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Soil Profile Characteristics As Affected By Land Use Systems In The Southeastern Adamawa State, Nigeria

Gailyson Y. Jamala[1] and David O. Oke[2]
[1]College of Agriculture, Ganye, Adamawa State, Nigeria
[2]Federal University of Technology Akure, Ondo State, Nigeria

Abstract: *The success of soil management to maintain soil quality depends on an understanding of how soils respond to agricultural use and practices over time. As a result, the important soil quality indicators were assessed under different land use systems to provide base line data for future research in Southeastern Adamawa State, Nigeria. The different land use systems were the cultivated land, natural fallow land, Gmelina plantation, pasture and the undisturbed natural forest land. One soil profile was opened in each land use system for field descriptions and laboratory studies in 2012/2013. The soil physical properties such as structure, colour, particle size distribution and soil depth characteristics showed notable variations due to different land use system, particularly in the surface horizons. The soil textures ranged from clay loam in the cultivated land, pasture land, undisturbed natural forest to sandy clay in the Gmelina plantation and sandy clay loam in the natural fallow land. The soil pH measured in water of the cultivated land, pasture, undisturbed natural forest and natural fallow lands varied from moderately acid to slightly acid in the Gmelina plantation. The OC and the total N decreased consistently from the surface to the subsurface horizons in all the land use systems. The surface horizons of the undisturbed natural forest, Gmelina plantation and the pasture land recorded the highest amount of OC/TN compared to the cultivated and natural fallow lands. This implies that intensive cultivation significantly deplete OC and TN. There was great variation in cation exchange capacity (CEC) of the soils under the different land use systems both in the upper and subsurface soil horizons. The CEC decreased almost inconsistently from the surface to the subsurface horizons in all the different land use systems. The decrease in CEC with depth could be attributed to a decrease in organic matter content with soil depth. Therefore, the depletion of organic matter as a result of intensive cultivation has reduced the CEC under the natural fallow and cultivated lands surface horizons respectively.*
Keywords*: Pasture, Land use systems, Soil quality, Soil profile, Horizon*

I. Introduction

The attainment of soil management to maintain soil quality depends on the knowledge of how soils respond to agricultural practices. Therefore, recent interest in evaluating the quality of soil resources has been stimulated by increasing awareness that soil is a critically important component of the earth’s biosphere, functioning not only in the production of food and fiber but also in the maintenance of environmental quality (Doran and Parkin, 1994). On the other hand, feeding the ever-increasing human population is most challenging in developing countries because of soil degradation. For instance, in Sub-Saharan African countries, soil fertility depletion is the fundamental biophysical cause for declining per capita food production (Sanchez et al., 1997). This challenge will continue as population pressure increases and degradation of soil resources is aggravated. Reversing this trend lies in the enhancement of sustainable development of the agricultural sector; however, the basis of sustainable agricultural development is good soil quality. Hence maintenance of soil quality is an integral part of sustainable agriculture.

The rate of soil quality degradation depends on land use systems, soil types, topography, and climatic conditions. Among these factors, inappropriate land use aggravates the degradation of soil physicochemical and biological properties (Singh et al., 1995; Saikhe et al., 1998; He et al., 1999). In line with these, Maddonni et al. (1999) reported that land use affects basic processes such as erosion, soil structure and aggregate stability, nutrient cycling, leaching, carbon sequestration, and other similar physical and biochemical processes.

The contribution of man as a factor of soil formation in relation to Adamawa State is very glaring, particularly in Southeastern part of the State. Overgrazing, constant bush burning, extensive tree felling for timber, fuel wood and continuous land cultivation have contributed negatively to soil formation. The soil morphological characteristics reflect the environment and are used to group soils into use-oriented units, or to classify soils in accordance with the processes involved in their formation.

In Adamawa State, soil degradation due to inappropriate land use system is threatening the livelihood of thousands of people. Similarly, large areas of land at the study area, Southeastern Adamawa State are been abandoned due to soil fertility depletion as the result of continuous cultivation. In order to make sound decisions regarding land use, knowledge of specific properties related to soil functioning under different land use systems are necessary. Dynamic properties such soil organic matter (SOM), cation exchange capacity (CEC), total Nitrogen (TN), soil reaction and texture are sensitive to land use practices and can provide valuable information about important soil processes such as nutrient cycling, decomposition and formation of SOM, and overall productivity potential (Zulfiia et al., 2012). Expected changes in global climate, land uses, population distribution, and water availability create challenges to meet societal needs for ecosystem services that agricultural, forestry, and pasture lands provide.

