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Soil Mechanical Composition and Texture as Indices for On-site and Field Precise Choice of Land Use Type to Adopt

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Authors' contributions

This work was carried out in collaboration between both authors. Author MOE designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft manuscript. Author KIO managed the analysis of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The soils of Agoi-Ibami in central Cross River State of Nigeria were evaluated for their mechanical and textural compositions in the field. The objective was to present to small scale, subsistence farmers, with limited access to external farm-inputs for time consuming and expensive laboratory analysis, soil data for on-site and field land use and management decisions. Three profile pits were sunk, along three well defined and selected toposequences, on three landscape elements of crest, middleslope and valley bottom in three land use types of forest (FS), rubber (RS), and arable (AS). Relevant environmental properties were inventorized and the profiles described in the moist state. Their textures were determined by the feel method in the field among other morphological properties. The field investigation showed the soils to be predominatly loamy soils. After the field investigation, soil samples were collected from the morphogenetic horizons for determination of their mechanical composition in the laboratory to supplement the field investigation. Their loamy textures and mechanical composition inferred from their loamy texture impact unique physical and chemical properties like good water holding capacity, good drainage, fertile and productive soils and good for

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irrigation. Loamy soils exhibit properties intermediate between sandy and clayey soils. Loamy soils are considered best for agricultural production because they hold more water and nutrients than sandy soils and have better drainage, aeration and tillage properties than clayey soils. They have slight plastic and sticky workable properties ideal for crop growth and crop productivity. Therefore knowing the texture of soils and their mechanical composition in the field their properties can be inferred and land use and management decisions can be taken on-site without recourse to expensive and time consuming laboratory analyses which are beyond the capacity of resource poor small-scale and subsistence farmers in developing countries and or sub-Saharan Africa. The land use and management decisions are taken after mutual adaptation and adjustments of the description of the land use and the increasingly known soil qualities in the field.

Keywords: Sand; silt; clay; loam; soils; mechanical composition; texture; indices; land use; choice; laboratory analysis; farm inputs.

1. INTRODUCTION

The mechanical or granulometric composition of soils also known as particle size distribution refers to the various amounts of the different separates in a soil sample. It is used to determine the texture of soils from a textural triangle. While soil texture refers to the proportions of mineral particles or soil separates within the various size classes less than 2mm in diameter. Specifically, the texture of a soil is defined by the percentages on a weight basis of sand, silt and clay. These three major fractions are defined by USDA standards as clay, soil particles <0.002mm in diameter, silt particles ranging in size from 2.00 to 0.05mm in diameter and sands, soil particles ranging from 2.00-0.05mm respectively in diameter. Soils can be placed on one of the twelve textural classes based on the proportions of these different sized particles in a soil. Soil texture is critical for understanding soil behavior and management. The texture of various soil horizons is often the first and most important property to determine when investigating soils on-site. Soil scientist can draw many conclusions from this information because the texture of a soil in the field is not readily subject to change, so it is considered a basic property of soil [1]. Soil mechanical composition and texture are basic aspects of their physical investigation because they are related to certain physical properties of soil such as plasticity, permeability, ease of tillage, fertility, water holding capacity as well as overall soil productivity. Texture also determines the microbiological population of a soil and hence the biological and biochemical reactivity of such soils [2]. The word ‘soil’ describes the unconsolidated mineral and organic material on the earth’s surface that serves as a natural medium for plant growth and a fundamental attribute that determines primary productivity [3]. The mechanical composition and texture of soils, determines to a large extent, the response of soils to various alternative forms of management and their investigation is a pre-requisite for soils occupying any particular landscape to properly classify the soils and make recommendations for utilitarian purposes [4]. The different particle sizes or separates impact certain unique characteristics to the soil that determines management decisions. Sand because of its small specific surface area contributes very little to the water and nutrient retention capacity of the soil. Sand shearing is facilitated because of lack of cohesion, therefore soils predominantly sandy, tend to be highly erosive because of ease of detachment and transportation of the particles. Sand, however, has some favorable effect on the soil by increasing total porosity because of its large size but particularly the proportion of the large pores and these pores are responsible for conduction of water and air in the soil. Silt has larger capacity for holding water by virtue of the larger specific surface. Clay has greater increased specific surface compared with silt and sand. Therefore clay contributes a lot more to the physical reactivity of the soils than silt and sand combined [5]. The mechanical composition of soils, ipso facto soil texture, determines to a large extent the physical and chemical behavior of the soil and is an indicator of the type of management needed for good plant growth [6]. Soils cannot be well managed and conserved unless its characteristics are measured and interpreted by skilled observers. Soil management is the sum total of all tillage operations, cropping practices, fertilizer, line and other treatments conducted on or applied to a soil for production of plants. Soil data analyses and procurement from laboratories is usually rigorous, time consuming, very expensive and beyond the reach of low-income, subsistence, small-scale farmers with limited access to external farm-inputs in developing and or sub-Saharan regions.

