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Pedological characterization and classification of soils underlain by basement complex at the Mambilla Plateau, Nigeria

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ABSTRACT

The study aimed to characterize and classify selected soils underlain by a basement complex at the Mambilla Plateau in Taraba State Northeast, Nigeria. A total of 12 pedons were dug to represent sampling units. Soil samples from the pedogenetic horizons of the pedons were collected after profile description, processed and analyzed. The pedons were very deep (> 150 cm) except for pedon 3, which was shallow. The soil texture of the pedons varies from sandy clay loam, sandy loam, sandy clay, loamy sand and clay across the surface and sub-surface horizons. Sand content of the horizons varied from 28.24 to 86.88 % across the pedons. The result of the pedons shows that bulk density was moderate. Soil pH was slightly to strongly acidic, and exchangeable bases were low to medium, indicating the relatively deficient primary nutrient status of the soils and occurred in the order $Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$. Base saturation was rated high in the soils. Organic carbon and total nitrogen varied from low to high, while available phosphorus of the pedons varied from low to medium. The soils of the pedons were classified according to the criteria of USDA soil taxonomy and correlated with World Reference Base soil classification systems at the sub-group level as Arenic Kandiustalfs (Loamic Lixisols) for the pedons 5 and 11; Typic Kandiustalfs (Hypereutric Lixisols) for the pedons 1, 2, 6, 7, 8, 9 and 10 and Typic Haplustepts (Eutric Cambisols) for the pedons 3, 4 and 12. to understand better factors controlling spatial variability of soil properties.

1.0 Introduction

Soil is an essential component in the total stock of natural resources available to mankind and underpins food production and environmental sustainability. The soil was described as a product of the environmental factors of climate, vegetation/organic material, geology, local relief and time (Ezeaku, 2011). Furthermore, soil exhibits the signatures of the afforested factors, as well as certain processes which combine to produce that specific characteristic (Asadu *et al.,* 2012). Soils are usually characterized using relevant morphological, physical and chemical properties inherent in them. It has been reported by Idoga *et al.* (2005) that soil as a natural resource can only be appropriately managed with a proper understanding of its characteristics. Lekwa *et al.* (2004) stated that soil characterization provides the fundamental information necessary to create functional soil classification schemes and assess soil fertility to resolve unique soil problems in an ecosystem. The classification includes the organization of knowledge, which eases remembering properties, enhancing understanding of relationships with ease of technology transfer and communication between scientists and end-users (Boul *et al.,* 2003). Sharu *et al.* (2013) reported coupling of soil characterization and classification provides a powerful resource for the benefit of mankind especially in the area of food security and environmental sustainability. Esu (2004) asserted that studying soil in detail through processes of soil characterization and land evaluation for various land utilization types is one of the strategies for achieving food security as well as a sustainable environment. There is little information on the characteristics of soils of the Mambilla Plateau but no information on soil classification. Considering the recent global food crises and the increasing need to ensure food security and environmental conservation, there is every need to harness the hitherto under-utilized soils of the Mambilla Plateau. Hence, there is a need to characterize and classify the soils of the Mambilla Plateau.

2.0 Materials and Methods

2.1 Study Area

The Mambilla Plateau is located between latitude 6° 30′ 24″ to 7° 19′ 48″ N and longitude 11° 02′ 42″ to 11° 37′ 12″ E, with a total land mass of 3,765.2 km^2 forming the tip of the Northeastern part of Nigeria. The entire plateau area falls under the Sardauna Local Government Area in Taraba State Northeast, Nigeria. The mean annual rainfall ranges from 1780 mm to 2200 mm, with peaks in June/ July and September (Chapman and Chapman, 2000). The mean annual temperature ranges from 25 °C to 35 °C (Bami, 2013).

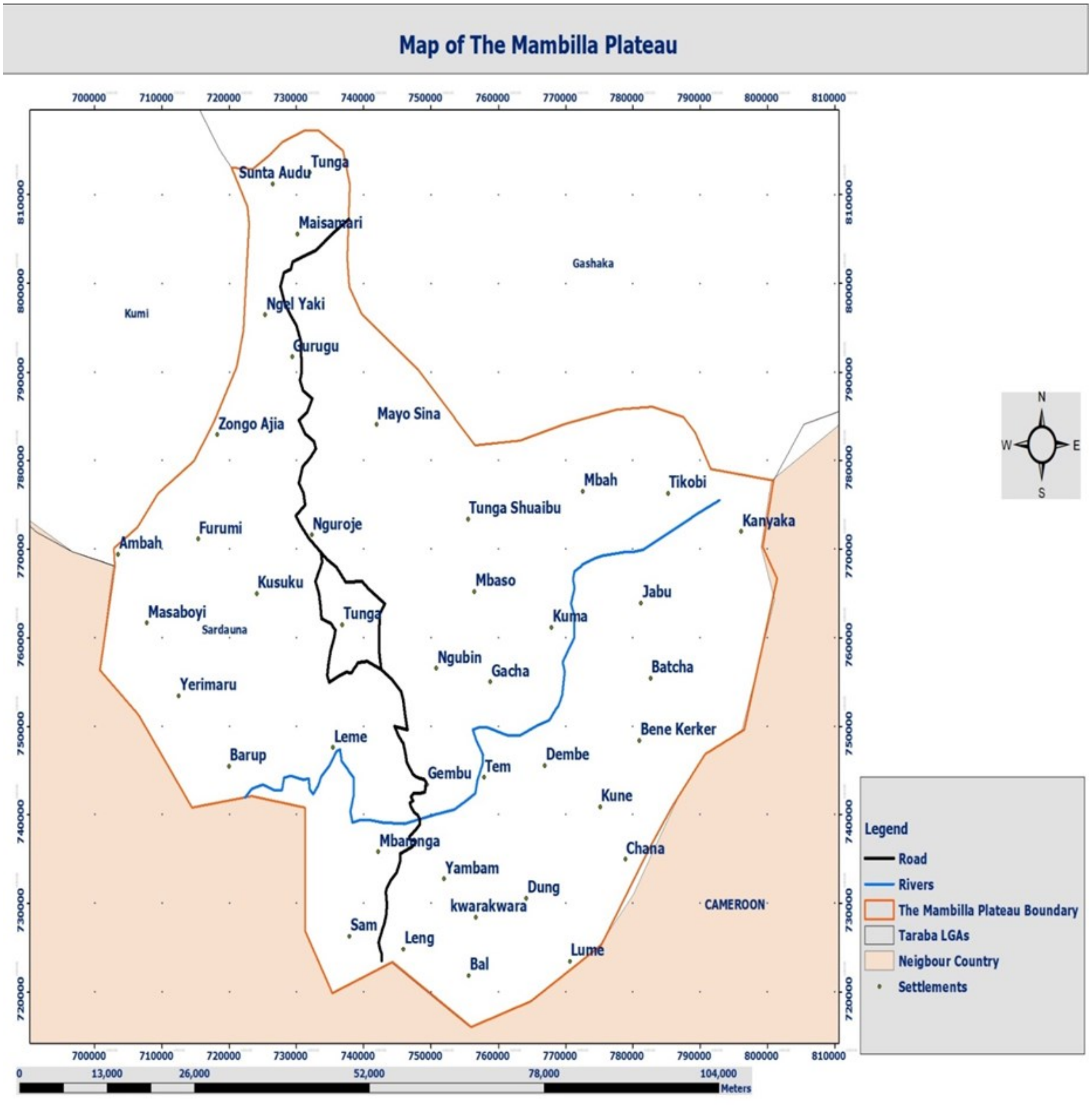

Fig 1: Map of the study area

2.2 Vegetation and Geology

The Mambilla plateau belongs to the Montane Guinea Savanna zone of Nigeria. Vegetation on the plateau comprises of averagely short grasses with trees being noticeably absent except for man-made forests. The areas are made up of many species of plants, some of which include Blue gum (*Eucalyptus globulus*), neem *(Azadirachta indica),* cassava (*Manihot esculenta*), stubborn grass (*Sida acuta*), spear grass (*Imperata cylindrica*), Siam weed (*Chromolaena odorata*,) mango (*Mangifera indica*), guava (*Psidium guajava*), Bamboo (*Phyllostachys aureosulcata*), avocado pea (*Persea americana*), tea (*Camellia sinensis*) and plantain and banana (*Musa spp.*).

