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Characterization and classification of soils of a paddy field in Badeggi, Niger State, Nigeria

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ABSTRACT

This study was conducted with the aim of characterizing and classifying the soils of a paddy field in Badeggi Katcha local Government Area of Niger State. Two pedons were dug representing upper and lower slopes of the field and were designated as Badeggi 1 and 2 (BDG1 and BDG2) respectively. The pedons were described on the field following the FAO guidelines for soil description. Soil samples were collected from each identified natural horizons and taken to the laboratory for analysis. Results revealed that BDG1 had greyish brown (10YR 5/2) at the topmost horizon and light brownish grey (10YR 6/2) at the subsoil, while BDG2 had light brownish grey (10YR 6/2) overlying light grey (10YR 7/2) at subsoil. Sand content ranged from 840 to 860 g/kg in BDG 1 and 690 to 830 g/kg in BDG 2, silt ranged from 50 to 70 g/kg in BDG 1 and 90 to 210 g/kg in BDG 2 and clay ranged from 90 to 100 g/kg in BDG 1 and 80 to 100 g/kg in BDG 2. Soils from the two pedons were moderately to slightly acidic, low in organic carbon and available phosphorus, while total nitrogen was rated low to medium and irregularly distributed down the two profiles, but exchangeable Calcium, Magnesium, Potassium and Sodium were high across the study area. Using the USDA soil taxonomy system, the soils were classified as Plinthic Petraquepts (BDG 1) and Fluvaquentic Endoaquepts (BDG 2) which corresponded to Petric Plinthosols (Abruptic) and Fluvic Cambisols (Eutric) respectively, under World Reference Base for Soil Classification (WRB). The study has revealed that BDG1 is moderately well-drained while BDG2 is imperfectly drained. The soils are moderate to slightly acid with low inherent fertility as evidenced by low organic carbon, total nitrogen and available phosphorous. The soils were classified as Inceptisols at Soil Order level.

Keywords: Characterization; Classification; Paddy field; Pedons; Organic carbon

INTRODUCTION

Agriculture is the predominant economic activity in Niger State and because of agricultural development and its increasing demand for experimental data in Nigeria, much emphasis was given to soil characterization. This provides the basic information needed to create functional soil classification schemes, assess soil fertility in order to unravel some unique soil problems in an ecosystem (Lekwa *et al.*, 2004). Soil is a complex entity formed through both destructive and creative processes. Destructive processes include the weathering of rocks and the decay of organic residues by microorganisms. On the other hand, synthesis processes lead to the formation of new minerals like certain clays and organic compounds. These processes give rise to horizontal layers known as soil horizons, which are a distinguishing feature of soil found in the upper regolith (Brady and Weil, 2010). In contrast, deeper regolith minerals lack this characteristic. During the early stages of Soil Science, different disciplines had varying perspectives on the nature of soil. Chemists considered soil as a repository of chemical compounds, while geologists viewed it as disintegrated and decomposed rock material, possibly mixed with organic matter from plant decay (Ojanuga, 2006). The widely accepted concept of soil is the agronomic view, which defines soil as the natural medium for plant growth, regardless of the presence of identifiable soil horizons (Olushola, 2009). Soil occupies the uppermost layer of the Earth's surface and exhibits significant variability across different locations (Olushola, 2009). Soil is a three-dimensional, dynamic entity comprising mineral and organic materials, as well as living organisms that support plant growth (Olushola, 2009). In Niger State, three major soil types can be found, Ferruginous Tropical Soils, Hydromorphic Soils, and Ferrosols (Anonymous, 2003). However, there is poor comprehensive soil surveying and classification in the region.The vegetation of the State is broadly classified as Northern Guinea savanna with dense population of grasses, shrubs and tree (Anonymous, 2011).Therefore, the objective of this research is to identify, characterize and classify the soils.

MATERIALS AND METHODS

Study Area

The study site was a fadama plain covering an area of 10 hectares of land at Badeggi in Katcha local Government Area of Niger State. It lies between Latitude 90° 30' 10"N to 90° 68' 10"N and Longitude 60° 50' 23"E to 60° 90' 13"E. It is located at an elevation of 118 meters above sea level and covers 1,681 km² with a population 11,657 as at 2015. Geographically, it is situated adjacent to Edati Local Government to the west, Bida Local Government Area to the north, Agaie Local Government to the east, and Katcha to the south-west (Ndaman, 2011 and Nafiu, H. (2019).