Objective: The objective of this study is to present to low income subsistence farmers, in sub-Saharan Africa and or developing countries, without access to external farm-inputs, cost effective, easy and accurate methods for decisions on types of land use to adopt and to avoid expensive, time consuming & rigorous laboratory analyses that are beyond their resources.

2. MATERIALS AND METHODS

2.1 Biophysical Data

2.1.1 Location

The study area is located at Agoi-Ibami in Cross River State. Cross River State lies between Latitudes 5°32` and 4°27`N and Longitudes 7°50` and 9°28`E while Agoi-ibami lies between Latitudes 05°43.27`and 08°32.2`E. [7] (Fig. 1).

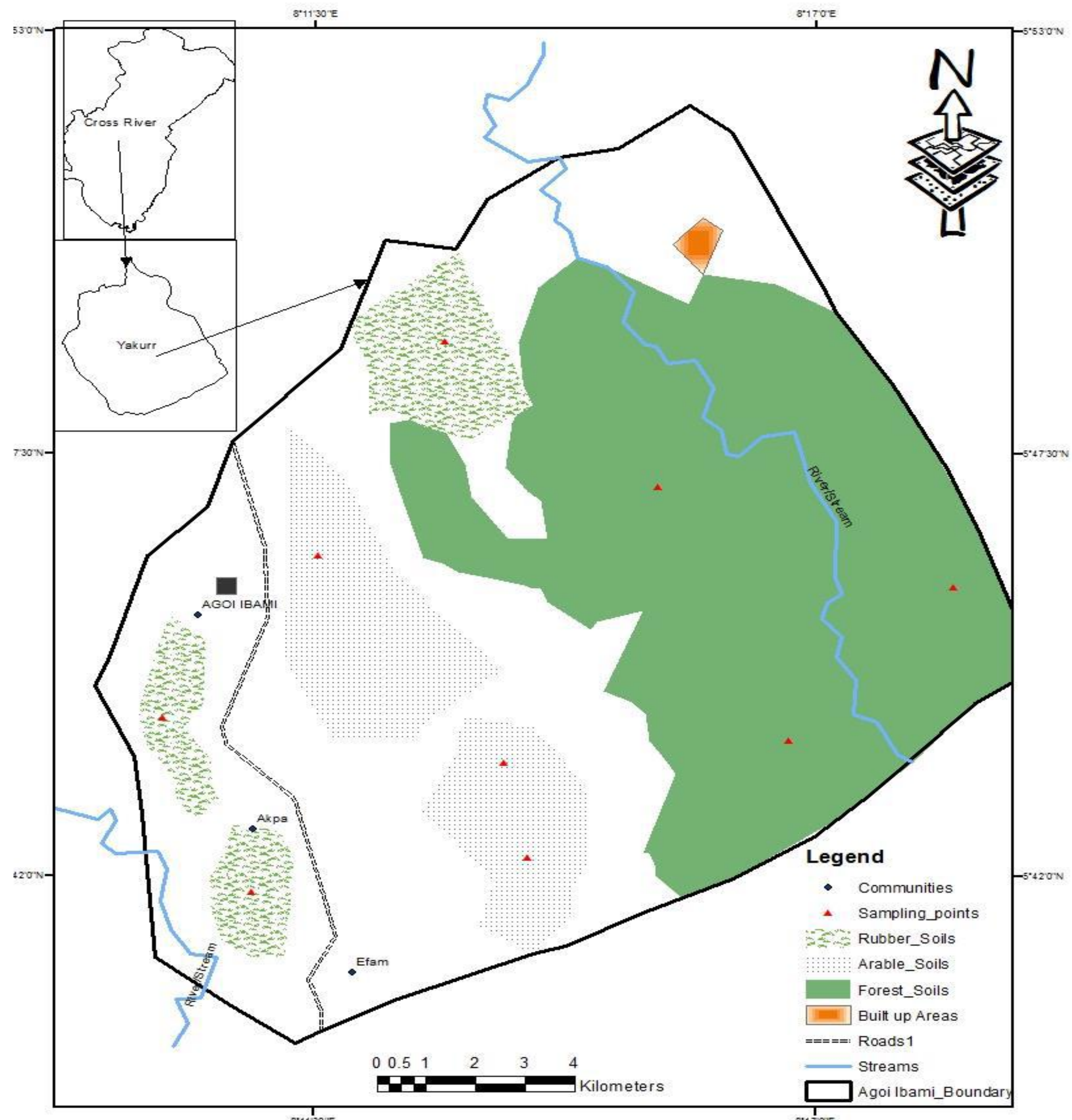

Fig. 1. Map showing the study area
Source: Geographic Information System (GIS) Laboratory, Department of Geography and Environmental Science, University of Calabar

2.1.2 Climate

The climate is tropical humid with a mean annual rainfall (MAR) between 2,500 to 3,000 mm while its distribution is bimodal with a dry season of four months between November and March [4]. The mean, daily and maximum temperatures vary between 21°to 24°C, 23° to 26° to 32°C respectively. The relative humidity varies between 82% and 92% [8].

