0.03 – 0.11 gkg-1), very low available P (2.31 to 5.90 mgkg-1), low to medium exchangeable bases (2.50 – 3.20 cmolkg-1), low CEC (5.80 to 8.10 cmolkg-1) and high to very high base saturation (78.77 to 91.60 %). Based on these properties, the major soils of the three topographic positions namely; middle slope (unit I), profile 1 was classified as Typic Plinthustalf/Plinthic Lixisols (Arenic) while profile 2 was classified as Aquic Haplustept/Haplic Cambisol (Greyic); unit II profiles 3 and 5 were classified as Aquic Eutrudept/ Endogleyic Cambisol (Greyic) while profile 4 was qualified as Fluventic Haplustept/Haplic Cambisol (Greyic). The soil unit III was classified as Aquic Eutrudept/Endogleyic Cambisol (Greyic)). Soils of Unit I were well drained with low-water holding capacity and were strongly acid and being rated as marginally suitable (S3) while soil units II and III were rated as highly suitable (S1) for rainfed rice production as a result of their high-water holding capacity, low lying and tolerable soil reaction (high pH). Six (6) rice varieties were used as test crop. The rice yield results showed a positive correlation between the suitability classes and the actual yield. From the experiment, the rice yielded far better in the lower and toe slopes in soil Units II and III and were rated highly suitable (S1)than soil Unit I which was rated as marginally suitable (S3). The yields of soil unit II were statistically higher (5.39 t/ha) while the middle slope (unit I) was significantly lower (2.66 t/ha). Among the varieties, the yields were statistically higher in the following order: Faro 44> FARO 57> OM6328> FARO 62> FARO 61 and > Local. FARO 44 from the results seems to have scale neutrality, having the highest yield in all topographic positions, hence they are highly recommended as the best variety among the common varieties in the community. FARO 57 and OM6328 varieties are also highly recommended since they were not statistically different in yield with the other best variety. Considering the low chemical fertility status of the soil in the study area, appropriate fertilizers (250 kg of NPK 20:10:10) are recommended to make up the deficiency. The lower and toe slope positions are better topographic positions and are recommended for lowland rice than the middle slope.

Keywords: Soil, Characterization, Suitability, Soil Units, Topographic Positions, OM6328, FARO, 44, 57, 61 and 62.

1. INTRODUCTION

Wetland soils are generally regarded as good rice soils. Farmers venture into rice production in these soils without taking into consideration soil characteristics and management and even without varietal considerations of rice especially water management. Rice is a major commodity in world trade. Rice has become the second most important cereal in the world after wheat in terms of production, due to a recent decline in maize production (Jones, 1995). It is widely cultivated throughout the tropics; and where flood controls are effective as in Southeast Asia, with high yield. Much of the rice imported into West Africa is from Southeast Asia. In sub-Saharan Africa, West Africa is the leading producer and consumer of rice (WARDA,1996). West Africa accounts for 64.2 % and 61.9 % of total rice production and consumption in Sub-Saharan Africa respectively. Except for Burkina Faso and Niger, rice is a staple crop throughout West Africa, especially in Nigeria, Cote d'Ivoire, the Gambia, Guinea, Guinea Bissau, Liberia, Senegal, and Sierra Leone. The River Niger drainage system is a major rice-growing environment in the region. Nigeria is the leading producer of rice in West Africa.

Nigeria ranks the highest as both the producer and consumer of rice in the Sub-region with figures slightly above 50 % (WARDA, 1996). Rice is known to have been grown along the Niger for over 3000 years (Imolehin and Wada, 2000). The trend for the region is that the production and consumption of rice are growing faster than for other food staples. The potential for commercial production of rice in West Africa includes wetlands as coastal plains, inland basins, floodplains as inland valley bottoms (Andriesse, 1986). The coastal wetlands as deltas, estuaries and tidal flats are yet to be fully exploited largely due to the non-availability of appropriate technology as in the Niger delta of Nigeria. The estuarine mouth of the Cross River in Nigeria is yet to be exploited for rice cultivation. The Gambia and the Corubal of Guinea Bissau are good estuaries. Tidal flats (lagoons) occur along the coast from Nigeria to Guinea Bissau. Inland basins in West Africa include the inland deltas of the Niger in Mali and the Lake Chad Basin. The floodplains occur along the Gambia River, the upper, middle, and lower Niger, the Sokoto - Rima, the Black Volta, the Cross River, and the Benue trough amongst others. Inland valley bottoms abound in West Africa. These are referred to by different names as fadamas in northern Nigeria (Savvides, 1981) and marigots in francophone and inland valley swamps in Sierra Leone (Millington et al., 1985).

The objectives were to: -

I. Determine the morphological, physical, and chemical characteristics of some selected soils of Adagi
ii. Characterize and classify some selected soils of Adagi using USDA soil taxonomy and WRB (2006)
iii. Identify suitable slope positions for sustainable productivity in the study area
iv. Identify suitable rice varieties in the study area for sustainable productivity

The increasing population upsurge in Nigeria is directly proportional to an increase in rice consumption and consequently, higher demands. But poor and un-realistic weather conditions have posed a major challenge to the smooth production of rice in Benue State. This situation has led to the exploitation of low-lying areas (fadama) for rice production. Even then experience in recent times points to decreasing rice yields with continuous cropping even in the Fadama (Idoga and Ayuba, 2001). This could be due to a lack of soil information and poor soil management. This is in line with Fasina et al., (2015) who opined that the major factor limiting optimum crop production in the tropics is the lack of detailed information on soil and land characteristics. Agriculture remains the base of Nigeria's economy, providing the main source of livelihood for most Nigerians.

Soil characteristics and properties are the outcomes of the interplay of pedogenic factors and processes prevailing in the area. The hilly and mountainous/low lying regions are endowed with a wide range of environmental factors that exert an influence on the spatial variability of soils. A review of those factors and processes that have contributed to soil formation is necessary for a better understanding of the wide range of soils. The qualities of the soil can be identified through the knowledge of soil characteristics and classification. The fundamental principle behind soil characteristics is that different kinds of land use have different soil requirements. When soils are characterized, their potentials can be accessed through their properties (Noma, et al., 2004, Azagaku, 2009).

Egboka et al., (2019) characterized and classified the soils formed under different landscape positions in Osina, Imo State as Arenic Kandiaqualfs and Psammentic Kandiaqualf which were correlated with WRB as Arenic Lixisols and Loamic Lixisols respectively. The soils are generally loamy, sandy-clay, or sandy loam with very strong acid reactions especially in the toe slope.

Azagaku and Idoga (2012) observed Aeric Chromic Vertic Epiaqualfs and Gleyic Luvisols in the floodplain soils of Agash, Benue state. Usman et al (2017) worked on the soils of the Gboko council area of Benue; the soils showed the characteristics of a well-drained condition.

Kyat and Idoga (2018) classified the soils of Rukubi in Doma-Nasarawa as Typic Haplostalfs and Typic Entropepts and Typic Psamments at a detailed level. Ajiboye et al., (2011) reported that low base saturated soils of Odeda belonged to Alfisols, and Inceptisols. However, the Alfisols were confined to a comparatively smaller area. Similarly, Usman et al (2017) classified the soils of Gboko plains into Alfisols and Inceptisols but with relatively higher base saturation. Raji (2016) characterized the soils of some basement complexes in Kwara state and classified them as Alfisols at the order level indicating matured soils with well-developed horizons with fairly base saturation.

Properties of soil are the features of a soil type that make it different from others. They are the combination of mineral particles, organic matter, water, and air (Ojanuga et al., 2003). Soil has a wide range of characteristic properties, consequently, they vary greatly in the sustainability for the production of various crops. Soil properties at very important in the determination of the degree of soil suitability for agriculture and other purposes (Ufot, 2012). Soil properties affect the productivity of soil (Foster et al., 2003).