Information about soil properties for this region will increase the knowledge base regarding how typical land uses in the region impact the functionality of the soil ecosystem. Although, the knowledge of important soil quality indicators is vital for replenishing and maintaining soil fertility, little information is available in southeastern Adamawa soils. Therefore, the study was conducted to assess the important soil quality indicators (OC, pH, TN, P, CEC and soil texture) under different land use systems (Cultivated land, Undisturbed natural forest, Gmelina plantation, natural fallow land, and Pasture land) to provide base line data for future research.

The Study Area

Adamawa State lies between latitudes 8^0 N and 11^0 N longitude 11.5^0 E and 13.5^0E of the equator. Sharing International boundaries with Cameroon Republic in the eastern border, it is bounded by Taraba State in the South and West, Gombe State in the North West and Borno State in the North (Adebayo and Tukur, 1999). The State covers land area of 39,742.12 Km^2 and with an estimated population of 3,168,101 people according to 2006 National census (Adamawa State Diary, 2009).

Majority of the people in Adamawa State are farmers. Crops cultivated include Groundnut, Cotton, Maize, Yam, Cassava, Guinea Corn, Millet, Beans, Sweet Potato and Rice. Cattle rearing are a major occupation, while village communities living on the banks of River Gongola and Benue in the State engage in fishing and dry season production of crops like Tomato, Onion, Pepper, Amaranthus, Okra, Garden egg, Rice, Maize and Melon using wash bore and tube well irrigation with water pumps.

Major livestock species are Cattle, Sheep and Goats with Poultry species reared all over the State (Tukur and Ardo, 1999). The dominant system of livestock management is nomadic herding (Tukur and Ardo, 1999).

Climate

The dominant influence on the climate pattern in Nigeria is the annual movement of the inter-tropical front from North to South across the country. In general the movement results in the division of the year into two principal seasons, wet and dry, the length of which, relative to each other, is related to latitude. During the wet season, deflected rain-bearing trade winds blow from the southwest of the Atlantic, while in the dry season, a dry often dust laden winds blows from the northeast off the Sahara. There is therefore a general picture of rainfall decreasing and the dry season increasing in length and severity in a northerly direction. This simple pattern of east-west climatic zone is however distorted by the influence of highland areas, with typically an increasing in rainfall on the crests and to windward and a rain shadow to leeward. The major vegetation formation of the State include, the Southern guinea savanna, comprising of Toungo, Ganye, Jada, Mayo-Belwa and some parts of Fufore local government areas. The Northern guinea savanna includes Lamurde, Numan, Guyuk, Shelleng, Song, Gombi, Maiha, Hong, Mubi and some parts of Fufore local government areas. The Sudan savanna zone covers Madagali, Michika and some parts of Mubi and Hong local government areas.

Rainfall

The mean annual rainfall of Adamawa State ranges from 700mm in the northwest part of the State to 1600mm in the extreme Southern part of the State.. Rainfall distribution is unimodal, with much of the rain falling between May and October. The wettest months are August and September (Adebayo, 1997). The rainy season is followed by a long dry season. During this period, the area comes under the strong influence of the hammattan (winds that originate in the Sahara and blow across the Sahel region). The hammattan are very dry, and, as a result, humidity may be as low as 10–20% during the dry season.

Temperature

The temperature characteristics are typical of the West African savannah climate. Temperature in this climate region is high throughout the year because of high radiation income, which is relatively evenly distributed throughout the year (Adebayo and Tukur, 1999). Maximum temperature can reach 40^{o}C particularly in April while minimum temperature can be as low as 18^{o}C between December and January. The mean monthly temperature ranges from 26.7^{o}C in the south to 27.8^{o}C in the northeastern part of the State (Kowal and Knabe, 1972).