The geology of the Mambilla plateau is developed on Basement Complex rocks. Moreover, the study area is part of Hawal Massif around the Northeastern Basement Complex of Nigeria (Obiefuna and Adamu, 2012). The major rock types in the Mambilla Plateau include granites, gneisses and migmatites. These rocks have experienced some tectonic deformations, as evidenced by the presence of joints, faults and intrusive bodies such as migmatities and microgranites, dykes and quartz-veins (Obiefuna and Adamu, 2012). Occasional tertiary basalts also exist on the plateau which resulted mainly from trachytic lavas and extensive basalts observed around Nguroje (www.ngrguardiannews.com 2015).

2.3 Sampling and Laboratory Analyses

Field reconnaissance was done with some conventional materials, and base maps were used to determine the features that exist in the study area. A flexible grid sampling technique was used for sample collection. A total of 12 pedons measuring 2 m × 1.8 m × 2 m were dug and soil samples from the pedogenetic horizons were collected after profile description according to the guideline of Soil Science Division Staff (2017). All pedons were georeferenced using a Handheld Global positioning system (GPS) receiver. Soil colour was determined using the Munsell soil colour chart (Munsell, 2009), while other morphological properties (consistency, root composition, drainage, and structure) were determined by visual observation. Soil samples were air-dried, crushed and sieved using 2.0 mm and 0.5 mm mesh. Soil samples were subjected to routine laboratory analyses. Samples were also collected with core samplers for determination of bulk density and moisture content. Particle size analysis was determined using the Bouyoucous hydrometer method as described by Gee and Or (2002). Bulk density was determined using the core method as described by Gross and Reinsch (2002). Exchangeable basic cations (Ca, Mg, K, and Na) were extracted with 1 N NH_4OAc (pH 7) (Thomas, 1996). Exchangeable calcium and magnesium were obtained using atomic absorption spectrophotometer, while exchangeable potassium and sodium were determined by flame photometry. Cation exchange capacity (CEC) was determined by ammonium acetate (NH_4OAc) of 1.0M leaching at pH 7 (Summer and Miller, 1996). Soil organic carbon was determined by Walkley and Black wet digestion method (Nelson and Sommers, 1996) while total nitrogen was determined by the Kjeldahl digestion method (Bremner, 1996). Available phosphorus was determined by the Bray-I method (Olsen and Sommers 1982). Soil pH was measured potentiometrically in water at the soil-liquid ratio of 1:2.5 (Thomas, 1996).

2.4 Soil Classification

The soils were classified according to the USDA soil Taxonomy (Soil Survey Staff, 2014) and correlated with World Reference Base (IUSS, 2015).

3.0 Results and Discussion

The results of the morphological properties of the pedons are presented in Table 1. The variation in soil depth and thickness of horizons could be attributed to differences in parent materials and the rate of pedogenesis among soils. Similarly, Idoga *et al.* (2007) affirm that variation in soil depth is associated with parent material, soil erosion, and slope of an area. Based on the soil depth class described by USDA SSS (2010), all the pedons were very deep (> 150 cm) except for pedon 3. The difference in colour change among the pedons and within a pedon could be attributed to the difference in OM content, parent material, and drainage conditions (Nahusenay *et al.,* 2014; Alem *et al.,* 2015; Osujieke *et al.,* 2016). The similarity in soil colours of the pedons under the various locations could be associated with the similarity in parent material, climatic conditions, and vegetation while the water table level of the pedons brings about variation among the horizons. Mottles observed on some surfaces and sub-soils can be attributed to oxidation-reduction cycles due to groundwater fluctuation (Babalola *et al.,* 2011). The soil texture of the pedons varies from sandy clay loam, sandy loam, sandy clay, loamy sand and clay across the surface and sub -surface horizons. The textural class is predetermined by parent material and climatic factors. FAO (2014) stated that the difference in the texture of the soil horizons could be a result of an illuvial accumulation of clay, predominant pedogenetic formation of clay in the subsoil, upward movement of coarser particles due to swelling and shrinking, biological activity, selective surface erosion of clay, and a combination of two or more of these different processes. The soil structure in all the pedons was predominantly moderate medium and strong coarse sub-angular blocky in most subsurface horizons, while the surface horizons were predominated by weak fine sub-angular blocky structure. This soil structure indicates that the soil has a good water holding capacity, approriate nutrient content and can support the soil microorganism. Ravikumar *et al.* (2009) and Coulombe *et al.* (1996) attributed such results to the characteristic features of soils with smectite as the dominant mineral. Evidence of loose, friable, nonsticky and non-plastic or slightly sticky and slightly plastic consistence is attributed to the low amount of expanding clay minerals (Thangasamy *et al.,* 2004; Sarkar *et al.,* 2001). The root presence varies from many very fine, many fine, many medium, common fine, few fine, common medium, few medium, very few coarse and few coarse, among horizons of the profile pits. The variation in root size and the population was associated with the difference in plant species and shallow rooting systems of most plants found in the studied sites (Osujieke *et al.,* 2020). Clear and smooth boundaries and clear and wavy boundaries are predominant among the horizons of the pedons.

The results of the physical properties of the pedons are presented in Table 2. Sand content dominated the mineral fraction in all the soil horizons of pedons studied, which may be partly attributed to parent material rich in quartz mineral, an essential component in granite Wilson (2010). Silt content ranged from 3.28 to 37.20 across the studied pedons. The irregular trend of clay distribution with profile depth might be due to variation in weathering of parent material (Sekhar *et al.,* 2014). The general increase in clay content with depth could be attributed to the vertical translocation of clay through the processes of lessivage and illuviation. Researchers (Chukwu, 2013; Yitbarek *et al.,* 2016; Kebede *et al.,* 2017) have earlier reported on higher clay content in the B horizon of soils as a result of illuviation, predominant in situ pedogenetic formation of clay in the subsoil, and destruction of clay in the surface horizon. The soil horizons bulk density value was less than 1.60 g cm^{-3} in all the pedons, thus rated medium, a range considered not to impede root penetration (Odunze, 2006; Akpan-Idiok *et al.,* 2012), which indicates that air and water movement in the soils are optimum for plant growth and development (Esu, 2010). However, the bulk density values of all the soils will support crop growth and development. Total porosity decreased with an increase in soil profile depth in an irregular trend. An irregular trend with depth may be due to the relatively high value of bulk density in surface horizons. This result conforms to the findings of Singh and Rathore (2015). They noticed that porosity was generally high in surface horizons and decreased with depth and attributed this to the higher value of bulk density in subsurface soils. The porosity of the pedons appears to be favourable for good aeration, root penetration and free water movement. This conforms to the findings of Hassan (2010) on the soils of Northern Nigeria.