2.1.3 Geology

The study area is underlain with cretaceous sediments consisting mainly of beds of unconsolidated cross-bedded and false bedded coarse textured sandstones, inter-bedded with layers of fine grained clay and lignite in some areas of Eocene, post middle Eocene and cretaceous ages [9].

2.1.4 Land use/ vegetation

The vegetation is a mosaic of farm lands grown to arable crops like maize, cocoyam, okra etc., forest and plantation tree crops like rubber and oil palm.

2.2 Field Study

Three profile pits were sunk on major landscape elements of Crest, Middleslope And Valley Bottom along well defined and identified Toposequences of three land use types of forest (FS), rubber (RS) and arable cropping (AS) in order to account for differences in soil properties and eliminate catenary differences. Profiles were dug 1.5 x 2.0 x 2.0m deep or to impenetrable layer or water table or whichever was shallower. Relevant environmental properties inventoried included surface characteristics, local relief, slope gradient and class, drainage, depth to water table, vegetation and land use. Soil morphological characteristics recorded were soil depth, color of matrix, texture by feel, structure and consistence. Each profile pit was described in the moist state following the guidelines of Schoeneberger et al. [10]. Thereafter, samples were collected from morphogenetic horizons of each profile pit into well labeled sample bags and taken to the laboratory.

2.3 Laboratory Analyses

The samples were air dried at room temperature for 48 hours and subsequently gently crushed with mortar and pestle and sieved in a 2 mm mesh to obtain fine earth fraction used for laboratory analyses. The following analyses of the less than 2.0 mm fraction were carried out: particle size analysis was determined by the Bouyoucos hydrometer method using sodium hexameter phosphate (vii) as dispersant [11]. Bulk density was determined using metal rings (100 cm^2) to collect undisturbed core samples from various horizons and oven dried at 105^0C to constant weight and bulk density calculated as described by Blake [12]. The pH was determined potentiometrically with a glass electrode pH meter in water at 1:25soil:water ratio [13]. Organic carbon was determined following Walkley and Black wet oxidation method as elaborated by Srikanth et al. [14]. Total nitrogen was obtained by the micro-kjeldhal method outlined by Bremmer and Mulvany [15]. Available phosphorous was determined by extraction with Bray P-1 extractant and phosphorous in the solution determined by the method of Riley and Murphy [16]. Exchangeable acidity was determined by successive leaching of soil with neutral un-buffered INKCl using 1:10 soil: liquid ratio. The amount of H^+ and AL^{3+} in the leachate were determined by the titration method of Maclean [17]. Exchangeable cations were determined with IN ammonium acetate (pH 7.0) using 1:10 soil: liquid ratio. Ca^{++} and Mg^{++} in the filtrate were determined with atomic absorption spectrophotometer (AAS) while Na^+ and K^+ were determined with a flame photometer [18]. Cation exchange capacity was determined by the neutral ammonium acetate (pH 7.0) method described by Chapman [18] while effective cation exchange capacity (ECEC) was calculated by summing up exchangeable bases, multiplied 100 percent and divided by ECEC (IITA, 1979).

2.4 Data Analyses

Data collected in each land use type were subjected to statistical analyses of variance and descriptive statistics with the help of SSPS software.

3. RESULTS AND DISCUSSION

3.1 Mechanical Composition

The data on mechanical composition are presented in Tables 1,2 and 3 and Figs. 2A-1C, Figs. 3A-2C and Figs. 4A-3C for forest soils (FS), rubber soils (RS) and arable soils (AS) respectively.

Table 1. Physical properties of soils under forest at Agoi-Ibami

Elev. (m)	Profile No	Horizon	Depth (cm)	PSD			TC	BD
				Sand	Silt	Clay		Mg/m^3
				←	%	→		
141	FS1	A	0-20	66	20	14	SL	1.25
		Bt	20-68	75	7	18	SL	1.36
		C	68-105	70	8	2	SL	1.38
121	FS2	A	0-15	77	13	10	SL	1.3
		BA	15-56	70	13	17	SL	1.45
		Bt	56-103	65	12	23	SCL	1.46
		C	103-150	65	12	23	SCL	1.46
115	FS3	A	0-20	84	6	10	LS	0.98
		Bt	20-51	64	6	30	SCL	1.2
		Btg	51-89	62	12	26	SCL	1.25
	Surface	Mean		75.7	13	11.3		1.18
		Min.		66	6	10		0.98
		Max.		84	20	14		1.3
		Mean.		67.3	10	22.7		1.37
	Subsurface	Min.		62	6	17		1.2
		Max.		75	13	30		1.46