Characterized by a tropical climate, Badeggi experiences distinct wet and dry seasons, with annual rainfall averaging 1127 or 32 mm less and a growing season of 200 or 15 days less (Adeyolanu *et al*. 2020). The wet season, from April to October, peaks in September, while the dry season spans November to March. Temperatures range from a maximum of 33°C in March to a minimum of 25°C in December, influencing evapotranspiration rates, which vary from 38 mm in September to 95 mm in March.

Underlain by pre-Cambrian Basement complex rocks, Badeggi exhibits granite, gneiss, and schist as its main lithological units. Granite, widespread and porphyritic, intrudes gneisses and features quartz veins. Groundwater tables, 0–50 cm in lowlands, fluctuate seasonally, impacting agriculture (Adeyolanu *et al*., 2020). Rainfall and rivers serve as primary water sources, crucial for extensive upland cultivation in the wet season. While natural vegetation remains in distant areas, communal spaces show signs of replacement, with fallow regions featuring regrowth and cultivated fields displaying diverse grasses and shrubs, indicating agricultural practices.

Sampling Techniques

Two profile pits were dug one each for upper and lower slope positions in the study area and designated as BDG1 and BDG2 respectively. Each of this profile was fully described on the field for morphological properties, while soil samples were collected from identified genetic horizons for laboratory analysis.