The results of the chemical properties of the pedons are presented in Table 3. Soil pH across the horizons of the pedons ranged from slightly to strongly acidic, according to the ratings of Chude *et al.* (2011). However, the result of the soil pH is contrary to the findings of Hassan *et al.* (2015) in basaltic soils of Plateau state, Nigeria. Soil pH had an increase or decrease irregular trend with increasing soil depth. Similar trends have been observed and reported by Sharu *et al.* (2013) and Fasina *et al.* (2007) in the soils of Nigeria. Electrical conductivity values of the pedons ranged from 1.00 to 2.24 dS m^{-1} and were rated very low (< 4 dS m^{-1}), which indicates a non-saline electrical conductivity class. This result conforms to Maniyunda and Gwari (2014) report in Northern Guinea Savanna. The organic carbon content of the pedons, ranged from 0.24 to 3.60 %; hence, it varied from low to high according to the ratings of Esu (1991). The rate of variation of organic carbon across the horizons of the pedons could be attributed to the effect of climatic factors and leaching. Organic carbon content decreases with depth which could be associated with a decrease in plant materials with depth. This confirms the report of Idoga and Azagaku (2005) and Nahusenay and Kibebew (2016) on the decrease in organic carbon with soil depth. Total nitrogen content of the soil horizons across the pedons varied from low to high according to the ratings of FMA&NR (1990) and Landon (1991). As a result, total nitrogen is mobile in soils; it is lost through various mechanisms like NH_3 volatilization, succeeding denitrification, chemical and microbial fixation, leaching, and runoff resulting in residual/available nitrogen becoming poor in soils (Abagyeh *et al.,* 2016). The carbon-nitrogen ratio (C:N) ratio across the horizons of the pedons was predominantly greater than 10:1 with the exception of the Bt3 and Bt4 horizons of pedon 6. The C:N demonstrates an irregular variation with profile depth for the studied pedons, suggesting the existence of different conditions of mineralization in the recognized horizons. The low value of available phosphorus as observed in some pedons could be attributed to the prevalent soil management practices which enhance the export of nutrients in harvested crops without adequate replacement (Voncir, 2002; Haruna, 2009). According to Nuga *et al.* (2008), the available P level was very low in some soils in Nigeria. Exchangeable bases occurred in the order of Ca^{2+}>Mg^{2+}>K^{+}>Na^{+} on the exchange complex and were rated low to medium in all the pedons examined. This could be associated with the nature of underlying materials, the intensity of weathering, leaching, low activity clay content, very low organic matter content and the lateral translocation of bases, according to Kang (1993). The exchangeable bases mainly higher in the epipedon than in other horizons in all soils studied. The organic matter accumulation at the soil surface could have been attributed to the increase in exchangeable bases recorded at the epipedon. The exchangeable acidity of the soil horizons was low according to the ratings of Tisdale *et al.* (1995). Raji and Mohammed (2000) reported similar results and submitted that the contribution of exchange acidity to potential acidity is very low in soils of the Nigerian savanna zone. The low exchangeable acidity could reflect the low amount of exchangeable Al^{3+} and H^{+} in the soils. The soil CEC and clay CEC of the horizons of the pedons were medium to high according to the ratings of Esu (1991) in all the pedons. The sub-surface horizons CEC value was higher when compared with surface values in some pedons and could be indicative of mineralogical nature and composition rather than the presence of organic carbon. The percentage base saturation value of the soil conformed with the findings of Lawal *et al.* (2012) and Afolabi *et al.* (2014) that the soils of the Guniea savanna zone have high base saturation values. The high base status of the soils shows that essential nutrients may occur in an available form for plant uptake despite low cation reserve in the soils (Aki *et al.,* 2014).

Table 1: Morphological properties of the pedons of the Mambilla Plateau

Horizon	Depth (cm)	Munsell Soil Colour (miost or wet)	Mottle (moist or wet)	Texture Class	Structure	Consistency (moist or wet)	Boundary	Inclusions
Pedon 1(Jabu) (N06º53′52.8″ E011º24′13.9″ and elevation= 1567 m)								
Ap	0 – 29	7.5YR 2.5/3 (VDB)	5R 5/4 (WR)	SL	1fsbk	fi	cw	3vfrt-2frt-1mrt
Bt1	29 – 48	5YR 4/4 (RB)	5R 4/6 (R)	SCL	2msbk	fi	cs	3frt-2vfrt
Bt2	48 – 71	5YR 3/4 (RB)	5R 4/6 (R)	SCL	2msbk	fi	cs	3mrt
Bt3	71 – 86	10YR 3/2 (VDGB)	5R 3/6 (R)	SCL	3csbk	v.fi	cs	1vfrt-1frt
Bt4	86 – 120	7.5YR 2.5/1 (B)	5R 3/8 (DR)	SCL	2msbk	fi	cw	0vfrt
Bt5	120 – 180	5YR 3/1 (VDG)	5R 3/8 (DR)	SCL	3csbk	fi		0vfrt
Pedon 2 (Tonga Shaibu) (N06º 51′11.5″ E011º23′06.05″ and elevation= 1435 m)								
Ap	0 – 54	10R 4/6 (DR)		SCL	1fsbk	fr	cs	3vfrt-3frt-3mrt
Bt1	54 – 85	10R 3/3 (DKR)		C	1msbk	fr	cs	3vfrt-3frt-1mrt
Bt2	85 – 126	10R 3/4 (DKR)		SC	1fsbk	fr	cw	1frt-0mrt
Bt3	126 – 144	10R 3/6 (DR)		SC	2msbk	fi	cs	0vfrt-1frt
Bt4	144 – 160	10R 4/6 (R)		C	3csbk	fi		0frt
Pedon 3 (Dembe) (N06º45′05.30″ E011º20′02.7″ and elevation= 1275 m)								
Ap	1 – 30	5YR 4/6 (YR)		C	3csbk	v.st	cs	3vfrt-3frt-3mrt
A1	30 – 39	10YR 4/4 (DYB)		SL	2fsbk	sl.st	cs	3frt-2mrt-1crt
AB	39 – 49	7.5YR 4/4 (B)		SCL	2msbk	v.st	cs	3frt-2mrt-0crt
BA	49 – 60	2.5YR 3/3 (DOB)		SL	1fsbk	sl.st	ds	1frt-1mrt
Bt	60 – 70	7.5YR 4/3 (B)		CL	3msbk	v.st	ds	0frt-0mrt
BC	70 – 83	10YR 3/4 (DYB)		LS	1fsbk	sl.st	cw	2frt-2mrt-0crt
CB	83 – 106	2.5YR 4/4 (OB)		LS	1fsbk	sl.st		1frt-1mrt-0crt

Colour: VDB= very dark brown, RB= reddish brown, VDGB= very dark grayish brown, B= brown, R= red, VDG= very dark gray, YR= yellowish red, DR= dark red, DYB= dark yellowish brown, DOB= dark olive brown, OB= olive brown, DKR= dusky red, WR= weak red. Texture: SL=sandy loam, LS=loamy sand, SCL=sandy clay loam, L= loam, CL=clay loam, S= sand. Structure: 1= weak, 2= moderate, 3= strong, f= fine, m= medium, c= coarse, sbk= sub-angular blocky. Consistency: fi= firm, v.fi= very firm, fr= friable, st= sticky, sl.st= slightly sticky, v.st= very sticky. Boundary: cs= clear and smooth, cw= clear and wavy, ds= diffuse and smooth. Inclusions: 0= very few, 1= few, 2= common, 3= many, vf= very fine, f= fine, m= medium, c= coarse, rt =root

Table 1: Morphological properties of the pedons of the Mambilla Plateau (cont'd)