FS= Forest soil; PSD= Particle size distribution; TC= Textural class; BD= Bulk density; SL= Sandy loam; SCL= Sandy clay loam; LS= Loamy sand

Table 2. Physical properties of soils under rubber at Agoi-Ibami

Elev. (m)	Profile No.	Horizon	Depth (cm)	PSD			TC	BD
				Sand	Silt	Clay		Mg/m^3
				←	%	→		
135	RS1	Ap	0-30	57	32	11	SL	1.42
	Crest	BA	30-68	54	30	16	SL	1.47
		Bt	68-110	47	26	27	SCL	1.55
		C	110-150	17	28	55	C	1.56
86	RS2	Ap	0-20	54	38	8	SL	1.3
	Mid. Sl.	Bt1	20-55	46	23	31	SCL	1.38
		Bt2	55-90	16	19	65	Si CL	1.39
		C	90-150	18	17	65	Si CL	1.45
53	RS3	Ap	0-25	47	46	7	SL	1.05
	Low sl.	Bt	25-90	19	36	45	C	1.4
		Bt2	90-110	16	23	61	C	1.47
	Surface	Ct2	110-145	24	26	50	C	1.49
		Mean		52.7	39	8.7		1.26
		Min.		47	32	7		1.05
		Max.		57	46	11		1.42
	Subsurface	Mean		28.6	25.4	46		1.5
		Min.		16	17	16		1.38
		Max.		54	36	65		1.57

RS= Rubber soils; PSD= Particle size distribution; TC= Textural class; BD= Bulk density; SL= Sandy loam; SCL= Sandy clay loam; Si CL= Silty clay loam; C=Clay

The mean sand, silt and clay values for surface forest soils (FS) are 76.0%(sand), 13.0% (silt) and 11.0% (clay) respectively while the mean subsoil values for same are 67.0% (sand), 10.0% (silt) and 23.0% (clay) respectively. For rubber soils (RS) the mean surface values for same are 29%, 25%, and 46% subsoil respectively. While the mean surface and subsurface values for sand, silt and clay for arable soils (AS) are 70%, 23%, and 70% and 55%, 13% and 32% respectively. Brady and Weil [1] observed that a relatively small percentage of clay is required to engender clayey properties in a soil whereas small amount of sand and silt have a lesser influence on soil behavior. The generalized influence of separates on some properties and behavior of soils are presented in Table 4. Sands and loamy sands are dominated by the properties of sand, for the sand separate comprises of least 70% of material by weight and less than 15% of the material is clay. While clays, sandy clays and silty clays are dominated by characteristics of clays. Brady and Weil [1] however noted that most soils are some type of loam.

Table 3. Physical properties of soils under arable soils at Agoi-Ibami

Elev. (m)	Profile No:	Horizon	Depth (cm)	PSD			TC	BD Mg/m^3
				Sand	Silt	Clay		
				←	%	→		
152	AS1	Ap	0-30	75	19	6	SL	1.15
	Crest	BA	30-49	65	10	25	SCL	1.26
		Bt	49-85	47	9	44	SC	1.3
		C	85-150	46	11	43	SL	1.35
157	AS2	Ap	0-18	68	24	8	SCL	1.3
	Mid. Sl.	BA	18-85	63	5	32	SC	1.35
		Bt	85-125	59	4	37	SC	1.35
		C	125-160	56	3	41	SL	1.4
52	AS3	Ap	0-20	67	26	7	SL	1.03
	Low. Sl.	BA	20-45	58	33	9	SCL	1.15
		Bt	45-96	54	14	32	SCL	1.3
		C	96-150	51	26	23	SCL	1.45
	Surface	Mean		70	23	7		1.16
		Min.		67	19	6		1.03
		Max.		75	24	7		1.3
	Subsurface	Mean		55	12.8	32		1.3
		Min.		46	3	9		1.15
		Max.		65	33	44		1.45

AS= Arable soils; PSD= Particle size distribution; TC= Textural class; BD= Bulk density; SL= Sandy loam; SCL= Sandy clay loam: LS; Loamy sand

Table 4. Generalized influence of soil separates on some properties and behavior of soils[a]

Property/behavior	Sand	Silt	Clay
Water holding capacity	Low	Medium to high	High
Aeration	Good	Medium	Poor
Drainage rate	High	Slow to medium	Very slow
Soil organic matter level	Low	Medium to high	High to medium
Decomposition of organic matter	Rapid	Medium	Slow
Warm-up in spring	Rapid	Moderate	Slow
Compactibility	Low	Medium	High
Susceptibility to wind erosion	Moderate (high if fine sand)	High	Low
Susceptibility to water erosion	Low (unless fine sand)	High	Low if aggregated, high if not.
Shrink swell potential	Very low	Low	Low
Suitability for tillage after rain	Good	Medium	Poor
Pollutant leaching potential	High	Medium	Low (unless cracked)
Ability to store plant nutrients	Poor	Medium to high	High
Resistance to pH changes	Low	Medium	High
Sealing of ponds, dams and landfills	Poor	Poor	Good