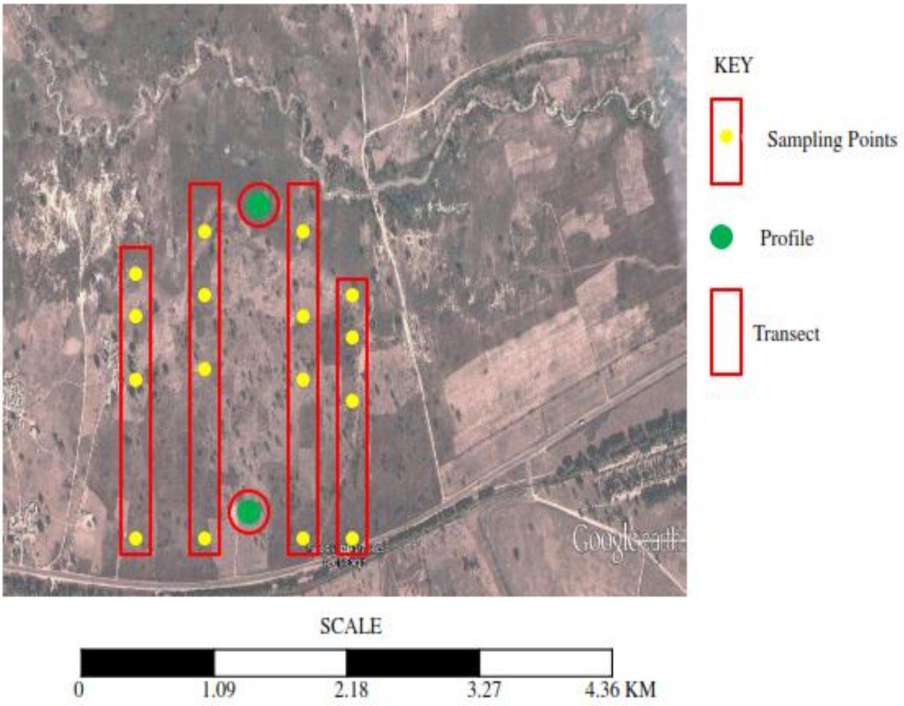

Plate 1: Google Earth View Baddeggi Study Site

Figure 1: Showing Sampling Points in Badeggi

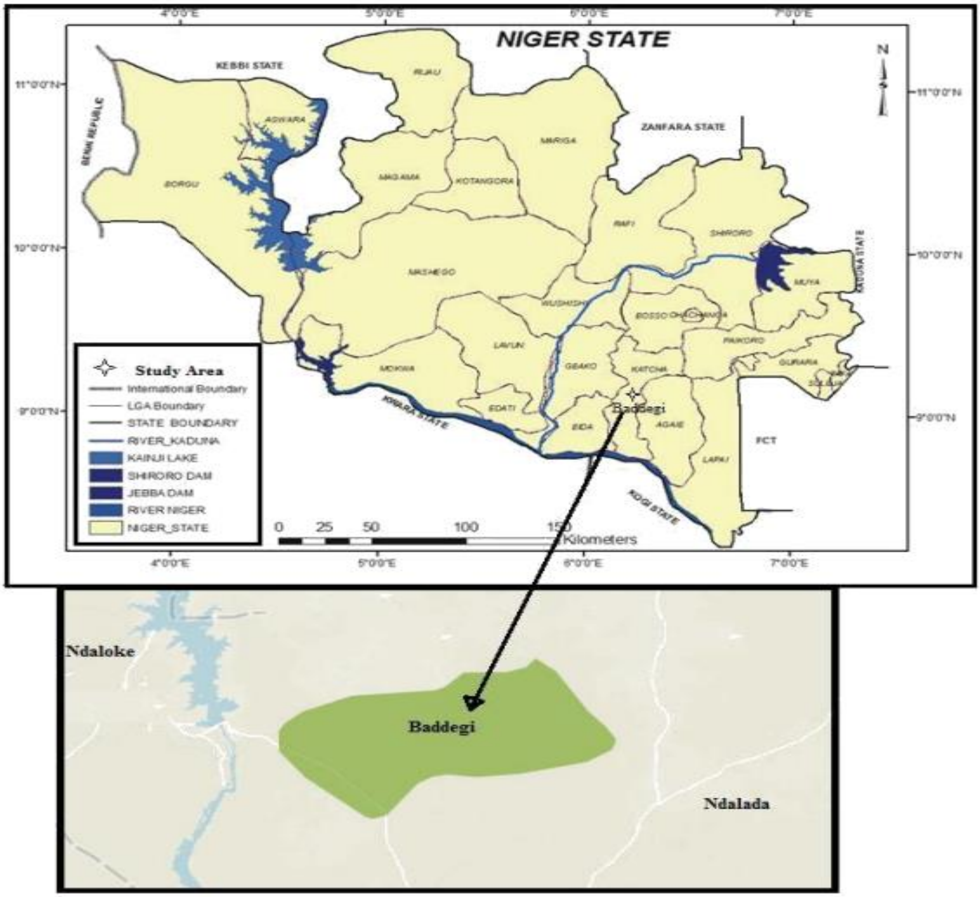

Figure 2: Map of the Study Area
Source: Niger State Geographic Information System (2018); Nafiu, H. (2019)

Laboratory Analysis

The soil samples were air-dried, gently crushed using a mortar and pestle, and passed through a 2 mm sieve to obtain a fine earth separate. Soil analyses were carried out in the laboratory following the procedures outlined by the International Soil Reference and Information Centre and Food and Agriculture Organization (ISRIC/FAO 2002). Particle size analysis was determined using Bouyocous hydrometer method. The soil pH in water (H_2O) 1:1 soil/water suspensions was measured with pH meter and also in calcium chloride ($CaCl_2$) 1:2. Organic carbon was determined following Walkley-Black method. Total nitrogen (TN) was determined by Macro-Kjeldahl digestion procedure. Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with 1 *N ammonium acetate* (NH_4OAC) solution. Calcium and magnesium in the extract were determined using Atomic Absorption Spectrophotometry, while potassium and sodium were determined by flame photometry. Exchange acidity was determined by titration with standard NaOH. Cation Exchange Capacity (CEC) was determined by the neutral 1 *N* NH_4OAC saturation method.

$$PBS = \sum \frac{(Ca^{2+} + Mg^{2+} + K^{+} + Na^{+})}{CEC} \times 100$$

The Exchangeable acidity (H^+ and Al^{3+}) was determined by saturating the soil samples with 1 *N* potassium chloride (KCl) solution and titrated against standard sodium hydroxide (NaOH) solution.

Data Analysis

The data generated were subjected to descriptive statistics of variation using Microsoft Excel version (2013).