Humidity

Humidity follows the simple relationship with the change of the seasons. It is generally lowest in the dry season about 20% and is very high in the wet season about 80% in August. An increase in the humidity always precedes the onset of the rains in April.

Wind

With the southerly movement of the inter-tropical convergence zone from October to April, the wing blows consistently from the north or more often the Northeast. During this period the area is exposed to very dry winds blowing from the Sahara, the hammattan, often carrying a thick haz of wind borne, conspicuously diatomaceous dust (Carroll and Hope, 1970). From May throughout the summer it rains until September, the direction is reversed and the wind blows mainly across the area from the southeast.
This area is richly supplied with a network of river and streams. River Benue and Yedsarem form the major rivers and joined by numerous tributaries. The topography is generally flat, becoming undulating and hilly toward the northeast.

Vegetation

Varied vegetation types largely controlled by rainfall distribution as affected by topography characterize Adamawa State. The identifiable vegetation types in the State include the southern guinea savanna, the northern guinea savanna and the Sudan savanna. The guinea savanna vegetation is the most extensive vegetation type in the State. It stretches from the Taraba River in the South to River Yedzeram in the Northern part of the State. In the more humid southern part of the State, the Southern guinea savanna has an interspersion of thickets tree savanna which gradually changes to the Northern. *Daniella olivera, Diospryos ellioti, Ceibe pentandra, Nauclee latifolia, Bombax costatum, Parkia biglbosa* and other characterize the Southern guinea savanna. The most abundant grass species include *Andropogon gayanus, Hyparrhenia panicum* and *ctenium*. The Northern guinea savanna is characterized by *Afzelia africana, Viterllaria paradox, Terminalia laxiflora, Annona senegalensis* woody species with *Andropogon, Pennisetum* and *Hyparrhenia* as the grass undergrowth (Adebayo and Tukur, 1999). *Acacia senegal, Acacia nilotica, Adonsonia digitata* and *Terminalia avicenniodes* woody species characterize Sudan savanna vegetation found in the north and eastern parts of the State. The more abundant grass species include *Aristida longiflora, Cenchrus biflorus, Pennisetum pedicellatum* and *Eragrostis* spp.

Land Use Systems and Soil Sampling

Five land use systems were considered for the study. These were the cultivated land, natural fallow land, Gmelina plantation, pasture land and undisturbed natural forest land. One soil profile was opened from each land use system for field descriptions and laboratory analysis in 2012/2013. The cultivated land and the natural fallow land have been under intensive cultivation with both mechanized and traditional tillage equipment for over three decades. The natural fallow land was left for about seven years without any crop cultivation. Nevertheless, some activities such as livestock grazing and annual bushfire were observed on the land. The soil profile representing the undisturbed natural forest land is located at 08 06′ 18″ N and 012 02′ 30″ E, the cultivated land was at 08 08′ 28″ N and 012 03′ 78″ E, pasture land at 08 54′ 24″ N and 012 10′ 81″ E, plantation at 08 64′ 43″ N and 012 13′ 30″ E and natural fallow land at 08 64′ 39″ N and 012 13′ 26″ E. Soil samples were collected from each soil profile and horizons of the different land use systems. The soil profile description and horizon designation were determined according to FAO guidelines (Anon, 1990). Soil color (dry and moist) was determined using the Munsell color chart (Munsell Color Company, 1975).

Soil Physicochemical Analysis

The soil samples collected from each horizon were air dried and passed through 2-mm sieve for the determination of most of the soil quality indicators. Particle size distribution was determined by hydrometer method. The pH of the soil was measured potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5, soil: water ratio. The exchangeable bases were extracted with 1M Ammonium acetate at pH 7, whereas cation exchange capacity (CEC) was determined according to Chapman (1965). The exchangeable acidity was determined by saturating the soil samples with 1N KCl solution and titrating with NaOH. The organic carbon was determined by the wet digestion method. Total N was determined with Kjeldahl method (Jackson, 1958). The available P was determined with Bray I methods (Bray and Kurtz, 1945).