Location

The study area is Adagi, located within Ikyurav-ya, Kwande Local Government Area, Benue of Nigeria (fig.1). Adagi lies about 23 km northeast of Kwande Local Government headquarter (Adikpo) with an average height of about 211 m above mean sea level (Kwande LGA water Aid project, 2017). The area lies between latitudes 05º35' and 05º47' N and longitudes and 07º55' and 07º39' E. Kwande Local Government Area is bounded in the north by Katsina-Ala Local government Area, in the northeast by Taraba State, in the east by the Cameroon Republic and to the southeast by Cross River State, in the west by Vande-ikya LGA and in the northwest by Ushongo Local Government Area (Fig.1). The study area lies southeast of the road linking Kwande Local Government Area with the Ikyogen cattle range and east of the Ikyurave-ya Council ward, Adagi. The River (Amile) watershed covers about 700 hectares of land.

Field Studies

The rigid grid soil survey method was used to investigate the morphological characteristics of the soils. The depression that separates the upper slope from the lower slope stands parallel to River Ahom which runs north-westward was used as the baseline. Soil colour, texture, structure, consistency, soil depth, stoniness, drainage, surface characteristic, parent materials, topography, vegetation, and inclusion were used in delineating soil boundaries.

A temporary soil map was prepared based on the above-auger point investigation and two profile pits dogged in each soil unit so delineated (upper, lower, and lower slopes). The soil profile pits were described according to the guideline for soil profile description (Soil Survey, Staff, 2014) and soil samples were collected from the identified soil horizons into polythene bags, carefully labeled, and taken to the laboratory for physical and chemical analyses.

Laboratory Studies

The labeled soil samples were air-dried, gently crushed using mortar and pestle, and sieved through a 2 mm sieve to obtain a fine earth fraction for laboratory analysis. The fine earth fractions (< 2 mm) were stored in polythene bags, neatly labeled, and kept for physical and chemical analysis. The sample was analyzed for particle size distribution (PSD), organic carbon, soil pH, total nitrogen, available phosphorus, cation exchange capacity (CEC), exchangeable bases (Ca, Mg, K and Na), and percentage base saturation. The soil analyses were carried out in the Soil Science Laboratory, Department of Soil Science, University of Agriculture, Makurdi. Where standard Laboratory method were used for the determination of; particle size distribution, organic carbon, soil pH, total nitrogen, available phosphorus, exchangeable bases (Ca, Mg, K and Na), cation exchange capacity (CEC), base saturation (BS).

Crop Trial

At each of the three (3) different slope levels (middle, lower and toe) identified in the study area, six (6) varieties of rice were tested to evaluate the effect of slope levels on the growth and yield of rice.

Experimental Methods

a) Treatments: The experimental treatments comprised of three slope levels and six rice varieties. The slopes levels were middle, lower, and toe while the rice varieties V1 (LOCAL VARIETY) {Gborogidi}; V2 (FARO 44) (Sipi); V3 (FARO 57) (Osi); V4 (FARO 61) (Nerica); V5 (FARO 62) (OFADA 1); V6 (OM 6328).

The rice varieties were obtained from National Cereal Research Institute (NCRI) Badagi, Bida, Niger State. They were chosen primarily based on their economic, social importance, and adaptability to the topographic ecology of the study area. The local variety (Gborogidi) was chosen because of its dominance among the local varieties being cultivated by the local population.

b) Experimental layout: The factorial combinations of slope levels and rice varieties were laid out in Randomized Complete Block Design (RCBD) and replicated three times (3x). In all, there were 18 treatments combinations. Each plot measured 2 m x 2 m (4 m2) and 1m alleyways between the plots. The total land area per slope level was 25 m x 10 m (250 m2).

Agronomic/Management practices

i. Land preparation: The land was chemically cleared in May using a non-selective herbicide, glyphosate IPA W/W (in the form of 480 g/L of glyphosate isopropylamine salt). The market or brand name is Vinash. 1,500 ml of the glyphosate 41 % W/W SL/ha was mixed with 400 l of water per hectare (20 loads of 75 ml of vinash/20 liters Knapsack sprayer) and blanket sprayed on the tip of the grasses and broadleaf weeds and allowed for a Month to dry before packing.

ii. Cultivation: The land was manually plowed in June using a hoe and designed into experimental blocks and plots.

iii. Planting: Two seeds/holes from each of the six rice varieties randomly distributed within the plots were manually drilled immediately after cultivation at a spacing of 20 cm x 20 cm to give 500,000 plants/ha (200 plants/4 m2). The seed rate was 70 kg/ha in line with the standard recommendation of the Benue State Agricultural and Rural Development Authority (BNARDA, 1993) and the Federal Ministry of Agriculture and Rural Development (FMARD).

iv. Fertilizer Application: 100 kg N/ha, 50 kg P2O5/ha, and 50 kg K2O/ha (250 kg of NPK 20:10:10) were basally broadcasted at 8 DAP to avoid leaching and washing away of mineral nutrients by erosion during heavy rainfall in July-August. The top dressing was done with 100 kg of Urea (45 % N) at 6 WAP (panicle initiation stage, Chude et al., 2011).

v. Weeding: 800 ml of selective, pre- and post-emergence herbicide, 2, 4-Dimethylamine salt (72 % W/V) was mixed with 900 l of water and 600 grams of SPADA 60 WG (a.i, propanil) wettable powder micro granules and sprayed to control grasses, broadleaf weeds and sedge at 2 WAP and the second weeding was done manually at 8 WAP. The surrounding was cleared to prevent rodents and other animals from destroying the rice paddies.

vi. Pests and Diseases Control: There were no significant effects of rice pests and disease attacks on crops

vii. Harvesting: The mature rice paddies were harvested at 20 WAP and 22 WAP, dried to a moisture content of 12-13 %, threshed, winnowed, weighed, bagged, and recorded for analysis. The experiment was carried out in the 2019 and 2020 cropping seasons.

Crop data collection

Growth and yield parameters; Ten plants were randomly tagged per plot to monitor the following growth and yield parameters at 2 weeks interval: plant height (cm), number of leaves, blade area (cm3), number of tillers, panicle length (cm), and matured seed of paddy weight.

Statistical analysis

The crop data collected on the various plant growth and yield parameters were subjected to a one-way Analysis of Variance (ANOVA) Technique's test using Genstart 17th edition at 5 % level of significance and the treatment means were separated with Duncan Multiple Range Test (DMRT: $P>0.05$). The mean yield of each variety was compared and the recommendation was made for the best variety (ies) of rice to be cultivated in each slope level.

2. RESULTS

Soil Morphology

The physical observations of the study area revealed three soil mapping units according to slope variation and morphological properties such as; depth, texture, structure, colour, surface characteristics such as; drainage, flooding, vegetation, and relief of the area. The physical distribution of the three (3) morphological units is shown in Figure one (1).

Soil mapping unit 1 (middle slope)

This soil unit occupied the middle slope position and covered about 33 % of the study area. There was evidence of moderate sheet erosion. The soils were deep (161 cm) and well-drained with slopes of 0 – 2 % gradients with the altitude of about 216 m above sea level. The major surface characteristic was some pebbles in few places. The soil texture was predominantly sandy loam at the surface and sandy clay loam at the subsurface. The structure was majorly strong fine granular at the surface horizon and strong medium sub-angular blocky at the subsurface horizon. The soil consistence ranged between slightly sticky wet to very sticky wet. There were common coarse and few fine roots at the surface and subsurface horizons respectively with a gradual to diffused smooth boundaries. A more detailed description of the representative profile is given below. All colour descriptions were under moist conditions (Table 1).