Horizon	Depth (cm)	Munsell Soil Colour (miost or wet)	Mottle (miost or wet)	Texture	Structure	Consistency (moist or wet)	Boundary	Inclusions
Pedon 7 (Leme) (N06°45′15.1″ E011°12′34.6″ and elevation= 1539 m)								
A	0 – 11	5YR 2.5/2 (DRB)		SL	2fsbk	fr	cs	3vfrt-3frt-2mrt
Bt1	11 – 42	2.5YR 4/6 (R)	10YR 6/4 (YB)	SCL	3csbk	v.fi	cs	3vfrt-2frt-0mrt
Bt2	42 – 71	5YR 3/4 (DRB)	10YR 5/4 (YB)	SCL	3csbk	fi	cs	3vfrt-2frt-1mrt-1crt
Bt3	71 – 87	5YR 2.5/2 (DRB)	10YR 5/6 (YB)	SCL	3csbk	v.st	cs	2vfrt-1crt
Bt4	87 – 120	10YR 3/2 (VDGB)		SCL	3csbk	v.st	cs	1frt-1mrt-1crt
BC	120 – 164	7.5YR 2.5/1 (BL)		LS	3csbk	ex.st	cs	1frt-1mrt-1crt
CB	164 – 200	10YR 2/1 (BL)		S	3csbk	ex.st		1frt
Pedon 8 (Yerimaru) (N06°47′39.4″ E011°02′42.1″ and elevation= 1522 m)								
Ap	0 – 25	2.5YR 2.5/2 (VDKR)		SCL	1fsbk	fr	cw	3vfrt-3frt-1mrt
Bt1	25 – 45	10R 3/3 (DKR)		SC	2msbk	fi	cw	3vfrt-3frt-1mrt
Bt2	45 – 115	2.5YR 4/6 (R)		C	2msbk	fi	cw	3vfrt-1frt-0crt
Bt3	115 – 132	10R 4/8 (R)		C	3csbk	v.fi	cs	3vfrt-1frt-1crt
Bt4	132 – 200	10R 3/6 (DR)		C	3csbk	v.fi		1frt-1mrt
Pedon 9 (Furumi) (N06°53′51.8″ E011°04′00.7″ and elevation= 1497 m)								
Ap	0 – 21	2.5YR 3/3 (DRB)		SL	1fsbk	fi	cs	3vfrt-3frt-2mrt
Bt1	21 – 35	2.5YR 4/6 (R)		SC	3msbk	v.fi	cs	3vfrt-2frt
Bt2	35 – 100	2.5YR 5/6 (R)		C	3csbk	ex.fi	cs	3vfrt-1frt
Bq	100 – 140	10R 4/8 (R)		SL	3csbk	ex.fi	cs	3vfrt
BC	140 – 186	10R 4/6 (R)		SC	2msbk	v.fi	cs	2vfrt
CB	186 – 200	10R 4/8 (R)		SC	3msbk	fi		2frt

Colour: DRB= dark reddish brown, VDGB= very dark grayish brown, R= red, YB= yellowish brown, DR= dark red, DKR= dusky red, VDKR= very dusky red, BL= black. Texture: SL= sandy loam, LS= loamy sand, SCL=sandy clay loam, SC= sandy clay, C= clay, S= sand. Structure: 1= weak, 2= moderate, 3= strong, f= fine, m= medium, c= coarse, sbk= sub-angular blocky. Consistency: fr= friable, fi= firm, v.fi= very firm, ex.fi= extremely firm, v.st= very sticky, ex.st= extremely sticky. Boundary: cs= clear smooth, cw= clear wav. Inclusions: 0= very few, 1= few, 2= common, 3= many, vf= very fine, f= fine, m= medium, c= coarse, rt =root

Table 1: Morphological properties of the pedons of the Mambilla Plateau (cont'd)

Horizon	Depth (cm)	Munsell Soil Colour (miost or wet)	Mottle (miost or wet)	Texture	Structure	Consistency (moist or wet)	Boundary	Inclusions
Pedon 10 (Nguroje) (N06°53′00.8″ E011°07′54.8″ and elevation= 1499 m)								
Ap	0 – 30	2.5YR 3/4 (DRB)		SL	1fsbk	fr	cs	3vfrt-3frt-1mrt
Bt1	30 – 62	10R 3/3 (DKR)		SC	2msbk	fi	cw	3vfrt-3frt
Bt2	62 – 93	2.5YR 3/6 (DR)		SL	3csbk	v.fi	cs	2vfrt-2frt
Bt3	93 – 122	2.5YR 4/8 (R)		C	3csbk	st	cs	1frt
Bt4	122 – 140	2.5YR 4/6 (R)		C	3csbk	st	cs	1frt
Bt5	140 – 180	5YR 5/6 (YR)		C	3csbk	v.st		1vfrt
Pedon 11(Ngel Nyake) (N07°05′27.6″ E011°05′17.0″ and elevation= 1608 m)								
Ap	0 – 34	5YR 2.5/2 (DRB)		SCL	1fsbk	fr	cs	3vfrt-3frt-2mrt
AB	34 – 87	5R 3/4 (DRB)		LS	2msbk	fi	cs	3vfrt-3frt-1mrt
BA	87 – 114	5YR 4/6 (YR)		SCL	3csbk	fi	cs	3vfrt-2frt
Bt1	114 – 132	5YR 4/4 (RB)		SC	3csbk	v.fi	cw	2vfrt-1mrt
Bt2	132 – 158	5YR 4/6 (YR)		SC	3csbk	sl.st	cw	2vfrt-1frt
Bt3	158 – 200	5YR 5/6 (YR)		C	3csbk	v.st		1frt
Pedon 12 (Maisamari) (N07°10′16.1″ E011°05′09.0″ and elevation= 1440 m)								
Ap	0 – 20	5YR 2.5/2 (DRB)		SL	1fsbk	fr	cs	3vfrt-3frt-2mrt
A1	20 – 43	5YR 3/3 (DRB)		SL	2msbk	fi	cw	3vfrt-2frt
AB	43 – 84	5YR 3/4 (DRB)		SL	2msbk	fi	cs	3vfrt-2frt
BA	84 – 111	5YR 2.5/2 (DRB)		SL	3csbk	sl.st	cs	3vfrt-1frt
BC	111 – 174	7.5YR 2.5/3 (VDB)		SL	3csbk	sl.st	cs	3vfrt-1frt
CB	174 – 200	5YR 3/4 (DRB)		SL	3csbk	st		2vfrt

Colour: DRB= dark reddish brown, VDGB= very dark grayish brown, R= red, YB= yellowish brown, DR= dark red, DKR= dusky red, VDKR= very dusky red, BL= black. Texture: SL= sandy loam, LS= loamy sand, SCL=sandy clay loam, SC= sandy clay, C= clay, S= sand. Structure: 1= weak, 2= moderate, 3= strong, f= fine, m= medium, c= coarse, sbk= sub-angular blocky. Consistency: fr= friable, fi= firm, v.fi= very firm, ex.fi= extremely firm, v.st= very sticky, ex.st= extremely sticky. Boundary: cs= clear smooth, cw= clear wav. Inclusions: 0= very few, 1= few, 2= common, 3= many, vf= very fine, f= fine, m= medium, c= coarse, rt =root

Table 1: Morphological properties of the pedons of the Mambilla Plateau (cont'd)