[a]Exceptions to these generalizations do occur, especially as a result of soil structure and clay mineralogy. Adapted from: Brady and Weil [1]

3.2 Soil Texture

Soil textural classes for forest (FS), rubber (RS) and arable soils (AS) are presented in Tables 1, 2 and 3 respectively. Soil texture is the relative proportions of various soils separate (sand, silt and clay) in a soil [5]. Three broad and fundamental groups of soil textural classes recognized are sands, loams and clays from which each groups specific textural class names have been derived [19] (Table 5)

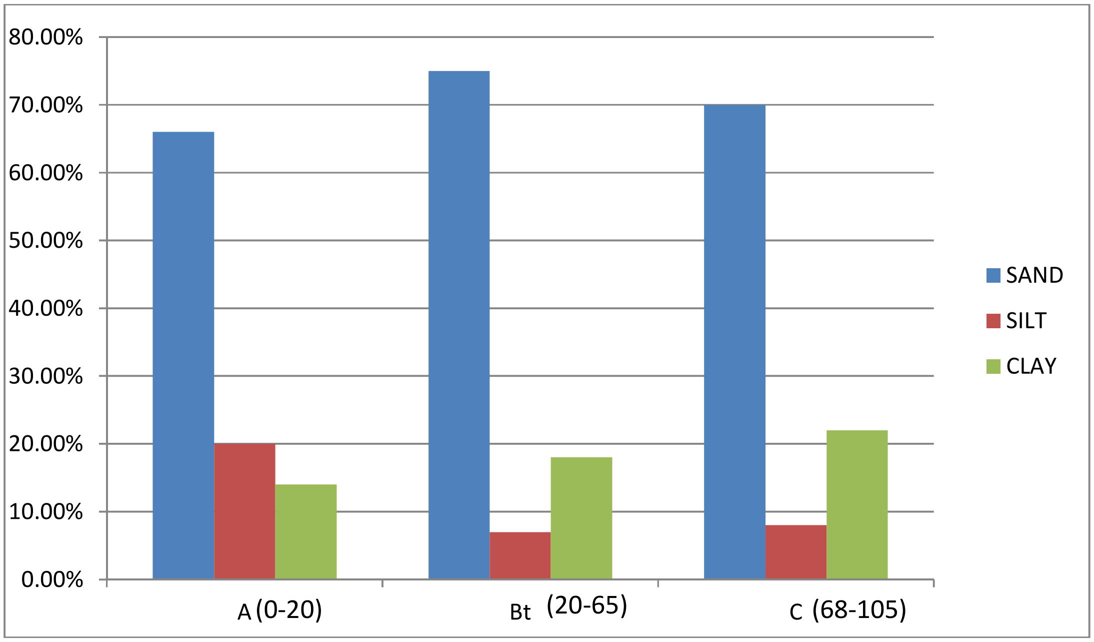

Fig. 2A. FS1 Horizons/Depth (cm) (Crest)