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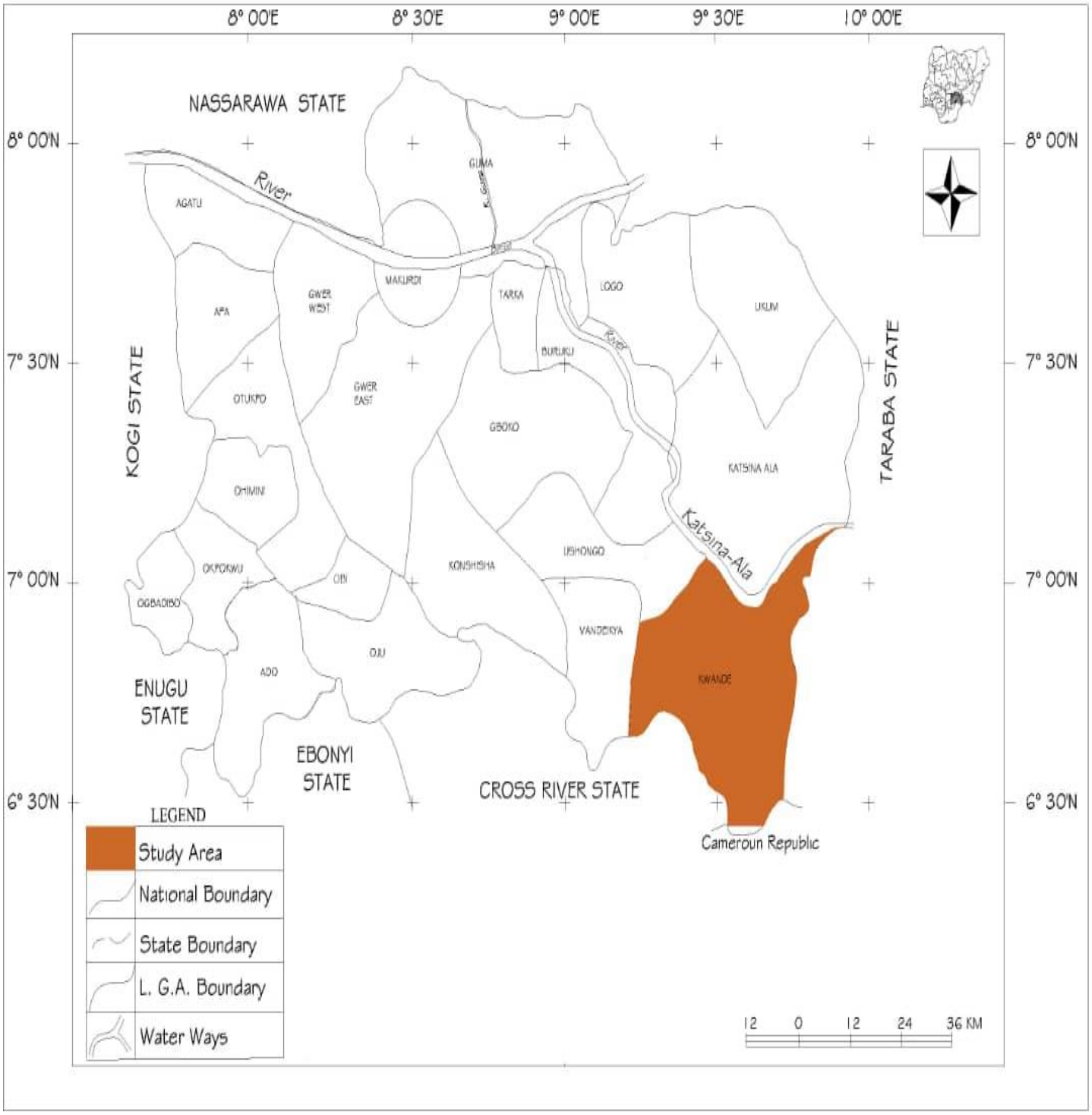

Fig. 1. Map of Benue State Showing Kwande L. G. A.

Source: Ministry of Lands, Survey and Solid Minerals, Makurdi. 2021

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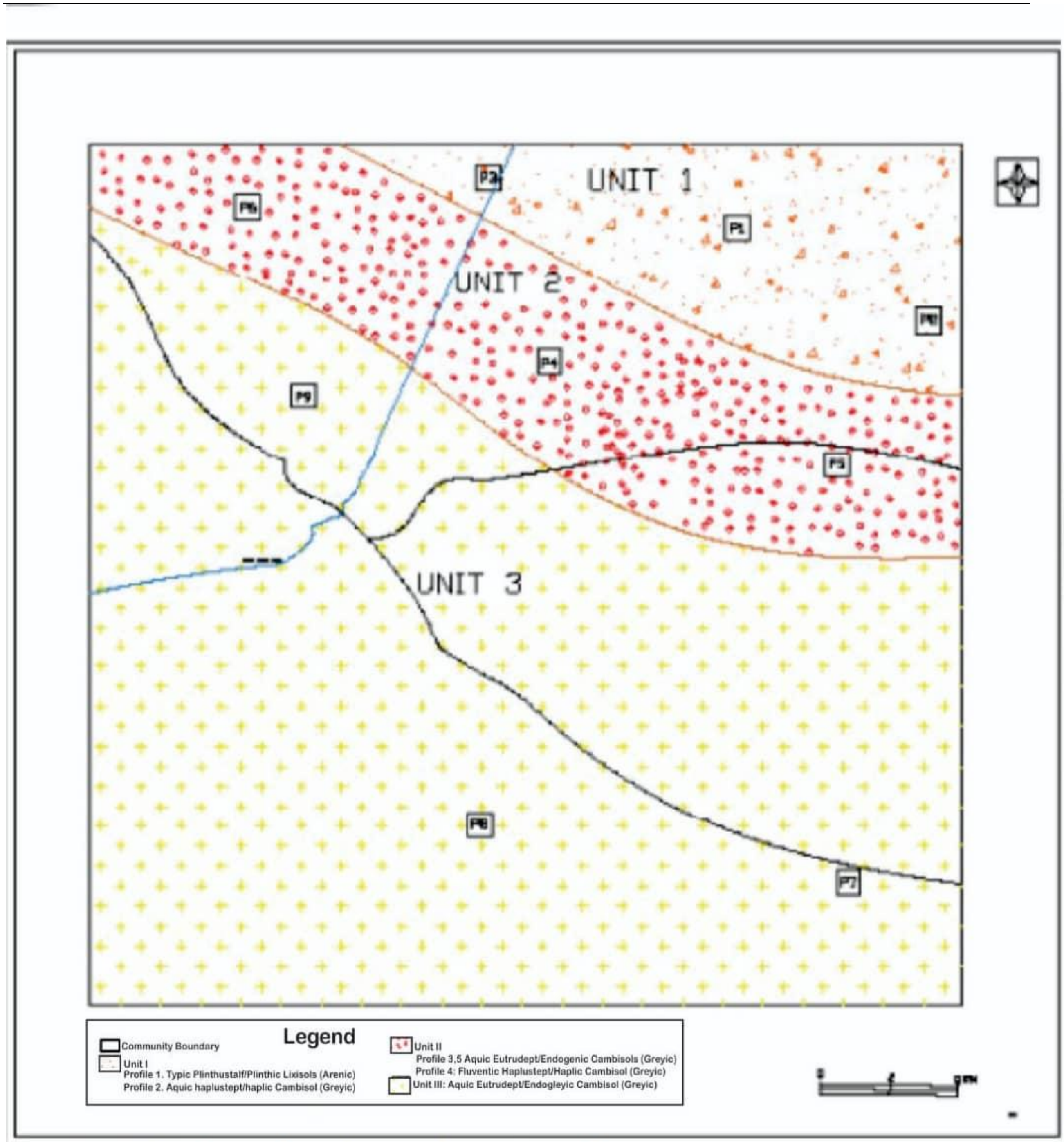

Figure 2. Soil Map of the Study Area

Soil mapping unit II (lower slope)

Soils of the lower slope covered about 18 % of the area. This soils unit is about 204 m above sea level. The soils were somewhat poorly drained with a predominant dark gray colour (7.5YR4/1) at the surface of the profiles. The soils were deep (about 167 cm) and generally low-lying with predominantly sandy clay loam texture at the surface horizons of soil profiles 4 and 5. However, the soil texture at the surface and subsurface of profile 5 was predominantly sandy loam and sandy clay loam respectively. Structurally, the soils were strong medium subangular blocky; strong coarse subangular blocky at the subsurface horizons of profile 4 and moderate medium subangular blocky the subsurface horizons of profile 5. The consistency of the soils mostly ranged from slightly sticky wet (surface) to very sticky wet (subsurface). The soils were very friable moist, soft dry with many coarse roots (inclusions) and predominantly had gradual smooth boundary (Table 1).