Horizon	Depth (cm)	Munsell Soil Colour (miost or wet)	Mottle (miost or wet)	Texture	Structure	Consistency (moist or wet)	Boundary	Inclusions
Pedon 10 (Nguroje) (N06°53′00.8″ E011°07′54.8″ and elevation= 1499 m)								
Ap	0 – 30	2.5YR 3/4 (DRB)		SL	1fsbk	fr	cs	3vfrt-3frt-1mrt
Bt1	30 – 62	10R 3/3 (DKR)		SC	2msbk	fi	cw	3vfrt-3frt
Bt2	62 – 93	2.5YR 3/6 (DR)		SL	3csbk	v.fi	cs	2vfrt-2frt
Bt3	93 – 122	2.5YR 4/8 (R)		C	3csbk	st	cs	1frt
Bt4	122 – 140	2.5YR 4/6 (R)		C	3csbk	st	cs	1frt
Bt5	140 – 180	5YR 5/6 (YR)		C	3csbk	v.st		1vfrt
Pedon 11(Ngel Nyake) (N07°05′27.6″ E011°05′17.0″ and elevation= 1608 m)								
Ap	0 – 34	5YR 2.5/2 (DRB)		SCL	1fsbk	fr	cs	3vfrt-3frt-2mrt
AB	34 – 87	5R 3/4 (DRB)		LS	2msbk	fi	cs	3vfrt-3frt-1mrt
BA	87 – 114	5YR 4/6 (YR)		SCL	3csbk	fi	cs	3vfrt-2frt
Bt1	114 – 132	5YR 4/4 (RB)		SC	3csbk	v.fi	cw	2vfrt-1mrt
Bt2	132 – 158	5YR 4/6 (YR)		SC	3csbk	sl.st	cw	2vfrt-1frt
Bt3	158 – 200	5YR 5/6 (YR)		C	3csbk	v.st		1frt
Pedon 12 (Maisamari) (N07°10′16.1″ E011°05′09.0″ and elevation= 1440 m)								
Ap	0 – 20	5YR 2.5/2 (DRB)		SL	1fsbk	fr	cs	3vfrt-3frt-2mrt
A1	20 – 43	5YR 3/3 (DRB)		SL	2msbk	fi	cw	3vfrt-2frt
AB	43 – 84	5YR 3/4 (DRB)		SL	2msbk	fi	cs	3vfrt-2frt
BA	84 – 111	5YR 2.5/2 (DRB)		SL	3csbk	sl.st	cs	3vfrt-1frt
BC	111 – 174	7.5YR 2.5/3 (VDB)		SL	3csbk	sl.st	cs	3vfrt-1frt
CB	174 – 200	5YR 3/4 (DRB)		SL	3csbk	st		2vfrt

Colour: DRB= dark reddish brown, VDB= very dark brown, R= red, YR= yellowish red, DR= dark red, DKR= dusky red, RB= reddish brown. Texture: SL=sandy loam, LS=loamy sand, SCL=sandy clay loam, C= clay, SC= sandy clay. Structure: 1= weak, 2= moderate, 3= strong, f= fine, m= medium, c= coarse, sbk= sub-angular blocky. Consistency: fr= friable, fi= firm, v.fi= very firm, st= sticky, sl.st= slightly sticky, v.st= very sticky. Boundary: cs= clear smooth, cw= clear wav. Inclusions: 1= few, 2= common, 3= many, vf= very fine, f= fine, m= medium, rt =root

Table 2: Physical properties of the pedons of the Mambilla Plateau

Horizon	Depth	Sand	Silt	Clay	BD	TP	MC	TC
	(cm)	→	%	←	(g/cm^3)	→	%	←
Pedon 1(Jabu) (N06°53′52.8″ E011°24′13.9″ and elevation= 1567 m)								
Ap	0 – 29	74.80	11.00	14.20	1.35	49.06	17.67	SL
Bt1	29 – 48	62.80	11.00	26.20	1.28	51.70	37.30	SCL
Bt2	48 – 71	67.80	12.00	20.20	1.26	52.45	37.29	SCL
Bt3	71 – 86	65.80	11.00	23.20	1.33	49.81	17.52	SCL
Bt4	86 – 120	64.80	12.00	23.20	1.40	47.17	21.18	SCL
Bt5	120 – 180	58.80	17.00	24.20	1.45	45.28	26.10	SCL
Pedon 2 (Tonga Shaibu) (N06° 51′11.5″ E011°23′06.05″ and elevation= 1435 m)								
Ap	0 – 54	54.24	11.28	34.48	1.49	43.77	30.20	SCL
Bt1	54 – 85	38.24	13.28	48.48	1.56	42.64	29.50	C
Bt2	85 – 126	45.24	9.28	45.48	1.52	42.64	28.62	SC
Bt3	126 – 144	46.24	9.28	44.48	1.50	43.39	31.40	SC
Bt4	144 – 160	44.24	9.28	46.48	1.53	42.64	29.31	C
Pedon 3 (Dembe) (N06°45′05.30″ E011°20′02.7″ and elevation= 1275 m)								
Ap	0 – 30	28.88	23.28	47.84	1.41	46.79	38.39	C
A1	30 – 39	74.88	11.28	13.84	1.10	58.49	28.41	SL
AB	39 – 49	52.88	23.28	23.84	1.18	55.47	29.38	SCL
BA	49 – 60	76.88	11.28	13.84	1.31	50.57	28.40	SL
Bt	60 – 70	34.88	29.28	35.84	1.32	50.19	39.12	CL
BC	70 – 83	82.88	5.28	11.84	1.33	49.81	29.16	LS
CB	83 – 106	86.88	3.28	9.84	1.39	47.55	21.06	LS

BD= bulk density, TP= total porosity, MC= moisture content, TC= textural class, SL= sandy loam, LS= loamy sand, SCL= sandy clay loam, C= clay, CL= clay loam, SC= sandy clay

Table 2: Physical properties of the pedons of the Mambilla Plateau (cont'd)

Horizon	**Depth**	**Sand**	**Silt**	**Clay**	**BD**	**TP**	**MC**	**TC**
	(cm)	→	%	←	(g/cm^3)	→ %	→	←
			Pedon 4 (Kune) (N06°43′24.4″ E011°21′56.7″ and elevation= 1271 m)					
Ap	0 – 32	65.80	10.00	24.20	1.17	55.85	31.54	SCL
AB1	32 – 65	66.80	12.00	21.20	1.16	56.23	23.30	SCL
AB2	65 – 90	69.80	11.00	19.20	1.09	58.87	28.68	SL
BA	90 – 113	66.80	13.00	20.20	1.14	56.98	31.14	SCL
B	113 – 138	72.80	14.00	13.20	1.06	60.00	34.98	SL
Bt1	138 – 165	67.80	10.00	22.20	1.06	60.00	37.21	SCL
Bt2	165 – 200	63.80	13.00	23.20	1.11	58.11	38.42	SCL
			Pedon 5 (Mbanga) (N06°37′03.4″ E011°12′28.1″ and elevation= 1481 m)					
Ap	0 – 40	86.24	5.28	8.48	1.24	53.21	38.19	LS
AB	40 – 89	78.24	13.28	8.48	1.29	51.32	36.22	SL
Bt1	89 – 122	58.24	17.28	24.48	1.46	44.89	31.32	SCL
Bt2	122 – 160	28.24	37.28	34.48	1.57	40.37	30.52	CL
Bt3	160 – 200	74.24	11.28	14.48	1.35	49.06	18.71	SL
			Pedon 6 (Dung) (N06°40′34.1″ E011°18′27.4″ and elevation= 1272 m)					
Ap	0 – 25	65.24	18.28	16.48	1.39	47.55	21.17	SL
Bt1	25 – 49	36.24	17.28	46.48	1.52	42.64	28.15	C
Bt2	49 – 130	30.24	9.28	60.48	1.55	41.51	27.33	C
Bt3	130 – 200	28.24	9.28	62.48	1.59	40.00	27.21	C

BD= bulk density, TP= total porosity, MC= moisture content, TC= textural class, SL= sandy loam, LS= loamy sand, SCL= sandy clay loam, C= clay, CL= clay loam, SC= sandy clay

Table 2: Physical properties of the pedons of the Mambilla Plateau (cont'd)