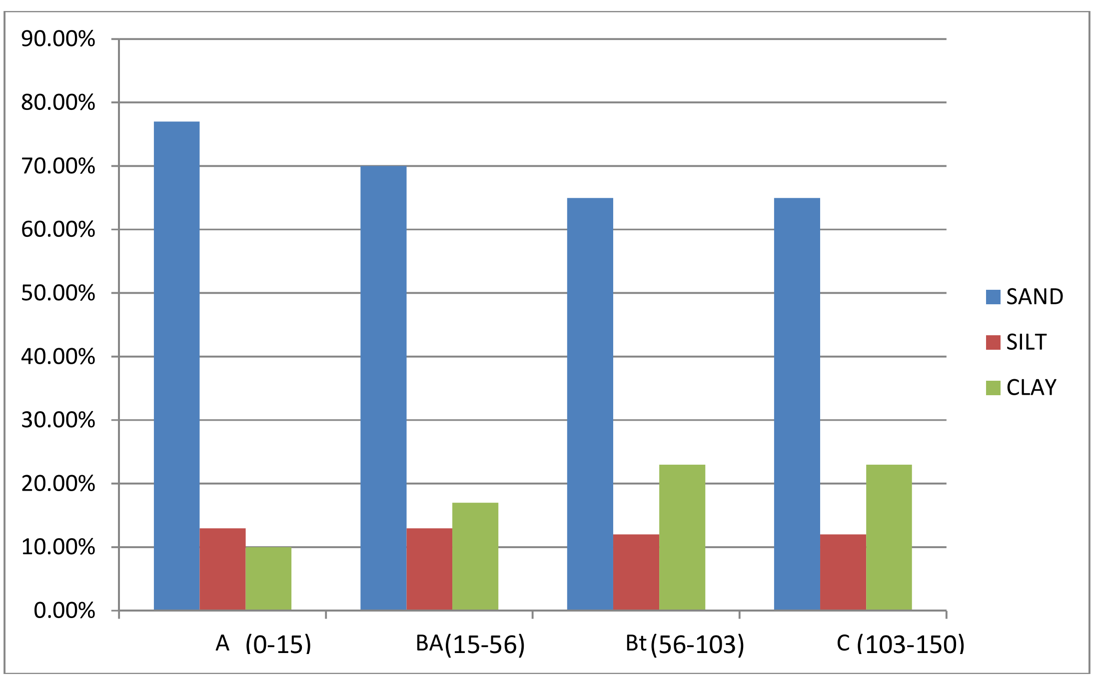

Fig. 2B. FS2 Horizons/Depth (cm) (Middleslope)

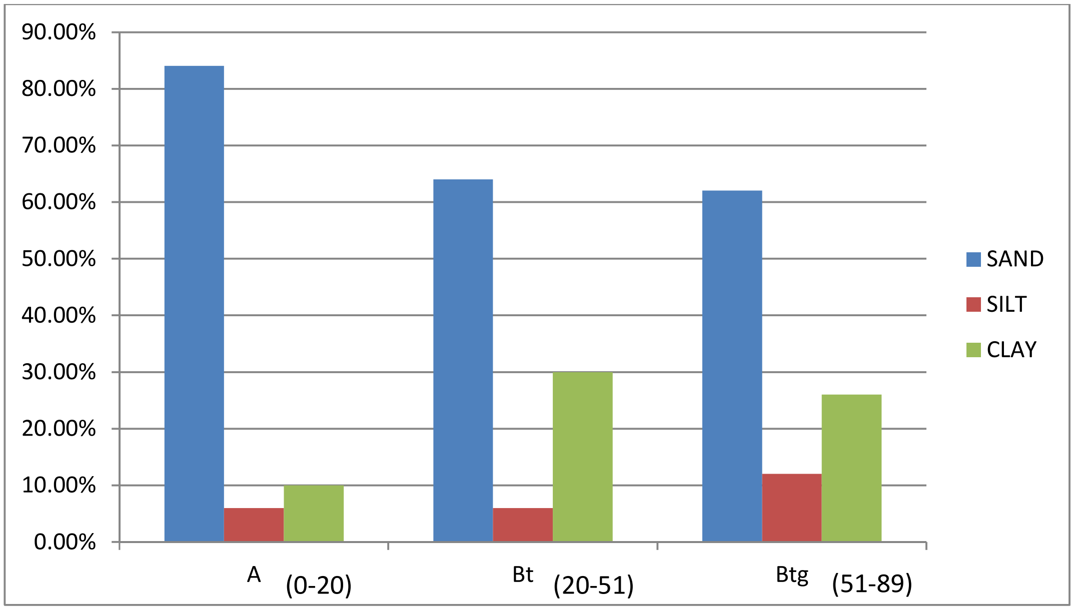

Fig. 2C. FS3 Horizons/ Depth (cm) (Valley bottom)

Fig. F2A-F2C. Particle size distribution for forest profile pits (FS1-FS3)

3.2.1 Sands

Sands include all soils in which sand separates make up at least 70% and the clay separates 15% or less the material by weight. These are mostly single grained in contrast with the sticky nature of clays are poor in fertility, dry and low Water Holding Capacity (WHC). Two specific textural classes are recognized (Table 5) i.e. sands and loamy sands. The two sub-classes used are loamy fine sand and loamy very fine sand. The twelve basic classes in order of increasing properties of fine separates are: sand<loamy sand<sandy loam<clay loam<silt loam<silt<sandy clay loam<clay loam<silty clay loam<sandy clay<silty clay<clay [19]. Data for sand is shown in Tables 1, and 3 and Figs. 2A-2C, 3A-3C and 3A-3C.