Soil mapping unit III (toe slope)

The soils of the toe slope covered about 49 % of the total area and about 100 m above sea level. The soils were about 162 cm deep as shown in Table 3. They were majorly dark brown (7.5YR4/2) at the surface of the soil profiles and gray (7.5YR5/1) at the subsurface horizons. The distinguishing feature of this unit was the presence of cracks measuring less than 2cm at the surface. There were common fine and few fine mottles at the surfaces of the profiles of this soil unit. The soils were sandy clay loam with a moderate fine granular structure and had a consistency that was slightly sticky wet, firm moist, soft dry. There were many fine roots at the surface of profile 5 and plinthite at 140 cm while profile 6 had a predominant common medium root with a water table encountered at 163 cm. The boundary was gradual smooth at the surface horizons of this soil unit. There was no bedrock exposed and no erosion nor its resultant deposits.

Soil Physical Characteristics

Soil physical characteristics are those responsible for the transportation of air, heat, water, and solutes through the soil. Several physical soil properties: soil texture, structure, texture, colour, and depth can be transformed through management. These soil qualities are very important for the varying features of the soil and their suitability.

The soils of the study area were majorly sandy loam in all the profiles except for profiles 5, 7, and 9 where the soil texture was predominantly sandy clay loam (Table 1). However, the soil texture in profile 3 was not evenly distributed with the increase in depth. The percentage (%) sand fractions of the soil in the study area were irregularly distributed with depth in all profiles except for profile 7 where the percentage sand fractions decreased with an increase in depth. The sand content ranged between 76.80 and 49.08 %. The sand content of the Ap horizon was lowest (50.08 %) in profile 3 and highest (76.80 %) in both Ap and AB horizons of profile 7. The sand content of the subsurface horizons was lowest (40.80 %) in the Bt2 horizon of profile 1 and highest (75.52 %) in the C horizon of profile 3.

The silt content of the soils in the study area ranged between 08.00 and 29.00 %. In the surface horizons, the silt contents were lowest (08.00 %) in the Ap horizon of profile 2 and highest (15.00 %) in the AB horizon of profile 5. While in the subsurface horizon, the silt contents were lowest (08.00 %) in the B horizon of profile 6 and highest (29.00 %) in the C horizon of profile 4.

The percentage clay content of the study area ranged between 13.20 and 40.92 %. The clay content of the surface horizon was lowest (13.20 %) in the Ap and AB horizon of profile 7 and highest (35.20 %) both in the Ap and AB horizons of profile 3. While the clay content of the subsurface horizon was lowest (12.20 %) in the C horizon and highest (40.92 %) in the BC horizon of profile 3.

Soil structure

The soils in the study area were structurally strong coarse subangular blocky in most of the horizons (Table 1). The soils of profile 1 were strong fine subangular blocky while those of profile 2 were weak fine granular. More so, the soils profiles 4, 5 and 6 had moderate medium granular and weak fine crumb respectively. The soil structure of unit III profile 3 were predominantly strong coarse subangular blocky especially at the surface horizons as shown in profile 6 (Table 1). Weak fine crumb was observed at the surface horizons of profile 7 and moderate medium subangular blocky in the subsurface horizons while profile 8 was weak fine crumb (surface horizons) and moderate fine granular at the subsurface horizons.

The particle size distribution test determines the amount, usually by mass, of the particles present in a soil sample (Jillavenkatesa, 2001). Particle size distribution also known as grain size gives information on the soil's ability to pack into a dense structure (Gooding, 1993). The particle sizes are classified as sand (coarse), silt and clay. The data in Table 2 showed the particle size distribution of the soils of the study area. The percentage sand content was the most dominant particle in the surface horizon in most of the mapping soil units (middle, lower, and the toe slopes) ranging from 50.80 % to 76.80 % in the surface Ap and AB horizons and 40.80 to 75.52 % in the subsurface soils (Table 1) which confirms Ojanuga's observations (1979).

The soils of Adagi have various colours and predominantly Brown (7.5YR4/2) to Dark Brown (7.5YR3/2 moist) in their Ap and B horizons of profiles 2, 5, 6, 7, 8, and 9 (Table 1). This could be attributed to moderately high organic matter which is the main colouring agent in the surface soil (Ufot, 2012, Brady and Ray, 2014). The strong brown (7.5YR 5/6 moist) in profiles 2, 6, and 8 subsurface Bt horizons.

Soil Chemical Properties

The pH values in Table 2 indicate that the soils of the study area were rated strongly acid to slightly acid in reaction (Chude et al., 2011). The pH of the soils ranged between 5.00 and 6.26 (H2O). The suitable range of pH for rice production is 4.5 – 7.5 (Tanaka et al., 1984). Hence, the soil reaction in the study area falls within the suitable range. Soil pH being an important factor affecting nutrient supply (Jonssen et al., 1990), the soil pH of the middle slope was classified into slightly acid and slightly alkaline with high base saturation. The variation of the soil pH within the soil profile and across the soil units seems to be about the cropping history with accompanying nutrient losses due to uptake and leaching (Malgwi and Abu, 2011).

The soil organic carbon refers to the carbon component of the soil organic matter. It is one of the major limiting factors including salinity, sodicity, and acidity for rice production. Low organic carbon restricts the yield of rice (Wolfe et al., 2009). The soil organic carbon (OC) in the study area ranged from 0.17 to 2.51 % and was classified as low to high according to the ratings of Chude et al., 2011).

Nitrogen (N) is the most deficient element for rice production in Nigeria (Kyat and Idoga, 2018) and its use can result in a substantial economic return for rice farmers. The total N values in the study area as shown in Table 2 ranged between 0.03 and 0.11 % and were classified as very low to moderately low (Abhisheik and Shanmugasundaram, 2020; Kowalenko, 2001). The total N values were higher at the surface horizons across the profiles. However, the total N was generally lower at the sub-surface horizons in all the soil profiles with a decreasing characteristic with depth in profiles 3, 5, 7, and 9 (Table 2).

The available phosphorus (P) of the soils in the study area ranged from 2.31 – 5.90 mg kg-1 and were classified as very low to low (Brady and Weil, 2002; Landon, 1991). This was similar to the work of Kadria et al., (2015) who reported a range of 1.45 – 2.14 mgkg-1 (Table 2) P in some highly calcareous soils by the addition of compost and inorganic phosphorus forms. The P values were irregularly distributed with depth in most of the profiles except for profiles 2, 3, 5, and 8 which agrees with the work of Kadria et al., (2015) who also reported a significant decrease of P with depth as a result of increasing the consumption of P with increasing plant growth; also increases the role of Ca^{2+}.

Calcium compared to FAO, (2016) ratings for Ca exchangeable Ca in the sorts of the study area which ranged from 2.50 to 3.20 cmolkg-1 was classified as low to medium this was similar to the work of (Malgwi and Abu 2011) who reported a very low Ca and Mg in the total exchangeable bases (Ca, Mg, K, and Na) of the soils in the study were low in all the soil units. The range of total exchangeable bases (TEB) in all the soil units was between 4.95 and 7.86 cmolkg-1 (Table 2). The TEB was observed to have an irregular distribution down the soil horizons. This was similar to the observations of Yakubu et al., 2011, and Ogbu, 2020).

This is the capacity of the soil colloids to adsorb nutrients. Each cation element has its distinct equivalent weight based on how much of it will react with or displace it from the soil exchange site (Ufot, 2012, Brady and Weil 2014). The CEC values of the soils shown in Table 2 ranged between 5.80 and 8.10 cmolkg-1

The percentage base saturation values of the soils ranged between 78.77 and 91.60 %. The base saturation (BS) was rated as high to very high. The distribution of BS was irregular with increasing soil depth. The high BS in the soils of the study area may be attributed to the high pH values of the soils (5.00 – 6.25). As the BS increases due to high CEC, the pH is also increased (due to the development of alkalinity) in a definite proportion.

The Crop

Crop Growth and Yield Parameters

The result on the main effect of slope and rice variety on plant height (Table 3) indicated that there was a significant difference in slope level and varietal treatment at 4, 6, and 8 WAS.