II. Results And Discussion

Soil Morphological Characteristics

The results of morphological characteristics of the land use systems are presented in Table 1. The soil depths of the different land use systems varied. The deepest soil profile was observed in the natural fallow land followed by the Gmelina plantation, pasture land, undisturbed natural forest then the cultivated land respectively. This implies that soil depth is one of the important soil quality indicators in determining the response of soil to intensive land use. The variation in soil depth under the different land use systems is most likely attributed to the variation in micro-relief and slope that influence soil formation and development through its effects on erosion and infiltration.

Similarly, there were color variations among the different land use systems at the soil horizons. These variations were attributed to differences in soil organic matter contents, which were highly influenced by soil organic matter in the upper soil horizon that significantly decreased with depth and was highly affected by land use as presented in Table 2-6. The dark yellowish brown color in subsurface horizons of the different land use systems is probably due to the presence of Fe oxides in the soils. There were also differences in soil structure among the different land use systems. These could be due to the different land use systems the lands were subjected to, such as animal grazing and intensive cultivation with tillage machinery. This finding is in agreement with the work done elsewhere. For instance, Saini and Grant (1980) reported that intensive tillage practices affected soil structure.

Soil Physical Properties

There were textural variations among the different land use systems particularly in the surface horizons. In the subsurface horizons, however, slight differences were noticed. The clay percentage increased whilst the sand decreased from the surface to the subsurface horizons in all land use systems (Table 1). Texture is an intrinsic soil property, but intensive cultivation could contribute to the variations in particle size distribution at the surface horizons of the cultivated and the natural fallow lands. This could be due to the removal of soil particles through sheet and rill erosion, and mixing of the surface and subsurface horizons during deep tillage activities.

Soil Chemical Properties

In all the upper soil horizons of the different land use systems, there was variation in soil reaction (pH) from moderately acid in the undisturbed natural forest, cultivated land, pasture land, natural fallow land to slightly acid in the Gmelina plantation. The subsurface horizons also show some slight variation like in the case of the upper horizons. Soil pH was significantly affected due to different land use systems and weatherable minerals. The results are in agreement with the reports of many research findings (Baligar et al., 1997; Blamey et al., 1997). There was great variation in cation exchange capacity (CEC) of the soils under the different land use systems both in the upper and subsurface soil horizons (Table 1). The CEC decreased almost inconsistently from the surface to the subsurface horizons in the different land uses throughout the soil profiles. The decrease in CEC with depth is attributed to a decrease in organic matter content. Therefore, the depletion of organic matter as a result of intensive cultivation has reduced the CEC under the natural fallow and the cultivated lands and this is in concurrence with several previous findings (Mesfin 1980; Gao and Chang, 1996).

Exchangeable K varied markedly due to differences in land use systems. The highest exchangeable K was recorded from the surface horizon of the natural fallow land, followed by the pasture land and Gmelina plantation as compared to the undisturbed natural forest and the cultivated lands surface horizons. Similarly, the exchangeable K in the sub-surface horizons showed a significant variation in all the land use systems (Table 1). Many research results supported the findings, since weathering, intensive cultivation and use of acid forming inorganic fertilizers on acid soils affect the distribution of K in the soil systems and enhance its depletion (Baker et al., 1997; Saikh et al., 1998).

Similarly, the exchangeable Ca concentration in the upper horizon of the pasture land, undisturbed natural forest and Gmelina plantation lands were higher than that of the natural fallow and the cultivated lands, respectively. The distribution of exchangeable Ca was tended to decrease from surface to subsurface horizons for the undisturbed natural forest and cultivated lands, whereas it tended to increase and decrease for the other land uses (Table 1). The concentration of exchangeable Mg was highest in the pasture land, Gmelina plantation and natural fallow lands and decreased from the sub-surface to surface horizons, but increased for the undisturbed natural forest and the cultivated lands surface horizons. The increasing trend of Ca and Mg concentration with depth in these lands could be due to the leaching effect and organic matter degradation. This is in agreement with the findings of different researchers who indicated that continuous cultivation and use of acid forming inorganic fertilizers deplete exchangeable Ca and Mg (Saikh et al., 1998; He et al., 1999; Aitken et al., 1999).