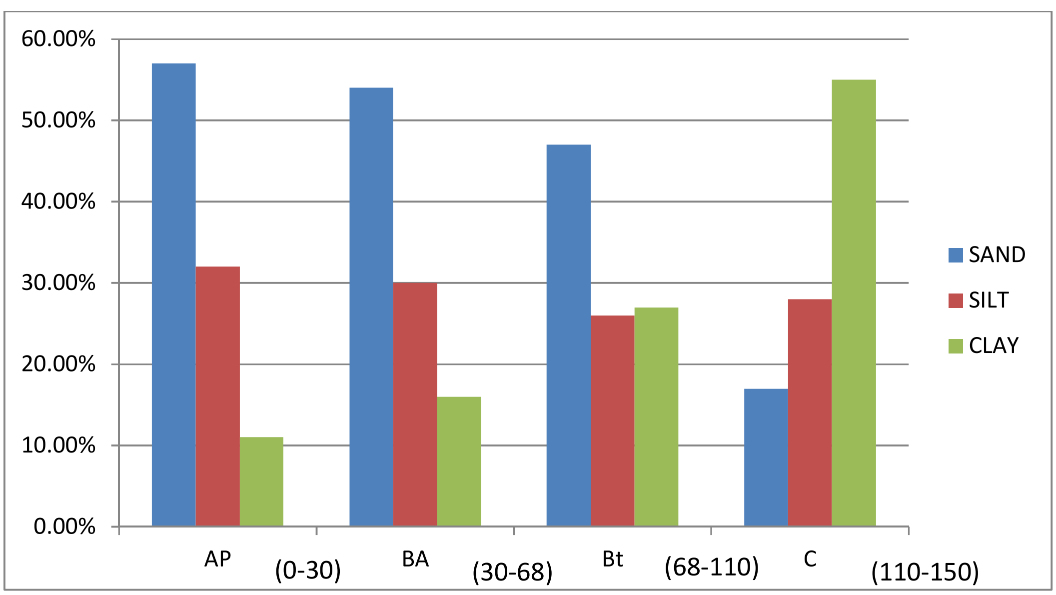

Fig. 3A. RS1 Horizons/Depth (cm) (Crest)