RESULTS AND DISCUSSION

Morphological Properties and Particle Size Distribution of the Soils

The results of morphological properties and particle size distribution of the soils are presented in Table 1. The Ap-horizon under the BDG1 has a greyish brown (10YR 5/2) colour, while at the subsurface layers, AC1 and AC2 horizons have light brownish grey (10YR 6/2) and very pale brown (10YR 4/4) colour, respectively. Mottling was observed at a depth of 42 cm, with main colour being yellowish red (5YR 5/8). The Ap-horizon under the BDG2 has a matrix colour, while at the subsurface layers, AC1 and AC2 horizons have light brownish grey (10YR 6/2) and light grey (10YR 7/2) colour, accordingly (Table 3). Mottling was observed at depth of 23 cm and the colour of mottles was brownish yellow (10YR 6/8). In Table 1, sand values ranged from 840 to 860 g/kg and 690 to 830 g/kg for BDG1 and BDG2 respectively. Sand fraction at BDG1 had decreased slightly with soil depth, and then its distribution became relatively uniform, while at the BDG2, the trend was irregular. According to Ojanuga (2006), the floodplain soils of Nigeria are of alluvial origin and differed widely in their properties. It could therefore be explained that the dominance and variations in pattern of sand distribution between the profiles may be attributed to parent material rich in quartz mineral (Brady and Weil, 2010) and frequent cycles of alluvial deposition and sorting of soil materials as a result of geological processes involving clay migration through eluviation and illuviation, or surface erosion/ deposition by runoff, or by biological activities, or their combinations (Malgwi *et al*., 2000; Akintola *et al.*, 2009). Silt content widely and ranged from 50 to 70 g/kg and 90 to 210 g/kg for BDG1 and BDG2 respectively. Variation in silt content of the soils may also be attributed to reasons explained for the sand. Clay content ranged from 90 to 100 g/kg and 80 to 100 g/kg for BDG1 and BDG2 respectively. Both pedons did not show evidence of clay migration. Silt clay ratios ranged between 0.56 and 0.78, and 1.13 and 2.10 at BDG1 and BDG2 respectively (Table 1). Silt/clay ratios had been used to describe age and/ stage or weathering pattern in soils. According to Ashaye (1969), a low silt/clay ratio of < 1 could mean that the soil had undergone Ferralitic pedogenesis. Low silt/clay ratio could also imply that the soils studied in the sites still had weatherable minerals in them. Young parent materials usually have silt/clay ratio above 0.25 (Asamoa, 1973).

Table 1: Morphological and physical properties of the study areas

Horizon	Depth	Munsell Colour		Structure	Consistence	Root	Boundary	Textural	Sand	Silt	Clay	Silt/Clay
	(cm)	Matrix	Mottle					Class		(gkg^{-1})		Ratio
BDG 1				Petric Plinthosols (Abruptic).								
Ap	0-23	10YR5/2	________	2cr	Vfr.sft(moist)	f.v.gd	g.w	LS	860	50	90	0.56
AC1	23-42	10YR6/2	________	1gr	Fr.shrd(moist)	md.b.g	g.w	SL	840	70	90	0.78
AC2	42-120	10YR7/4	5YR5/8	2sg	Fr.shrd(moist)	f.bd	a.w	LS	840	60	100	0.60
	120+	-	-	-	-	-	-	Iron pan	-	-	-	-
BDG 2				Fluvic Cambisols (Eutric).								
Ap	0-24	10YR6/2	________	2cr	lo (moist)	f.md.v.gd	g.w	SL	760	140	100	1.40
AC1	24-84	10YR7/2	10YR6/8	1abk	Fr.shrd(moist)	f.gd	g.w	SL	690	210	100	2.10
AC2	84+	10YR8/1	________	M	sstk.splst (wet)	f.bd	-	SL	830	90	80	1.13

Determined at wet and moist, **Note**: symbols or codes according to FAO (2006)
Texture: c = clay, s = sandy, sl = sandy loam, ls = loamy sand, scl = sandy clay loam, **Structure:** 1 =weak, 2 = moderate, 3 =strong, sg=single grain, cr=crumb, gr=granular sbk = subangular blocky, abk = angular blocky, m=massive; **Consistence:** nstk=non sticky,, sstk=slightly sticky, s=sticky, nplst =non plastic, splst = slightly plastic, vplst =plastic, lo=loose, sft=soft, fr=friable, firm, frm =vfrm=very firm, shrd = slightly hard, hrd = hard, hrd =hard; **Root**: f=fine, f.m-fine and many, md.b = medium and big bd = bad, gd = good, v.gd=very good. **Boundary**: a= abrupt, c= clear, g= gradual, = smooth, w =wavy d=diffuse.