Data obtained from the study presented in Table 5, indicated that slope had a significant effect on the number of tillers at 8 WAS for both 2019 and 2020 cropping seasons. The toe slope had a higher number of tillers (35.39) followed by the lower slope (20.06) and middle slope (10.11) in the 2019 cropping season. Similarly, in 2020, the toe slope was highest (14.39), the lower slope (9.56), and the least was recorded in the middle slope (2.22). Among the varieties, the effect of variety on the number of tillers was statistically significant at 8 WAS in the 2019 and 2020 cropping seasons. The highest number of tillers was recorded with FARO 44 (25.44) in 2019 and (13.67) in 2020 cropping seasons. Hassan et al. (2016) also reported similar results that the number of tillers depends on the genetic variation of the crop.

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The interaction effect of slope and variety on the number of tillers was statistically significant at 8 WAS is presented in Table 6. FARO 44 recorded the highest number of tillers for both slopes (toe slope, 20.67; lower slope, 15.00 and middle slope, 5.33). The local variety recorded zero (0) a tiller at 8 WAS in the 2020 cropping season. This could be attributed to the prolonged drought during the growing period of the crop. Since, it has been established that tillering is genetic dependent; the local variety (Gborogidi) could not genetically withstand the moisture stress (table 6).

There was a significant difference in the effect of slope and variety on the length of a panicle of rice both in the 2019 and 2020 cropping seasons (Table 7). The toe slope recorded the longest panicle in 2019 (38.22 cm) and the shortest was at the middle slope (18.06 cm) while in 2020 cropping season, the lower slope recorded the longest panicle (26.39 cm), while the shortest panicle was recorded at the middle slope (21.70 cm). Among the varieties, FARO 57 (31.11 cm) recorded the longest panicle in 2019 while FARO 44 (28.07 cm) was the longest in the 2020 cropping season. The variety with the shortest panicle was the local variety (Gborogidi) (21.00 cm) in 2019 and (20.99 cm) in the 2020 cropping season. Shrirame and Muley, (2003) found a non-significant difference in panicle length in tested genotypes but Sharma, (2002) reported a significant difference in panicle length among fine grain rice genotypes.

Grain yield was significantly affected by slope and variety in their interaction 2020 cropping season but there was an influence in 2019 (Table 7). The variety had a statistically higher in the lower slope (5.39 t/ha) but was poor in the middle slope (2.66 t/ha) in the 2020 cropping season. FARO 44was significantly higher in terms of yield (5.00 t/ha) in 2020 while the local variety (Gborogidi) had the least yield (2.31 t/ha) in the same year (2020). The significantly higher grain yield of FARO 44, FARO 44, OM6328 and FARO 62 in the toe slope may not be unconnected with the fertility status of the soil, good water habitat, climatic factors, genetic make-up, and time of planting. The least significant yield of the local variety (Gborogidi) may be connected to its poor competitive advantage genetically (Table 7).

Soil Classification

The soils of unit I (middle slope) profile I were classified as Alfisols because they have an ochric epipedon, an argillic horizon, and moderate to high base saturation. In the Subgroup, they were qualified as the Ustalf because they had an ustic soil moisture regime neither do they have, near the soil surface aquic conditions within 50 cm for some time in a normal year. They were also qualified as Typic Plinthustalfs at the Great Group level becausetheyhad one or more horizons within 150 cm of the mineral soil surface in which plinthite either forms a continuous phase or constitutes one-half or more of the volume. The soils had no duripan that has its upper boundary within 100 cm of the soil surface. However, the soils of profile 2 (middle slope) were classified as the Inceptisol. The soils of unit I (middle slope) profile 2 and profile 4 of soil unit II were classified as Inceptisol because they were likely formed quickly through frequent deposition of eroded materials from the crest of the mountainous terrain in the area. They had an ochric horizon and a cambic subsurface horizon showing evidence of relative clay content alteration in the underlying horizons. They (profiles 2, 3 and 5) were classified as Ustepts in the Subgroup level because they were freely drained Inceptisols that have an ustic soil moisture regime. In the Great-group, the soil of profile 2 were qualified as the Haplustepts because they are relatively freely drained with a high base status while profiles 3 and 5 were classified as Eutrudept due to high base saturation of 60 % or more in the sub-horizon that is between depths of 25 and 75 cm below the mineral soil surface. Soils of profile 2, 3 and 5 were qualified as Aquic Haplustept and Aquic Eutrudept respectively because they were saturated with water in one or more layers within 100 cm of the mineral soil surface for either 20 or more consecutive days or 30 or more cumulative days.

The soils of unit II (Lower slope) profile 4 were classified as Inceptisol. At the Subgroup level, they were qualified as Fluventic Haplustept because had an irregular decrease in organic-carbon content between a depth of 25 cm and either a depth of 125 cm below the mineral soil surface or a densic, lithic, or paralithic contact.The soils of unit III were classified as Aquic Eutrudepts they were saturated with water in one or more layers within 100 cm of the mineral soil surface for either 20 or more consecutive days or 30 or more cumulative days.

Classification according to World Reference Base (WRB)

The soils had higher clay contents in the subsurface horizons than the surface soils. This could be as a result of pedogenic processes (illuviation and eluviation) leading to argillic horizons. Soil Unit I profile 1 showed because of higher clay content in the subsoil than in the topsoil. They had low-activity clays in the argichorizon hence, they were classified as Lixisol (FAO - WRB, 2014). They are qualified as Plinthic Lixisol because the soils were well-drained with plinthite occurring at depths between 125 cm. The soils of profiles 2 and 4 were classified as Cambisol because of a cambic horizon starting from less than 50 cm and having its lower limits ≥ 25 cm from the surface soil. They were further qualified as Haplic Cambisol (Gleyic) because it had a typical expression of certain features (typical in the sense that there is no further or meaningful characterization).

Soil mapping Unit II (Lower Slope) profiles 3 and 5 and Unit III profiles 6-8 were classified as Endogleyic Cambisols because of a cambic horizon starting from less than 50 cm and having its lower limits ≥ 25 cm from the surface soil.

Suitability Rating for Rainfed Rice (Oryza sativa) Production

Water is the most important requirement of rice crops throughout the growing period (Idoga, 2005). This was, therefore, the most important limiting factor in rainfed rice production. Soil depth, drainage, slope, porosity, texture, and structure are important physical characteristic that influences water retention. Soil unit I (middle slope) profiles 1, 2, and 3 were nearly leveled (0 – 2) slope. However, they do not allow for water accumulation from the surrounding areas leading to ustic soil conditions. The structure was, however, mostly strong fine granular and the sandy conditions of the soils do not allow for good water retention capacity for plant use.

Consequently, cases of agricultural drought (as experienced in 2020) due to poor rainfall were very severe leading to limited water availability. The low levels of organic carbon, total nitrogen, CEC, available P, and exchangeable bases indicate the low nutrient status of the (Adagi) area. For the soil unit II (lower slope), the major limitations were the inability of the soils to hold enough moisture (WHC), porosity due to high sand fraction, low nutrient status of the soils, low slope which favours flooding and wetting of the soils and the aquic moisture regime. Despite the limitations, the clay content and the good soil structure positively influenced water retention for some period of the cropping season for rice use irrespective of the pronounced effects of drought especially in the middle and lower slopes of the study area.

3. SUMMARY

The lowland soils of Adagi, Kwande LGA of Benue State, extensibly cultivated to lowland rice, were characterized and evaluated for rainfed rice production in three different slope positions. The soils were deep (107 – 167 cm), well-drained to poorly drained, having 40.80 % to 76.80 % of sand, 08.00 % to 29.00 % of silt, and 12.20 % to 40.92 % of clay. Unit I soil which occupied the middle slope soils were well-drained while the other units were somewhat poorly drained as a result of their topographical positions and their structure (moderate to strong sub-angular blocky). The soils had various colours, but at the Ap horizon of all the soil profiles, it was predominantly brown (7.5YR4/2) to dark brown (7.5YR3/2).

The soils were rated as strongly acid to slightly alkaline in reaction with pH ranging from 4.5 – 7.5. The soils had low organic carbon (0.17 to 2.51 %), very low total nitrogen (0.03 – 0.11 %), very low available P (2.31 to 5.90 mgkg-1), low to medium exchangeable bases (2.50 – 3.20 cmolkg-1), low CEC (5.80 to 8.10 cmolkg-1) and high to very high base saturation (78.77 to 91.60 %).