Horizon	**Depth**	**Sand**	**Silt**	**Clay**	**BD**	**TP**	**MC**	**TC**
	(cm)	→	%	←	(g/cm^3)	→	%	←
			Pedon 4 (Kune) (N06°43′24.4″ E011°21′56.7″ and elevation= 1271 m)					
Ap	0 – 32	65.80	10.00	24.20	1.17	55.85	31.54	SCL
AB1	32 – 65	66.80	12.00	21.20	1.16	56.23	23.30	SCL
AB2	65 – 90	69.80	11.00	19.20	1.09	58.87	28.68	SL
BA	90 – 113	66.80	13.00	20.20	1.14	56.98	31.14	SCL
B	113 – 138	72.80	14.00	13.20	1.06	60.00	34.98	SL
Bt1	138 – 165	67.80	10.00	22.20	1.06	60.00	37.21	SCL
Bt2	165 – 200	63.80	13.00	23.20	1.11	58.11	38.42	SCL
			Pedon 5 (Mbanga) (N06°37′03.4″ E011°12′28.1″ and elevation= 1481 m)					
Ap	0 – 40	86.24	5.28	8.48	1.24	53.21	38.19	LS
AB	40 – 89	78.24	13.28	8.48	1.29	51.32	36.22	SL
Bt1	89 – 122	58.24	17.28	24.48	1.46	44.89	31.32	SCL
Bt2	122 – 160	28.24	37.28	34.48	1.57	40.37	30.52	CL
Bt3	160 – 200	74.24	11.28	14.48	1.35	49.06	18.71	SL
			Pedon 6 (Dung) (N06°40′34.1″ E011°18′27.4″ and elevation= 1272 m)					
Ap	0 – 25	65.24	18.28	16.48	1.39	47.55	21.17	SL
Bt1	25 – 49	36.24	17.28	46.48	1.52	42.64	28.15	C
Bt2	49 – 130	30.24	9.28	60.48	1.55	41.51	27.33	C
Bt3	130 – 200	28.24	9.28	62.48	1.59	40.00	27.21	C

BD= bulk density, TP= total porosity, MC= moisture content, TC= textural class, SL= sandy loam, LS= loamy sand, SCL= sandy clay loam, CL= clay loam, C= clay

Table 2: Physical properties of the pedons of the Mambilla Plateau (cont'd)

Horizon	**Depth**	**Sand**	**Silt**	**Clay**	**BD**	**TP**	**MC**	**TC**
	(cm)	→	%	←	(g/cm^3)	→	%	←
			Pedon 7 (Leme) (N06°45′15.1″ E011°12′34.6″ and elevation= 1539 m)					
A	0 – 11	74.24	11.28	14.48	1.36	48.68	17.65	SL
Bt1	11 – 42	56.24	15.28	28.48	1.48	44.15	27.73	SCL
Bt2	42 – 71	56.24	13.28	30.48	1.47	44.53	27.74	SCL
Bt3	71 – 87	62.24	9.28	28.48	1.38	47.92	21.19	SCL
Bt4	87 – 120	64.24	9.28	26.48	1.39	47.55	21.20	SCL
BC	120 – 164	87.24	4.28	8.48	1.21	54.34	32.10	LS
CB	164 – 200	89.24	3.28	7.48	1.23	53.58	36.30	S
			Pedon 8 (Yerimaru) (3N06°47′39.4″ E011°02′42.1″ and elevation= 1522 m)					
Ap	0 – 25	72.24	7.28	20.48	1.33	49.81	34.98	SCL
Bt1	25 – 45	48.24	9.28	42.48	1.06	60.00	32.33	SC
Bt2	45 – 115	40.24	13.28	46.48	1.38	47.92	40.20	C
Bt3	115 – 132	38.24	13.28	48.48	1.48	44.15	40.20	C
Bt4	132 – 200	38.24	13.28	48.48	1.48	44.15	38.20	C
			Pedon 9 (Furumi) (N06°53′51.8″ E011°04′00.7″ and elevation= 1497 m)					
Ap	0 – 21	74.24	11.28	14.48	1.16	56.23	31.17	SL
Bt1	21 – 35	48.24	9.28	42.48	1.38	47.92	31.32	SC
Bt2	35 – 100	38.24	13.28	48.48	1.49	43.77	40.21	C
Bq	100 – 140	78.24	13.28	8.48	1.50	43.40	27.76	SL
BC	140 – 186	48.24	9.28	42.48	1.40	47.17	30.32	SC
CB	186 – 200	46.24	9.28	44.48	1.38	47.92	29.32	SC

BD= bulk density, TP= total porosity, MC= moisture content, TC= textural class, SL= sandy loam, LS= loamy sand, SCL=sandy clay loam, SC= sandy clay, C= clay, S= sand

Table 2: Physical properties of the pedons of the Mambilla Plateau (cont'd)

Horizon	Depth	Sand	Silt	Clay	BD	TP	MC	TC
	(cm)	→	%	←	(g/cm^3)	→	%	←
Pedon 10 (Nguroje) (N06°53′00.8″ E011°07′54.8″ and elevation= 1499 m)								
Ap	0 – 30	76.88	5.28	17.84	1.15	56.60	31.53	SL
Bt1	30 – 62	54.88	9.28	35.84	1.23	53.59	30.06	SC
Bt2	62 – 93	68.88	7.28	23.84	1.45	45.28	40.21	SL
Bt3	93 – 122	36.88	17.28	45.84	1.50	43.40	40.20	C
Bt4	122 – 140	36.88	17.28	45.84	1.48	44.15	40.20	C
Bt5	140 – 180	42.88	13.28	43.84	1.39	47.55	31.32	C
Pedon 11(Ngel Nyake) (N07°05′27.6″ E011°05′17.0″ and elevation= 1608 m)								
Ap	0 – 34	62.24	9.28	28.48	1.28	51.70	37.30	SCL
AB	34 – 87	82.24	7.28	10.48	1.33	49.81	29.16	LS
BA	87 – 114	62.24	9.28	28.48	1.28	51.70	37.30	SCL
Bt1	114 – 132	46.24	9.28	44.48	1.37	48.30	38.20	SC
Bt2	132 – 158	46.24	9.28	44.48	1.38	47.92	38.31	SC
Bt3	158 – 200	44.24	9.28	46.48	1.37	48.30	40.20	C
Pedon 12 (Maisamari) (N07°10′16.1″ E011°05′09.0″ and elevation= 1440 m)								
Ap	0 – 20	76.80	11.00	12.20	1.39	47.55	21.16	SL
A1	20 – 43	77.80	10.00	12.20	1.25	52.83	26.25	SL
AB	43 – 84	74.80	12.00	13.20	1.31	50.57	17.38	SL
BA	84 – 111	78.80	11.00	10.20	1.33	49.81	17.49	SL
BC	111 – 174	78.80	10.00	11.20	1.27	52.08	17.22	SL
CB	174 – 200	72.80	10.00	17.20	1.31	50.57	17.35	SL

BD= bulk density, TP= total porosity, MC= moisture content, TC= textural class, SL=sandy loam, LS=loamy sand, SCL=sandy clay loam, C= clay, SC= sandy clay