Chemical Properties of the Soils

The chemical properties of the profiles studied are presented in Table 2. Data interpretation was according to guidelines for rating of Nigerian soils by Esu (1991) and Chude *et al*. (2011). Generally, soil pH measured in $CaCl_2$ was lower than that measured in H_2O. The observed differences may be attributed to significant displacement and subsequent hydrolysis of exchangeable aluminum and hydrogen ions complexed on the exchange sites of the soils (Esu, 2010). Soil pH in BDG1 ranged from 6.0 to 6.5 and were rated as moderately acidic to slightly acidic, while the pH value for BDG2 ranged from 5.1 to 6.2 and was also rated strongly acidic to moderately acidic. Lawal *et al*. (2012a) reported similar pH values for some hydromorphic soils developed on basement complex rocks and sedimentary rocks formations in Niger State, Nigeria. For both pedons, the pH values varied irregularly with soil depths, a characteristic peculiar to hydromorphic soils (Ojanuga, 2006).

Organic carbon (OC) content in the BDG1 and BDG2 ranged from 0.64 to 3.39 g/kg and 0.85 to 3.18 g/kg, respectively. Although the OC was predominantly rated lowfor both pedons irrespective of soil horizons and topographic positions, its concentration was highest at surface horizon and decreased with soil depth. Result obtained from the study corroborated the findings of Lawal *et al*. (2012b) who also reported low OC content from studies in various hydromorphic soils underlined by Nupe sandstones within the same agro-ecological zone the current work was undertaken.

The total N content ranged from 0.08 to 0.10 g kg^{-1} and 0.05 to 0.26 g kg^{-1} in BDG 1 and BDG 2, respectively. The result indicates that the soils are rated low to medium in TN content. Brady and Weil (2010) reported that nitrogen has been a limiting factor in plant nutrient in tropical soils. Mustapha and Sing (2003) also reported low nitrogen rates obtained from fadama soils in Bauchi State. The low TN content obtained in this study could be as a result of losses of N through various sources. Nitrogen being a very mobile nutrient is very prone to losses through leaching and percolation under flooded situation, and volatilization once the flood water recedes. Kparmwang (1996) in his study observed significant loss of soil total nitrogen after flooding.

The distribution pattern of available phosphorus (AP) within the profiles was irregular and ranged from 4 to 5 mg/kg and 4 to 8 mg/kg at BDG1 and BDG2, respectively. According to Esu (1991), available soil P level of < 10 mg/kg is rated as low; 10 to 20 mg/kg as medium and > 20 mg/kg is rated high. Hence, the P status of the soils investigated was rated low. These would confirm that soils of the Nigerian Savanna have inherently poor fertility status (Jones and Wild, 1975; Lombin, 1987; Odunze *et al.*, 2004).

Exchangeable $Ca^{2+}$of BDG 1 and BDG 2 ranged between 2.80 and 6.00 $cmol_{(+)}$/kg and4.0 and 6.00 $cmol_{(+)}$/kg respectively (Table 2). These ranges of exchangeable Ca^{2+} at the surface and subsurface horizons are in the medium to high ratings (Tisdale and Nelson, 1985; Esu, 1991). Exchangeable Ca^{2+} of the soils was within the range of moderate to high value (2 to 5 $cmol_{(+)}$/kg), but its distribution appeared to be irregular with increase in soildepths. Also, values of Ca^{2+} recorded in this study, is a clear indication that calcium was the dominant cation. Adegbite and Ogunwale (1994) also found calcium to be the dominant cation in the soils of River Niger in nearby Kogi State.

The result of the exchangeable Mg^{2+} is also presented in Table 2 and the content was next in abundance after Ca^{2+}, for both profiles. At Badeggi site, The values of Mg^{2+} ranged from 2.00to 2.80 $cmol_{(+)}$/kg in BDG 1 and were irregularly distributed within the profile and 2.80 to 3.20 $cmol_{(+)}$/kg in BDG 2 which decrease down the depth. In this study, the trend in the distribution of Mg and Ca was similar to the previous findings (Adegbite and Ogunwale, 1994; Lawal *et al*. (2012b). The Exchangeable potassium (K) values across the study area ranged from 0.26 to 0.27cmol $_{(+)}$/kg for both BDG 1and BDG 2 (Table 2). The K^+ concentration was irregularly distributed in the profiles, the Ap-horizon and subsoil were rated medium, for the two pedons.