Based on these properties, the major soils of the three topographic positions namely middle slope (unit I), profile 1 was classified as Typic Plinthustalf/Plinthic Lixisols (Arenic) while profile 2 was classified as Aquic Haplustept/Haplic Cambisol (Greyic); unit II profiles 3 and 5 were classified as Aquic Eutrudept/ Endogleyic Cambisol (Greyic) while profile 4 soils were qualified as Fluventic Haplustept/Haplic Cambisol (Greyic). The soil unit III was classified as Aquic Eutrudept/Endogleyic Cambisol (Greyic). Soils of Unit I were somewhat poorly drained with low water holding capacity and were strongly acid and therefore rated as marginally suitable (S3) while Units II and III soils were rated as highly suitable as a result of their high-water holding capacity, low lying, and tolerable soil reaction (high pH).

4. CONCLUSION

The physical and chemical properties of soil Unit I (middle slope) indicate that they have marginal limitations to rice production, hence, there is a need for some manipulations to obtain the maximum yield of rice. The major part of the soils under study had high water holding capacity, with moderate soil reactions, some vertic characteristics, aquic conditions were highly suitable for rainfed rice production as proven by the test crop yield obtained from the soil units. However, soil Unit III is likely to be faced with flooding in some months of the year, especially in September.

5. RECOMMENDATIONS

Considering the low chemical fertility status of the soil in the study area, appropriate fertilizers (250 kg of NPK 20:10:10) are recommended to make up the deficiency. FARO 44 from the results seems to have scale neutrality, having the highest yield in all topographic positions, hence they are highly recommended as the best variety among the common varieties in the community. FARO 57 and OM6328 varieties are also highly recommended since they were not statistically different in yield with the other best variety.

Due to the poor yields of the local (Gborogidi) across the slope positions, it is not recommended for the study area. The lower and toe slope positions are better topographic positions and are recommended for lowland rice than the middle slope.

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Table 1. Soil Morphological Properties of Soil of Adagi

Horizon	Depth (cm)	Munsell Colour (Moist)	Mottling	Texture	Structure	Consistence	Boundary	Remarks
UNIT I								
Middle Slope Profile 1								
AP	0-16	7.5YR7/1LG	-	Sandy loam	3FGR	NSW	ds	common medium roots
AB	16-25	7.5YR4/2B	-	Sandy loam	2MGR	SSW	ds	common coarse roots
B	25-45	7.5YR4/3B	-	Sandy clay loam	3FSBK	SPW	ds	few fine roots
Bt_1	45-70	7.5YR3/3DB	-	Sandy clay loam	3FSBK	SSW	ds	few fine roots
Bt_2	70-88	10YR8/6Y	-	Sandy clay loam	3CSBK	SSW	ds	few fine roots
Bt_3	88-108	7.5YR5/6SB	-	Sandy Clay loam	3FSBK	SSW	-	plinthite at 108 cm
Middle Slope Profile 2								
AP	0-23	7.5YR7/1LG		Sandy loam	1FGR	SSW	gs	common coarse roots
AB	23-55	7.5YR4/1DG		Sandy loam	3MSBK	SSW	gs	few medium roots
B	55-120	7.5YR4/4B	10YR5/6 f1f	Sandy loam	3CSBK	VSW	gs	common fine roots
Bt_1	120-163	7.5YR5/6SB	-	Sandy loam	3CSBK	SSW	-	plinthite at 163 cm
UNIT II								
Lower Slope Profile 3								
AP	0-20	7.5YR4/1DG	-	Sandy clay loam	2MSBR	SSW	gs	many coarse roots
A	20-28	7.5YR3/2DB	10YR3/3 B c1f	Sandy clay loam	3MSBK	VSW	gs	few fine roots
B	28-68	7.5YR4/2VDB	-	Sandy clay loam	3MSBK	VSW	gs	few fine roots
BC	68-110	7.5YR3/2DB	-	Silty clay	3CSBK	VSW	gs	few fine roots
C	110-167	7.5YR5/2B	-	Sandy loam	3CGR	SSW	-	plinthite at 167 cm
Lower Slope Profile 4								
AP	0-13	7.5YR4/2B	-	Sandy clay loam	1FCR	VSW	gs	common medium roots
B	13-27	7.5YR3/2DB	-	Sandy clay loam	3MSBK	VSW	gs	common coarse roots
Bt_1	27-78	7.5YR3/2DB	-	Silty loam	3CSBK	VSW	gs	few fine roots
Bt_2	78-152	7.5YR3/2DB	-	Sandy Clay loam	3CSBK	VSW	-	plinthite at 152 cm
Lower Slope Profile 5								
AP	0-12	7.5YR3/4DB	-	Sandy loam	1FGR	SSW	gs	many coarse roots
B	12-42	7.5YR4/1DG	10YR3/3 B	Sandy loam	2MGR	NPW	gs	few fine roots
Bt_1	42-56	7.5YR5/6SB		Sandy loam	2MGR	SSW	gs	few fine roots
Bt_2	56-98	7.5YR3/3DB	-	Sandy clay	2MGR	SSW	gs	few fine roots
Bt_3	98-140	7.5YR5/6SB	-	Sandy clay loam	2MGR	VSW	-	plinthite at 140 cm
UNIT III								
Toe Slope Profile 6								
Horizon	**Depth (cm)**	**Munsell Colour (Moist)**	**Mottling**	**Texture**	**Structure**	**Consistence**	**Boundary**	**Inclusion**
Ap	0-30	7.5YR3/3DB	2.5YR7/2 LG	Sandy clay loam	3CSBK	SSW	gs	common medium roots
AB	30-94	7.5YR3/1VDG	10YR5/2 GB	Sandy clay loam	3CSBK	VSW	ds	common medium roots
B	94-129	7.5YR3/1DG	-	Sandy clay loam	3CSBK	VSW	gs	few fine roots
B_1	129-163	7.5YR3/1 VDG	2.5YR7/6 Y	Sandy clay loam	3CSBK	VSW	-	water table encountered at 163 cm
Toe Slope Profile 7								
Ap	0-20	7.5YR3/2 DB	-	Sandy loam	1FCR	VSW	gs	few fine roots
AB	20-48	7.5YR4/4 B	-	Sandy loam	2MGR	VSW	gs	few fine roots
B	48-105	7.5YR5/1 G	10YR3/2 VDGB	Sandy loam	2MSBK	VSW	gs	few fine roots
B_t	105-160	7.5YR5/8 SB	-	Sandy clay loam	2MGR	VSW	-	water table encountered at 160 cm
Toe Slope Profile 8								
Ap	0-15	7.5YR4/2VDB	-	Sandy loam	1FCR	VSW	gs	few fine roots
AB	15-43	7.5YR4/2B	5YR5/2G B	Sandy clay loam	2FSBK	VSW	ds	few fine roots vertic characteristics about 2 cm wide.
B	58-107	7.5YR5/2GB	-	Sand clay loam	2MGR	VPW	ds	few fine roots
BC	107-162	7.5YR5/1G	-	Sand clay loam	2MGR	VPW/VSW	-	water table encountered at 162 cm

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Table 2: Soil Physical and Chemical Properties of Adagi, Kwande Local Government Area