Table 3: Chemical properties of the pedons of the Mambilla Plateau

Horizon	Depth	pH	EC	OC	TN	C/N	Av. P	TEB	TEA	CEC (clay)	CEC(soil)	BS
	(cm)	(H_2O)	(dS m^{-1})	→	%	←	(mg/kg)	→		cmol/kg	←	(%)
Pedon 1(Jabu) (N06°53′52.8″ E011°24′13.9″ and elevation= 1567 m)												
Ap	0 – 29	5.70	1.21	3.49	0.110	31.73	8.00	7.06	1.08	1.30	12.4	56.93
Bt1	29 – 48	5.78	1.32	1.56	0.086	18.14	5.30	5.94	1.00	8.93	7.8	76.15
Bt2	48 – 71	5.83	1.41	1.44	0.070	20.57	5.40	6.22	1.09	15.15	8.1	85.09
Bt3	71 – 86	5.81	1.23	1.52	0.080	19.00	5.24	6.23	1.07	12.85	8.3	85.34
Bt4	86 – 120	5.81	1.12	1.66	0.092	18.04	6.30	6.00	1.06	8.15	7.7	84.99
Bt5	120 – 180	5.78	1.12	2.51	0.065	38.62	6.00	7.56	1.02	1.72	9.2	88.11
Pedon 2 (Tonga Shaibu) (N06° 51′11.5″ E011°23′06.05″ and elevation= 1435 m)												
Ap	0 – 54	5.31	1.21	2.45	0.074	33.11	8.20	8.91	1.08	4.71	10.2	87.35
Bt1	54 – 85	5.82	1.10	2.07	0.043	48.14	5.70	6.12	1.03	2.38	8.4	72.86
Bt2	85 – 126	5.78	1.22	1.90	0.040	47.50	5.74	7.41	1.04	6.27	9.5	78.00
Bt3	126 – 144	5.84	1.20	1.66	0.061	27.21	4.40	6.42	1.03	6.50	8.7	73.79
Bt4	144 – 160	5.80	1.21	1.54	0.057	27.02	4.52	5.95	1.01	4.32	7.4	80.41
Pedon 3 (Dembe) (N06°45′05.30″ E011°20′02.7″ and elevation= 1275 m)												
Ap	0 – 30	6.24	1.13	1.78	0.053	33.59	7.64	7.00	1.15	9.97	11.0	63.64
A1	30 – 39	6.17	1.04	1.10	0.041	26.82	6.80	6.47	1.09	29.99	8.0	80.88
AB	39 – 49	6.16	1.25	1.56	0.044	35.46	5.40	6.47	1.05	10.65	8.0	75.63
BA	49 – 60	6.14	1.31	1.84	0.061	30.16	5.34	6.12	1.04	11.99	8.1	75.56
Bt	60 – 70	6.20	1.22	2.11	0.070	30.14	4.20	7.25	1.02	5.06	9.2	78.80
BC	70 – 83	6.16	1.31	1.34	0.045	29.78	3.24	5.32	1.00	26.27	7.8	68.21
CB	83 – 106	6.17	1.00	0.90	0.028	32.14	3.04	5.72	1.16	46.24	7.7	74.29

EC= electrical conductivity, OC= organic carbon, TN= total nitrogen, Av. P= available phosphorus, TEB= total exchangeable base, TEA= total exchangeable acidity, CEC= cation exchange capacity, BS= base saturation

Table 3: Chemical properties of the pedons of the Mambilla Plateau

Horizon	Depth	pH	EC	OC	TN	C/N	Av. P	TEB	TEA	CEC(clay)	CEC(soil)	BS
	(cm)	(H_2O)	(dS m^{-1})	→	%	←	(mg/kg)		→	cmol/kg	←	(%)
Pedon 4 (Kune) (N06°43′24.4″ E011°21′56.7″ and elevation= 1271 m)												
Ap	0 – 32	5.88	1.38	2.15	0.100	21.50	4.40	5.85	1.06	6.10	9.0	65.00
AB1	32 – 65	5.70	1.23	1.34	0.096	13.96	6.30	6.86	1.11	15.61	8.0	85.75
AB2	65 – 90	5.68	1.43	1.32	0.088	15.00	5.20	5.45	1.04	12.40	7.0	77.86
BA	90 – 113	5.68	1.34	0.72	0.069	10.44	4.10	6.10	1.03	27.13	8.0	76.25
B	113 – 138	5.71	1.31	1.20	0.094	12.77	5.30	6.21	1.05	28.79	8.0	77.23
Bt1	138 – 165	5.15	1.02	0.76	0.068	11.18	4.25	6.05	1.02	24.05	8.0	75.63
Bt2	165 – 200	5.16	1.22	0.72	0.066	10.91	4.20	5.44	1.07	19.31	7.0	77.71
Pedon 5 (Mbanga) (N06°37′03.4″ E011°12′28.1″ and elevation= 1481 m)												
Ap	0 – 40	5.66	1.33	2.05	0.062	33.07	7.10	7.42	1.08	33.31	10.0	74.20
AB	40 – 89	5.68	1.07	1.24	0.075	16.53	4.14	4.99	1.01	19.58	6.0	83.17
Bt1	89 – 122	5.68	1.06	0.94	0.055	17.09	3.60	4.66	0.98	11.07	6.0	77.67
Bt2	122 – 160	5.76	1.27	1.86	0.047	39.58	5.41	7.23	1.04	7.22	9.0	80.33
Bt3	160 – 200	5.76	1.15	2.03	0.043	47.21	6.34	5.82	1.01	6.18	8.0	83.14
Pedon 6 (Dung) (N06°40′34.1″ E011°18′27.4″ and elevation= 1272 m)												
Ap	0 – 25	5.75	1.25	1.18	0.080	14.75	4.44	5.67	1.06	17.42	7.0	81.00
Bt1	25 – 49	5.60	1.19	0.62	0.061	10.16	3.36	4.91	1.01	8.24	6.0	81.83
Bt2	49 – 130	5.55	1.16	0.24	0.041	5.85	3.34	4.58	1.02	8.53	6.0	76.33
Bt3	130 – 200	5.54	1.18	0.54	0.072	7.20	3.30	4.81	0.99	8.18	7.0	68.71

EC= electrical conductivity, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, TEB= total exchangeable base, TEA= total exchangeable acidity, CEC= cation exchange capacity, BS= base saturation

Table 2: Physical properties of the pedons of the Mambilla Plateau (cont'd)

Horizon	Depth	pH	EC	OC	TN	C/N	Av. P	TEB	TEA	CEC(clay)	CEC(soil)	BS
	(cm)	(H_2O)	(dS m^{-1}) ⟶ % ⟵				(mg/kg)	⟶		cmol/kg ⟵		(%)
Pedon 7 (Leme) (N06°45′15.1″ E011°12′34.6″ and elevation= 1539 m)												
A	0 – 11	5.73	1.36	3.60	0.162	22.22	8.06	8.61	1.08	2.76	13.0	66.25
Bt1	11 – 42	5.70	1.24	2.09	0.041	50.98	5.64	6.52	1.04	2.41	8.0	81.50
Bt2	42 – 71	5.67	1.31	1.82	0.038	47.89	5.43	7.60	1.05	8.63	9.0	84.44
Bt3	71 – 87	5.68	1.34	2.61	0.087	30.00	7.19	8.69	1.09	3.04	10.0	86.90
Bt4	87 – 120	5.66	1.25	2.03	0.039	52.05	5.85	6.59	1.03	3.38	8.0	82.38
BC	120 – 164	5.61	1.30	2.79	0.061	45.74	8.10	9.05	1.07	14.56	11.0	82.27
CB	164 – 200	5.63	1.33	3.33	0.051	65.29	9.08	9.17	1.11	4.61	12.0	76.42
Pedon 8 (Yerimaru) (3N06°47′39.4″ E011°02′42.1″ and elevation= 1522 m)												
Ap	0 – 25	6.03	1.20	2.60	0.13	20.00	8.17	6.10	1.06	4.58	10.10	60.39
Bt1	25 – 45	5.98	2.20	1.18	0.01	118.00	4.26	8.16	1.14	17.11	11.14	83.48
Bt2	45 – 115	5.96	1.62	1.20	0.01	120.00	4.23	8.15	1.14	15.02	11.18	83.09
Bt3	115 – 132	5.92	1.53	1.20	0.02	60.00	4.31	6.95	1.09	12.38	10.20	78.82
Bt4	132 – 200	5.89	1.45	0.90	0.01	155.00	3.63	6.97	1.07	12.56	9.24	87.01
Pedon 9 (Furumi) (N06°53′51.8″ E011°04′00.7″ and elevation= 1497 m)												
Ap	0 – 21	5.68	1.01	2.15	0.07	30.71	4.10	5.21	1.08	5.63	8.34	62.47
Bt1	21 – 35	5.78	2.24	2.45	0.18	13.61	6.31	6.13	1.10	1.52	9.22	66.49
Bt2	35 – 100	5.88	1.56	2.09	0.06	34.83	5.20	7.02	1.12	5.85	10.15	86.24
Bq	100 – 140	5.89	1.65	1.66	0.04	41.50	4.12	5.25	1.07	29.48	8.31	83.07
BC	140 – 186	5.92	1.65	1.54	0.02	77.00	4.13	6.12	1.09	8.99	9.21	66.45
CB	186 – 200	5.92	1.21	0.64	0.03	21.33	3.52	6.09	1.10	13.38	8.19	74.36