Table 2 also presents the result of the exchangeable Na^+ and the values obtained at site in BDG 1 were medium in ratings and ranged from 0.19 to 0.22 cmol$_{(+)}$/kg while BDG 2 values ranged from 0.18 to 0.34 cmol$_{(+)}$/kg and also rated medium. The concentration of Na^+ was irregularly distributed in BDG 1 and BDG2. Cation exchange capacity (CEC) values at BDG1 ranged from 7.25 to 10.24 cmol$_{(+)}$kg and in BDG 2 8.88 to 14.82 cmol$_{(+)}$/kg. The distribution of CEC was irregular with depth and falls within the medium class of rating (Esu, 1991). Cation exchange capacity of the soil was relatively high in BDG2showing the capacity of the soils to retain nutrient elements. Exchange acidity of soils across site had values ranging from 0.04 to 0.06 cmol$_{(+)}$/kg in BDG 1 and in BDG 2 values ranged from 0.06 to 0.07 cmol$_{(+)}$/kg. Basedon Esu (1991) rating, soils from BDG2 was ratedhigh and BDG1 medium. In the two pedons, the values of exchangeable acidity were irregularly distributed with depth similar results were also reported (Lawal *et al.,* 2013).

Table 2: Chemical properties of profiles of the study areas

Pedon	Horizon	Depth	pH		Org.C	T N	Av. P	Exchangeable Bases				CEC	Exchange Acidity	%Base Saturation
		cm	H_2O	$CaCl_2$	g/kg		mg/kg	Ca	Mg	K	Na			
								cmol/kg						
1	BDG 1	Petric Plinthosols (Abruptic).												
	Ap	0-23	6.5	5.6	3.39	0.08	5.0	5.20	2.40	0.27	0.22	9.90	0.04	81.71
	AC1	23-42	6.2	4.2	2.12	0.10	4.0	2.80	2.80	0.26	0.19	7.25	0.06	83.41
	AC2	42-120	6.0	5.9	0.64	0.08	4.0	6.00	2.00	0.27	0.22	10.24	0.05	82.71
		120+	-	-	-	-	-	-	-	-	-	-	-	-
2	BDG 2	Fluvic Cambisols (Eutric)												
	Ap	0-24	5.1	4.4	3.18	0.05	4.0	4.40	3.20	0.26	0.21	11.90	0.06	67.81
	AC1	24-84	6.0	5.4	0.85	0.26	8 .0	6.00	3.20	0.27	0.34	14.82	0.07	66.19
	AC2	84+	6.2	5.9	1.06	0.08	4.0	4.00	2.80	0.26	0.18	8.88	0.06	81.53

Taxonomic Classification of the Soils

BDG 1 At Great group level, they are classified as Petraquepts because of the occurrence of a plinthite horizon in the subsurface which forms a continuous phase. At subgroup level, it fitted into Plinthic Petraquepts, because the plinthite horizon was within 125 cm of the mineral soil surface forming a continuous phase. The subgroup name of the USDA Soil Taxonomy correlated with FAO system (WRB) classified the soils as Petric Plinthosols (Abruptic).

BDG 2 At Great group level, the pedon on the bottomland fitted into Endoaquepts due to endosaturation starting from depth 84 cm. Furthermore, on the basis that it occupies a slope position of < 2 % and at depth of 125 cm below the mineral soil surface, an organic-carbon content of ≥ 0.2 g/kg, in addition to absence of densic, lithic, or paralithic contact within 125 cm depth, the pedon was classified at Subgroup level as Fluvaquentic Endoaquepts which correlated with FAO system (WRB) classified the soils as Fluvic Cambisols (Eutric).

CONCLUSION

In conclusion, the paddy soils of Badeggi were characterized and classified to determine their agricultural potentials. The colour of the soils was found to be generally darker with 10YR and 5YR. BDG1 is moderately well-drained while BDG2 is imperfectly drained. The soils are moderate to slightly acid with low inherent fertility as evidenced by low organic carbon, total nitrogen and available phosphorous. The soils were classified as Inceptisols at Soil Order level.

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