The organic carbon (OC) and the total N (TN) was highly affected by different land use systems particularly in the surface horizons. The OC and the total N decreased consistently from the surface to the subsurface horizons in all of the land use systems (Table 1). The surface horizons of the undisturbed natural forest, Gmelina plantation and the pasture land recorded the highest contents of OC/TN compared to the crop and natural fallow lands. This implies that intensive cultivation significantly deplete OC and TN. Some authors also reported similar trend of OC and TN depletion as a result intensive land use and cultivation (Solomon et al., 2002; Wakene, 2001) with traditional oxen plowing and mechanized tillage machinery.

The highest concentrations of available P was recorded in the Gmelina plantation, followed by the undisturbed natural forest, and the natural fallow lands, then the pasture and cultivated lands in the surface horizon. The available P was observed to consistently decrease with increase in soil horizon depth of all the different land use systems. This result is in line with the findings of Ransmussen and Douglas (1992) and Whitebread et al. (1998). The low available P in the other land use systems could be due to either continuous removal of P by crop plants or due to the inherent P deficiency of the soils in this region and/or the presence of P in unavailable forms as presented in Table 1.

III. Conclusion

Most of the important soil quality indicators were significantly influenced by different land use systems, particularly at the surface horizon. The OC, soil pH, CEC, total N, available P, and exchangeable bases, were affected due to intensive cultivation and use of acid forming inorganic fertilizers. The undisturbed natural forest land and Gmelina plantation were superior in most of the soil quality indicators. In general, the continuous intensive cultivation and use of acid forming inorganic fertilizers on acid soils for crop production without appropriate soil management has degraded most of the important soil quality indicators. Therefore, reducing intensive cultivation, and integrated use of inorganic and organic fertilizers could replenish the degraded soil quality parameters for sustainable agricultural production and productivity in the study area.

Table 1: Physico-chemical properties of the various profiles of the study areas

Site	Hor.	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture	pH 1:1in H_2O	EA (AL^++H^+)	EC µs/cm	TOC (%)	Total N (%)	Avail. Total P(g/kg)	Exch. Cations (Cmol(+)/Kg soil)				
													Ca	Mg	K	Na	CEC
Natural Forest	AB	0-17	58.92	29.64	11.44	SL	5.76	0.2	17.33	1.99	0.30	18.1	14.1	8.4	0.66	0.73	23.9
	CA	17-30	51.84	30.72	17.44	L	5.25	0.2	10.96	1.36	0.11	6.6	10.4	6.0	0.57	0.74	17.72
	GY	30-67	39.84	18.72	41.44	CL	5.3	0.3	15.34	0.92	0.08	2.8	5.9	5.2	0.56	0.76	19.13
	NG	67+	34.2	19.64	46.16	CL	5.69	0.3	10.51	0.66	0.05	2.4	2.5	6.0	0.84	0.71	10.05
Crop Land	AP	0-11	39.28	42.92	17.80	L	5.8	0.1	17.13	1.46	0.10	6.3	6.2	6.8	0.28	0.76	13.38
	Br	11-17	31.28	33.28	35.44	CL	5.09	0.3	25.6	1.10	0.09	4.7	3.4	6.2	0.62	0.33	10.98
	JJ	17+	21.84	32.36	45.80	CL	5.08	0.3	25.6	0.81	0.03	2.8	2.1	6.4	0.56	0.30	9.39
Grazing Reserve	Ag	0-18	46.56	34.00	19.44	L	5.61	0.2	19.53	1.88	0.31	6.9	15.3	11	0.92	0.79	27.53
	Bc	18-44	31.28	33.28	35.44	CL	5.77	0.3	23.4	1.23	0.12	5.3	14.6	9.4	0.93	0.44	25.72
	G	44-68	55.84	6.72	37.44	SC	5.17	0.2	11.7	0.78	0.03	3.9	15.0	4.8	0.95	0.57	21.19
	R	68+	39.84	18.72	41.44	CL	5.25	0.2	29.4	0.52	0.04	2.3	16.0	10.4	1.38	0.30	28.35
Plantation	AC	0-10	73.28	15.28	11.44	SL	6.36	0.2	16.63	1.96	0.31	19.9	15.5	6.2	0.87	0.20	23.31
	Bs	10-32	64.20	20.36	15.44	SL	6.45	0.2	14.6	1.29	0.14	16.4	6.4	11.6	0.82	0.33	19.02
	C2	32-71	44.92	17.64	37.44	L	6.18	0.2	20.5	0.96	0.06	6.5	12.0	5.4	0.46	0.71	18.19
	2R	71-131	34.20	19.64	46.16	CL	5.88	0.4	17.7	0.65	0.04	2.5	13.4	7.6	1.04	0.34	22.75
	Yc	131+	37.28	16.92	45.80	CL	5.74	0.2	15.4	0.42	0.04	1.3	13.1	10.8	0.97	0.31	25.22
Fallow Land	AP	0-22	71.28	19.28	9.44	SL	5.96	0.1	21.4	1.46	0.21	14.4	10.4	5.0	1.00	0.72	16.70
	B1	22-48	65.28	15.28	19.44	SL	5.76	0.1	34.5	0.83	0.14	14	10.8	6.0	1.02	0.71	18.55
	C3	48-114	63.84	14.72	21.44	SL	5.71	0.2	31.1	0.51	0.06	3.3	9.8	10.2	0.97	0.31	21.69
	D2	114-149	44.92	17.64	37.44	L	6.35	0.3	6.31	0.34	0.05	2.7	13.0	9.0	0.61	0.34	22.92
	G2	149-179	34.20	19.64	46.16	CL	6.49	0.3	14.22	0.27	0.04	1.6	12.2	8.2	0.66	0.39	21.41
	G3J	179+	31.28	33.28	35.44	CL	5.97	0.2	11.94	0.18	0.02	0.9	11.8	5.2	0.87	0.38	18.26