EC= electrical conductivity, OC= organic carbon, TN= total nitrogen, Av. P= available phosphorus, TEB= total exchangeable base, TEA= total exchangeable acidity, CEC= cation exchange capacity, BS= base saturation

Table 3: Chemical properties of the pedons of the Mambilla Plateau

Hori-zon	Depth	pH	EC	OC	TN	C/N	Av.P	TEB	TEA	CEC(clay)	CEC(soil)	BS
	(cm)	(H_2O)	(dS m^{-1}) ⟶ % ⟵				(mg/kg)	⟶		cmol/kg ⟵		(%)
Pedon 10 (Nguroje) (N06°53′00.8″ E011°07′54.8″ and elevation= 1499 m)												
Ap	0 – 30	6.06	1.112	3.29	0.060	53.93	8.54	7.46	1.17	2.72	12.0	62.17
Bt1	30 – 62	6.10	1.314	2.77	0.057	49.00	7.08	7.26	1.15	0.85	10.0	72.60
Bt2	62 – 93	6.15	1.511	1.28	0.032	40.00	6.23	6.67	1.04	18.96	9.0	74.11
Bt3	93 – 122	6.17	1.401	1.44	0.040	36.00	6.17	6.61	1.03	10.82	10.0	66.10
Bt4	122 – 140	6.16	1.226	1.24	0.022	56.36	6.82	6.43	1.03	10.17	9.0	71.44
Bt5	140 – 180	6.19	1.134	0.74	0.021	35.24	4.30	5.62	1.03	10.06	7.0	80.29
Pedon 11(Ngel Nyake) (N07°05′27.6″ E011°05′17.0″ and elevation= 1608 m)												
Ap	0 – 34	5.90	1.210	3.41	0.20	17.05	7.25	6.93	1.12	1.11	12.25	56.67
AB	34 – 87	5.94	1.012	3.49	0.31	11.26	8.15	6.28	1.06	1.19	12.34	50.89
BA	87 – 114	5.94	1.121	2.42	0.13	18.62	6.33	6.25	1.07	2.91	9.30	67.20
Bt1	114 – 132	5.96	1.310	1.18	0.04	29.50	4.42	5.20	1.05	9.85	8.51	61.11
Bt2	132 – 158	5.95	1.220	0.94	0.03	31.33	4.35	5.13	1.03	9.29	7.42	69.14
Bt3	158 – 200	6.00	1.213	0.80	0.02	40.00	3.64	5.06	1.02	9.96	7.43	63.10
Pedon 12 (Maisamari) (N07°10′16.1″ E011°05′09.0″ and elevation= 1440 m)												
Ap	0 – 20	5.74	1.221	2.64	0.10	26.40	7.00	6.44	1.13	1.11	8.0	64.40
A1	20 – 43	5.84	1.012	2.71	0.10	27.10	7.10	6.11	1.05	1.19	8.0	61.10
AB	43 – 84	6.32	1.310	1.80	0.09	20.00	6.60	6.57	1.13	2.19	7.0	59.73
BA	84 – 111	6.31	1.420	3.10	0.14	29.29	8.00	8.14	1.10	9.85	10.0	62.62
BC	111 – 174	6.15	1.003	3.37	0.12	28.08	7.24	7.37	1.04	9.29	9.0	61.42
CB	174 – 200	6.08	1. 110	1.78	0.09	19.78	6.37	6.66	1.03	9.96	8.0	66.60

EC= electrical conductivity, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, TEB= total exchangeable base, TEA= total exchangeable acidity, CEC= cation exchange capacity, BS= base saturation

3.1 Soil Classification

The soils of the pedons were classified according to the criteria of USDA soil taxonomy, namely; temperature, moisture regimes, morphological, physical and chemical characteristics of the soils were considered in Classification according to Soil Survey Staff, (2014) and correlated with the world reference base (IUSS, 2015) soil classification systems.

3.2 Soil temperature regime

The mean maximum and minimum annual temperature of the study area was >22 °C Bami, (2013). The difference between the mean maximum and minimum annual soil temperature is greater than 5 °C at a depth of 50 cm which qualifies the Mambilla Plateau as an iso-hyperthermic temperature regime (Soil Survey Staff, 2014).

3.3 Soil moisture regime

The soil moisture regime of the Mambilla plateau was Ustic according to the criteria of Soil Survey Staff (2014). The study area has more than 90 cumulative days with dry soil in the moisture control section (upper 50 cm). The mean annual rainfall is about 1990 mm.

3.4 Diagnostic surface horizons (epipedons)

The pedons 5 and 11 had a plaggen epipedon which is a human-made surface layer 50 cm or thicker that has been produced by long-continued manuring/ locally raised land surfaces. In contrast, pedons 1, 2, 6, 7, 8, 9, and 10 had mollic epipedons, and pedons 3, 4 and 12 had ochre epipedons because they had medium to low P, were poor in humus, and were too thin to be qualified either as mollic or umbric epipedons.

3.5 Diagnostic sub-surface horizons

The pedons 1, 2, 5, 6, 7, 8, 9, 10 and 11 had a significant accumulation of illuviated layered-lattice silicate clays formed below the eluvial horizons. The argillic horizons were confirmed to be present by the clay ratio of the illuvial to the eluvial horizon of 1.2 or greater, and the total thickness was more than 15 cm in all the pedons (Soil Survey Staff, 2014). The subsurface horizons are, therefore, argillic B-horizon. The pedons 2, 4 and 12 showed little evidence of the development of diagnostic horizons and therefore are classified as the cambic subsurface horizon.

3.6 Classification of the pedons

The pedons 1, 2, 5, 6, 7, 8, 9, 10 and 11 had an argillic horizon which increased in clay content with depth. The organic matter content decreased progressively with profile depth, base saturation above 50 %. A clay enriched argillic horizon, a fragipan, <16 cmol kg-1 of clay CEC. Hence, the soil is grouped into the order Alfisols, while pedons 3, 4 and 12 had an ochric epipedon over cambic subsoil horizons and high base saturation >60 %, which qualifies them into the order Inceptisols. The pedons 1, 2, 5, 6, 7, 8, 9, 10 and 11 were placed into sub-order Ustalfs, while pedons 3, 4 and 12 were placed into sub-order Ustept by their ustic moisture regime. At the Great Group, the pedons 1, 2, 5, 6, 7, 8, 9, 10 and 11 were classified as Kandiustalfs because they had thick kandic subsoil horizon, relatively high base saturation but low clay CEC, clay content increases by 3 % below, no root-limiting layer within the depth of 150 cm, and do not have densic, lithic and paralithic contact within 150 cm of the mineral soil surface. While the pedons 3, 4 and 12 had base saturation >60 % in the upper 75 cm, freely drained ustepts and an ochric horizon over a cambic subsoil horizon which qualifies them as Haplustepts (Soil Survey Staff, 2014). However, at the sub-group level, pedons 5 and 11 were classified as Arenic Kandiustalfs (Loamic Lixisols), pedons 1, 2, 6, 7, 8, 9, and 10 were classified as Typic Kandiustalfs (Hypereutric Lixisols) while pedons 3, 4 and 12 were classified as Typic Haplustepts (Eutric Cambisols).

4.0 Conclusion

The pedogenic, physical and chemical properties of the soil horizons across the pedons varied. This could be associated with the soil forming factors and processes. The soils were classified as Arenic Kandiustalfs (Loamic Lixisols) in pedons 5 and 11, Typic Kandiustalfs (Hypereutric Lixisols) in pedons 1, 2, 6, 7, 8, 9 and 10 and Typic Haplustepts (Eutric Cambisols) in pedons 3, 4 and 12. This has prepared useful soil information, which will guide the land users on land-use practices to adopt.

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