Horizon		Particle size dist.			Texture	pH	OC	N	AP	Exchangeable Properties							
Desc.	Depth	Sand	Silt	Clay		H_2O				Ca	Mg	K	Na	TEB	CEC	EA	BS
Unit	Cm	%					%		mgl^{-1}	cmolkg^{-1}							%
UNIT I																	
Middle Slope Profile 1																	
AP	0-16	70.08	13.00	16.20	SL	5.94	1.30	0.09	4.16	2.96	2.90	0.29	0.25	6.38	8.10	0.56	78.77
AB	16-25	69.80	14.00	16.20	SL	5.94	1.00	0.08	4.00	2.88	2.80	0.25	0.22	6.15	7.80	1.00	78.85
B	25-45	66.80	12.10	21.10	SCL	5.95	0.21	0.04	3.44	2.45	2.30	0.23	0.20	5.18	5.80	0.58	89.31
Bt_1	45-70	62.64	10.00	27.36	SCL	5.80	0.40	0.06	3.50	2.50	2.40	0.21	0.20	5.31	6.20	0.61	85.65
Bt_2	70-88	40.80	16.00	29.20	SCL	5.82	0.21	0.03	2.80	2.38	2.30	0.22	0.21	5.11	6.50	0.57	78.62
C	88-108	54.80	15.00	14.64	SL	5.77	0.17	0.03	2.70	2.31	2.26	0.20	0.18	4.95	6.00	0.49	82.50
Middle Slope Profile 2																	
AP	0-23	71.33	08.00	20.27	SL	5.39	0.21	0.08	3.44	2.41	2.32	0.24	0.26	5.23	6.23	1.00	84.00
AB	23-55	69.80	13.00	17.20	SL	5.84	0.54	0.07	3.46	2.50	2.42	0.25	0.24	5.41	6.51	1.10	83.10
B	55-120	68.80	11.00	21.20	SL	5.44	1.20	0.90	4.40	2.93	2.70	0.25	0.22	6.10	7.11	1.01	86.00
B_t	120-163	56.80	14.00	29.20	SCL	5.91	0.70	0.07	3.10	2.79	2.63	0.25	0.23	5.90	6.90	1.00	85.51
UNIT II																	
Lower Slope Profile 3																	
AP	0-20	50.80	14.00	35.20	SCL	6.26	1.50	0.10	4.20	3.00	2.78	0.26	0.23	6.27	7.60	1.12	82.50
AB	20-28	56.80	11.00	32.20	SCL	5.47	1.10	0.06	4.20	2.96	2.85	0.25	0.20	6.26	7.26	1.00	86.22
B	28-68	58.80	12.70	29.20	SCL	5.48	1.28	0.08	4.80	3.06	2.90	0.26	0.24	6.46	7.50	1.04	86.13
BC	68-110	49.08	10.00	40.92	SC	5.88	0.68	0.09	3.80	2.81	2.70	0.23	0.21	5.95	6.90	1.14	85.49
C	110-167	75.52	12.28	12.20	SL	5.87	0.24	0.03	3.00	2.50	2.36	0.21	0.18	5.25	6.30	0.59	83.33
Lower Slope Profile 4																	
AP	0-13	64.30	08.20	23.50	SCL	5.00	2.21	0.10	5.80	3.10	3.00	0.28	0.26	6.64	7.74	1,10	86.00
Horizon		Particle size dist.			Texture	pH	OC	N	AP	Exchangeable Properties							
Desc.	Depth	Sand	Silt	Clay		H_2O				Ca	Mg	K	Na	TEB	CEC	EA	BS
Unit	Cm	%					%		mgl^{-1}	cmolkg^{-1}							%
A	13-27	64.64	11.10	24.26	SCL	5.31	1.54	0.10	5.10	2.82	2.78	0.26	0.23	6.09	7.09	1.00	86.00
B	27-78	62.80	11.00	26.20	SCL	5.30	0.94	0.10	4.80	2.80	2.60	0.20	0.20	5.80	6.70	0.90	87.00
C	78-152	50.80	29.00	29.20	SCL	5.93	0.58	0.07	3.94	2.68	2.60	0.22	0.20	5.90	6.80	0.98	83.82
Lower Slope Profile 5																	
Ap	0-12	66.80	13.00	20.20	SL	5.24	2.51	0.10	5.90	3.00	2.96	0.29	0.24	6.49	7.52	1.03	86.30
AB	12-42	64.80	15.00	20.20	SL	6.09	0.68	0.09	4.00	2.80	2.65	0.24	0.21	5.90	7.30	1.10	80.82
B	42-56	72.80	10.00	17.20	SL	5.95	0.66	0.08	3.96	2.76	2.60	0.25	0.24	5.85	7.00	1.11	83.57
B_1	56-98	50.80	11.00	38.20	SC	5.89	1.00	0.09	4.10	2.90	2.80	0.02	0.19	6.13	7.40	1.00	82.84
B_{t1}	98-140	56.80	13.00	30.20	SCL	5.84	0.30	0.04	3.40	2.56	2.40	0.24	0.22	5.42	5.90	0.63	85.09
UNIT III																	
Toe Slope Profile 6																	
Ap	0-30	64.80	09.00	26.20	SCL	5.32	2.31	0.10	5.80	2.92	2.88	0.26	0.23	6.29	7.39	1.10	85.11
AB	30-94	66.80	10.00	23.20	SCL	5.37	1.92	0.09	4.00	2.80	2.56	0.26	0.22	6.29	7.29	1.00	86.30
B	94-129	62.80	08.00	29.20	SCL	5.42	1.32	0.08	3.96	2.70	2.48	0.22	0.20	5.60	7.00	1.06	84.00
B_1	129-163	63.36	11.00	25.64	SCL	5.43	0.53	0.05	3.40	2.84	2.50	0.21	0.20	6.00	7.00	1.00	86.00
Toe Slope Profile 7																	
Ap	0-20	76.80	10.00	13.20	SL	5.31	2.19	0.09	4.30	3.10	2.94	0.25	0.24	6.53	7.55	1.02	87.00
AB	20-48	76.80	10.00	13.20	SL	5.43	0.74	0.08	4.10	2.90	2.60	0.24	0.21	5.95	7.06	1.11	84.30
B	48-105	72.20	12.00	15.80	SL	5.48	0.42	0.05	3.40	2.63	2.46	0.18	0.16	5.43	6.51	1.08	83.41
B_t	105-160	68.50	10.00	21.50	SCL	5.44	0.72	0.08	3.70	2.86	2.52	0.25	0.23	5.86	7.00	1.10	84.00
Toe Slope Profile 8																	
Ap	0-15	66.80	14.00	19.20	SL	5.27	1.02	0.09	4.20	2.91	2.61	0.27	0.24	6.03	7.01	0.98	90.00
A	15-43	65.80	14.00	20.20	SL	5.28	1.12	0.07	4.30	3.00	2.70	0.28	0.25	6.23	7.23	1.00	86.20
AB	43-58	66.64	12.00	21.36	SCL	5.37	1.08	0.07	4.10	2.94	2.68	0.26	0.24	6.12	7.23	1.11	84.00
B	58-107	68.80	11.16	20.64	SCL	5.38	0.90	0.06	5.60	2.92	2.80	0.24	0.21	6.17	7.05	0.88	88.00

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Table 3. Effect of Slope and Variety on Plant Height of Rice in 2019 and 2020 Cropping Seasons in Adagi

Treatments	4 WAS		6 WAS		8 WAS	
Slope (s)	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
Middle	28.00	14.83	35.22	25.39	44.06	30.50
Lower	40.00	31.06	54.72	43.56	69.33	55.00
Toe	39.33	25.11	62.33	55.11	81.61	70.83
LSD	**4.58**	**0.73**	**3.69**	**1.62**	**4.38**	**1.42**
Variety						
V1 (Gborogidi)	27.11	19.00f	39.67d	32.33e	51.22a	33.56f
V2 (FARO) 44	47.11a	28.89a	57.56a	50.11a	71.11a	64.44a
V3 (FARO 57)	49.78b	35.78b	65.44ab	65.00b	79.89ab	78.67b
V4 (FARO 61)	30.67cd	20.56c	47.22c	37.11b	63.22b	49.44c
V5 (FARO 62)	33.56bcd	23.11d	50.56bc	40.33c	66.33ab	51.89d
V6 (OM 6328)	36.44bc	24.67e	54.11ab	43.22d	68.22ab	54.67e
LSD	**6.48**	**1.03**	**5.21**	**2.29**	**6.19**	**2.01**

LSD= Least Significant Difference, V1-6= Varieties 1 – 6, WAS= Weeks After Sowing

Table 4. Interaction Effects of Slope and Variety on Plant Height (cm) at Adagi in 2019 and 2020 cropping seasons