NB: SL=Sandy Loam, L=Loam, CL=Clay Loam, SC=Sandy Clay

Source: Field and Laboratory Analyses (2013)

Morphological characteristics of the various Soil profiles

Morphological characteristics of the various Soil profiles sunk in the study areas are presented in Table 2-6. All the areas belong to sandstone and shales geology. The drainage of the areas varied from well drained in the undisturbed natural forest, cultivated land, Gmelina plantation and fallow land, to poorly drain in the subsurface layers of the pasture land. The areas fall within the Southern guinea type of vegetation under different land use management.

Table 2: Morphological characteristics of the natural forest profile (Pit 1)

Pedon No.	Horizon designation	Profile depth (cm)	Profile description	Remarks
Pit 1	AB	0-17	Gray (10YR6/1) moist; sandy loam; moderate medium sub angular blocky structure. Slightly sticky and slightly plastic when wet, friable when moist and soft when dry with clear and smooth boundary. Inclusions are many and medium roots with common, fine and many pores.	Flat to gently undulating, well drained medium texture soils. No cropping cultivation restricted as a National park
	CA	17-30	Dark yellowish brown (10YR6/3) moist; loam; moderate medium sub angular blocky structure. Slightly sticky and slightly plastic when wet, very friable when moist and soft when dry. The boundary is gradual and wavy with common and medium roots. Pores common and medium in size.	
	GY	30-67	Light yellowish brown (10YR6/4) moist; Clay loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. The boundary is gradual and wavy with fine and medium roots.	
	NG	67-91	Yellowish brown (10YR5/4) moist; Clay loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. Common distinct mottles, with few fine roots and medium concretion.	

Table 3: Morphological characteristics of the crop land profile (Pit 2)

Pedon No.	Horizon designation	Profile depth (cm)	Profile description	Remarks
Pit 2	AP	0-11	Dark grayish brown (10YR4/2) moist; loam; moderate fine blocky structure. Sticky and plastic when wet, firm when moist and hard when dry with gradual diffuse boundary. Inclusions are many and medium roots with common, fine and few pores.	Flat to gently undulating, well drained medium texture soils. This site is extensively cultivated crops grown include Sorghum, Cowpea, *Arachis hypogea*, Yam and Maize. Grazing of livestock is also carried out.
	Br	11-17	Brown (10YR4/3) moist; clay loam; strong fine prismatic structure. Very sticky and plastic when wet, very firm when moist and very hard when dry. The boundary is gradual and diffuse with few and fine roots. Pores common and medium in size.	
	JJ	17-60	Yellowish brown (10YR5/4) moist; Clay loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry with fine and medium roots.	

Table 4: Morphological characteristics of the grazing reserve profile (Pit 3)

Pedon No.	Horizon designation	Profile depth (cm)	Profile description	Remarks
Pit 3	Ag	0-18	Dark grayish brown (10YR4/2) moist; loam; moderate medium sub angular blocky structure. Slightly sticky and slightly plastic when wet, friable when moist and soft when dry with clear and smooth boundary. Few fine faint mottles. Inclusions are many and medium roots with common, fine and many pores.	Flat to gently undulating, well drained surface horizons. Deep somewhat poorly drained medium texture soils. No cropping cultivation exclusively restricted for livestock grazing.
	Bc	18-44	Brown (10YR5/3) moist; clay loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. The boundary is gradual and wavy with common and medium roots. Common medium distinct mottles Pores few and fine in size.	
	G	44-68	Dark yellowish brown (10YR6/4) moist; Sandy clay; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. Many coarse prominent mottles. The boundary is gradual and diffuse with few and fine roots.	
	R	68-87	Brown yellow (10YR6/6) moist; Clay loam; strong fine prismatic structure. Sticky and plastic when wet, very firm	

			when moist and hard when dry. Few fine faint mottles, with few fine roots and medium concretion.	

Table 5: Morphological characteristics of the plantation profile (Pit 4)

Pedon No.	Horizon designation	Profile depth (cm)	Profile description	Remarks
Pit 4	AC	0-10	Dark gray (7.5YR4/1) moist; sandy loam; moderate medium sub angular blocky structure. Slightly sticky and slightly plastic when wet, friable when moist and soft when dry with clear and smooth boundary. Inclusions are many and medium roots with common, fine and many pores.	Flat to gently sloping, well drained medium texture soils. The site is under Gmelina plantation established 1993.
	Bs	10-32	Brown (7.5YR4/2) moist; Sandy loam; moderate medium sub angular blocky structure. Slightly sticky and slightly plastic when wet, very friable when moist and soft when dry. The boundary is gradual and wavy with common and medium roots. Pores few and fine in size.	
	C2	32-71	Strong brown (7.5YR4/6) moist; Loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. The boundary is gradual and diffuse with common and medium roots. Few and fine pores.	
	2R	71-131	Strong brown (7.5YR5/6) moist; Clay loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. With gradual and wavy boundary. Few fine roots and fine concretion.	
	Yc	131-146	Strong brown (7.5YR5/8) moist; Clay loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. Common and fine roots. Few and fine pores.	

Table 6: Morphological characteristics of the fallow land profile (Pit 5)

Pedon No.	Horizon designation	Profile depth (cm)	Profile description	Remarks
Pit 5	AP	0-22	Dark brown (7.5YR3/2) moist; sandy loam; moderate medium sub angular blocky structure. Slightly sticky and slightly plastic when wet, friable when moist and soft when dry with clear and smooth boundary. Inclusions are many and medium roots with common, fine and many pores.	Flat to gently sloping, well drained medium texture soils. Under natural fallow and livestock grazing.
	B1	22-48	Brown (7.5YR4/3) moist; Sandy loam; moderate medium sub angular blocky structure. Slightly sticky and slightly plastic when wet, very friable when moist and soft when dry. The boundary is gradual and wavy with common and medium roots. Pores common and medium in size.	
	C3	48-114	Strong brown (7.5YR5/6) moist; Sandy loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. The boundary is gradual and wavy with fine and medium roots. Common and medium pores.	
	D2	114-149	Strong brown (7.5YR5/8) moist; Loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. Gradual and diffuse boundary. Common medium distinct mottles, with few fine roots and fine concretion.	
	G2	149-179	Light brown (7.5YR6/4) moist; Clay loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. The boundary is gradual and wavy with fine and few roots. Common medium distinct mottles.	
	G3J	179-200	Reddish yellow (7.5YR6/6) moist; Clay loam; strong fine prismatic structure. Sticky and plastic when wet, very firm when moist and hard when dry. Common distinct mottles, with few fine roots and medium concretion.	

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