		Plant Height (cm)					
Treatments		**4 WAS**		**6 WAS**		**8 WAS**	
Slope	**Variety**	**2019**	**2020**	**2019**	**2020**	**2019**	**2020**
Middle	V1 (Gborogidi)	21.33	11.33	26.33	19.67	30.33	0.00
	V2 FARO 44	41.67	21.67	42.33	34.00	49.67	42.00
	V3 FARO 57	30.00	35.67	49.67	39.00	58.67	51.00
	V4 FARO 61	22.67	12.67	29.67	20.00	42.67	31.67
	V5 FARO 62	25.00	13.00	35.33	23.00	45.00	33.33
	V6 OM 6328	27.33	14.67	38.00	26.67	48.00	35.00
Lower	V1 (Gborogidi)	31.67	23.67	43.67	32.67	60.33	43.00
	V2 FARO 44	47.00	36.67	61.67	56.00	74.00	64.00
	V3 FARO 57	55.33	39.67	69.00	67.33	81.67	69.00
	V4 FARO 61	36.33	25.67	51.00	37.00	67.67	52.67
	V5 FARO 62	38.33	31.67	53.67	42.33	70.33	54.67
	V6 OM 6328	41.33	34.00	58.33	46.00	72.00	56.67
Toe	V1 (Gborogidi)	28.33	22.00	49.00	44.67	63.00	57.67
	V2 FARO 44	52.67	28.33	68.67	60.33	89.67	87.33
	V3 FARO 57	54.00	37.00	76.67	68.67	90.33	89.00
	V4 FARO 61	33.00	23.33	61.00	54.33	79.33	64.00
	V5 FARO 62	37.33	24.67	62.67	55.67	83.67	67.67
	V6 OM 6328	40.67	25.33	66.00	57.00	84.67	72.33
LSD p≤0.05		**NS**	**1.77**	**NS**	**3.97**	**NS**	**3.48**

LSD= least significant difference
V1-6= Varieties 1 – 6
WAS= weeks after sowing
NS= Not significant

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Table 5. Effect of Slope and Variety and Number of Rice Tillers in Adagi for 2019 and 2020 Cropping Seasons

Treatments	Number of Race Tillers					
Slope (s)	4WAS		6WAS		8WAS	
	2019	2020	2019	2020	2019	2020
Middle	10.50	1.17	6.56	1.94	10.11	2.22
Lower	16.00	4.22	24.78	13.67	20.06	9.56
Toe	22.83	13.44	32.22	7.22	35.39	14.39
LSD p≤0.05	**2.28**	**1.03**	**1.68**	**2.20**	**2.06**	**4.86**
Variety						
V1 (Gborogidi)	11.22d	3.33e	15.22d	5.00c	17.56c	3.22c
V2 (FARO) 44	20.22a	9.44a	25.11a	11.11a	25.44a	13.67a
V3 (FARO 57)	19.33a	8.00ab	24.00ab	9.44ab	24.33a	12.00ab
V4 (FARO 61)	13.78cd	4.56bc	20.11c	6.00bc	20.00bc	5.44abc
V5 (FARO 62)	15.89bc	5.78cd	20.78c	6.56bc	21.22b	8.11abc
V6 (OM6328)	18.22ab	6.56de	21.89bc	7.56c	22.56ab	9.89bc
LSD p≤0.05	**3.22**	**1.45**	**2.37**	**3.11**	**2.92**	**6.87**

LSD= least significant difference
V1-6= Varieties 1-6
WAS= weeks after sowing

Table 6. Interaction Effects of Slope and Variety on Number of Tillers at Adagi in 2019 and 2020 cropping seasons

Treatments	Variety	Number of Tillers					
		4 WAS		6 WAS		8 WAS	
Slope		2019	2020	2019	2020	2019	2020
Middle	V1 (Gborogidi)	6.67	0.00	5.33	1.00	8.00	0.00
	V2 FARO 44	12.33	3.00	8.67	3.33	13.00	5.33
	V3 FARO 57	12.00	1.33	8.00	2.67	12.00	4.00
	V4 FARO 61	9.33	0.67	5.33	1.33	8.33	0.00
	V5 FARO 62	11.00	1.00	5.67	1.67	9.67	1.33
	V6 OM 6328	11.67	1.00	6.33	1.67	9.67	2.67
Lower	V1 (Gborogidi)	11.67	2.33	17.67	11.33	17.33	5.33
	V2 FARO 44	20.00	6.67	28.00	17.33	22.00	15.00
	V3 FARO 57	19.00	5.33	28.00	15.67	22.00	12.33
	V4 FARO 61	12.33	3.00	24.00	11.67	18.67	7.00
	V5 FARO 62	15.00	3.33	24.67	12.00	19.33	8.33
	V6 OM 6328	18.00	4.67	26.33	14.00	21.00	9.33
Toe	V1 (Gborogidi)	15.33	7.67	22.67	2.67	27.33	4.33
	V2 FARO 44	28.33	18.67	38.67	12.67	41.33	20.67
	V3 FARO 57	27.00	17.33	36.00	10.00	39.00	19.67
	V4 FARO 61	19.67	10.00	31.00	5.00	33.00	9.33
	V5 FARO 62	21.67	13.00	32.00	6.00	34.67	14.67
	V6 OM 6328	25.00	14.00	33.00	7.00	37.00	17.67
LSD≤0.05		**NS**	**2.51**	4.11	**5.39**	**NS**	**11.90**

LSD= least significant difference
V1-6= Varieties 1-6
WAS= weeks after sowing
NS= Not significant

Table 7. Effect of Slope and Variety on Panicle Length (cm) and Yield (ton/ha) of Rice at Adagi in 2019 and 2020 cropping seasons

Treatments	Panicle Length		Yield (ton/ha)	
Slope (s)	**2019**	**2020**	**2019**	**2020**
Middle	18.06	21.70	4.11	2.66
Lower	27.89	26.39	7.49	5.39
Toe	38.22	25.79	8.61	4.57
LSD≤0.05	3.19	0.98	NS	0.77
Variety				
V1 (Gborogidi)	21.00a	20.99d	2.33a	2.31d
V2 (FARO) 44	30.67a	28.07a	4.59ab	5.00a
V3 (FARO 57)	31.11a	26.88ab	4.16ab	4.84a
V4 (FARO 61)	27.00a	22.11b	3.56ab	3.88c
V5 (FARO 62)	28.87a	24.01c	3.81b	4.02b
V6 (OM6328)	29.89b	25.69b	3.98c	4.25b
LSD≤0.05	**4.52**	**1.38**	**0.81**	**1.09**

LSD= least significant difference
V1-6= Varieties 1-6
WAS= weeks after sowing
NS= Not significant

Table 8. Interaction Effects of Slope and Variety on Panicle Length (cm) and Dry Seed Weight (ton/ha) of Rice at Adagi in 2019 and 2020 cropping seasons

Treatments	Variety	Length of Panicle (cm)		Yield (ton/ha)	
Slope		**2019**	**2020**	**2019**	**2020**
Middle	V1 (Gborogidi)	18.06	15.00	3.50	0.25
	V2 FARO 44	24.83	21.67	4.80	4.08
	V3 FARO 57	25.05	20.33	4.07	3.85
	V4 FARO 61	18.21	16.00	3.87	2.05
	V5 FARO 62	19.94	16.67	4.17	2.65
	V6 OM 6328	24.10	18.67	4.27	3.10
Lower	V1 (Gborogidi)	22.33	24.33	3.23	3.17
	V2 FARO 44	30.57	36.67	5.67	4.03
	V3 FARO 57	28.77	43.33	4.75	4.93
	V4 FARO 61	23.67	41.00	4.40	5.08
	V5 FARO 62	26.40	41.67	5.42	4.60
	V6 OM 6328	26.60	28.67	5.25	4.77
Toe	V1 (Gborogidi)	22.57	24.33	3.50	3.27
	V2 FARO 44	28.80	36.67	4.00	4.93
	V3 FARO 57	26.83	43.33	4.25	5.47
	V4 FARO 61	24.47	41.00	3.50	4.40
	V5 FARO 62	25.70	41.67	4.00	4.67
	V6 OM 6328	26.37	42.33	4.19	3.90
LSD≤0.05		**2.40**	**NS**	**NS**	**NS**