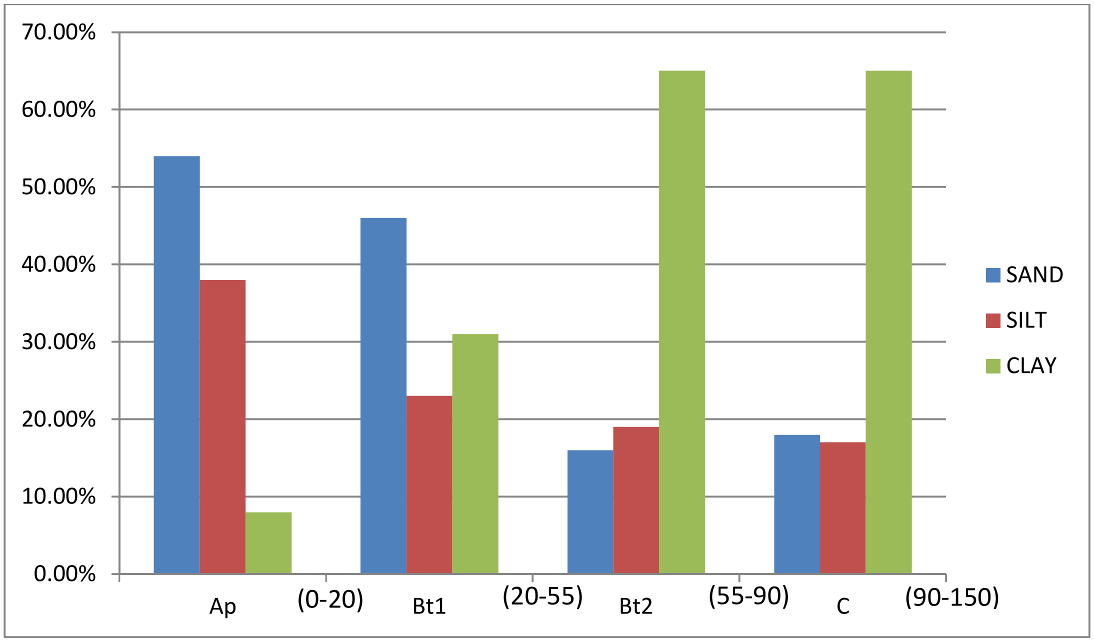

Fig. 3B. RS2 Horizons/Depth (cm) Middleslope

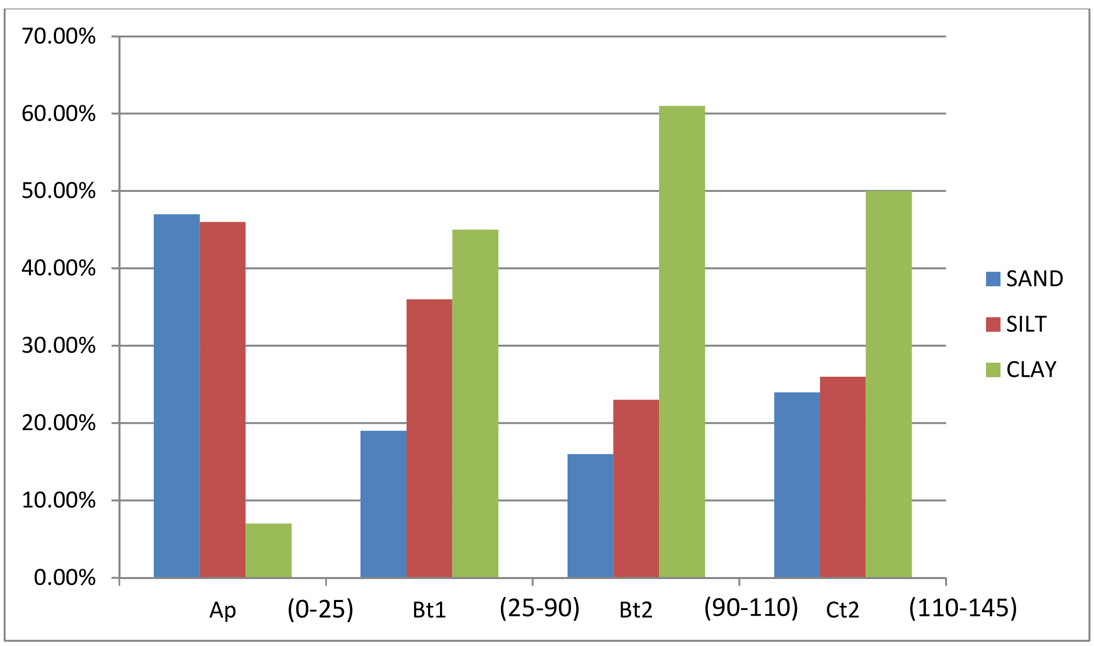

Fig. 3C. RS3 Horizons/Depth (cm) (Valley bottom)

Fig. 3A-3C. Particle size distribution for rubber soils profile pits (RS1-RS3)

3.2.2 Loams

The central concept of a loam may be defined as a mixture of sand, silt and clay particles that exhibits light and heavy properties of these separates in about equal proportions. This definition does not mean that the three separates are present in equal amount. It is roughly a half and half mixture on basic properties so that such soils have more agricultural importance [1]. The classes named are silt loam, silt, sandy clay loam, silty clay loam and clay loam (Table 5).

3.2.3 Clays

These soils contain at least 35% of clay separates and in most cases not less than 40% and the characteristics of clay separates are distinctly dominant. The class names are sandy clay, silty clay and clay (Table 5).

From their mechanical composition, the soils texturally are predominantly loamy soils (3.1), Tables 1, 2 and 3, Figs. 2A-2C, 3A-3C and 4A-4C.

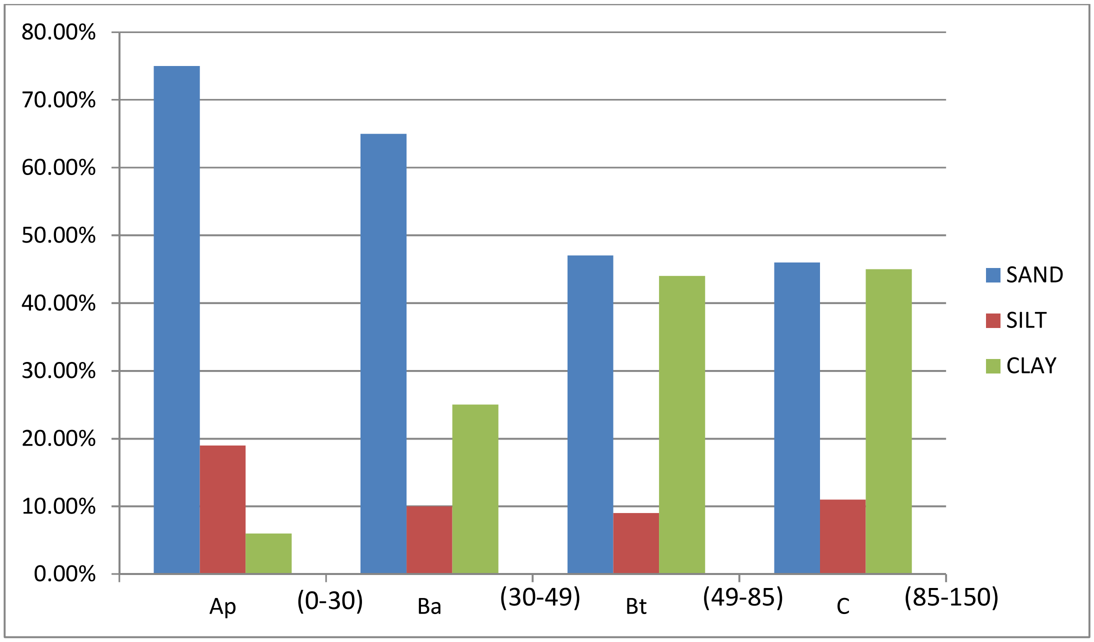

Fig. 4A. AS Horizons/Depth (cm) (Crest)

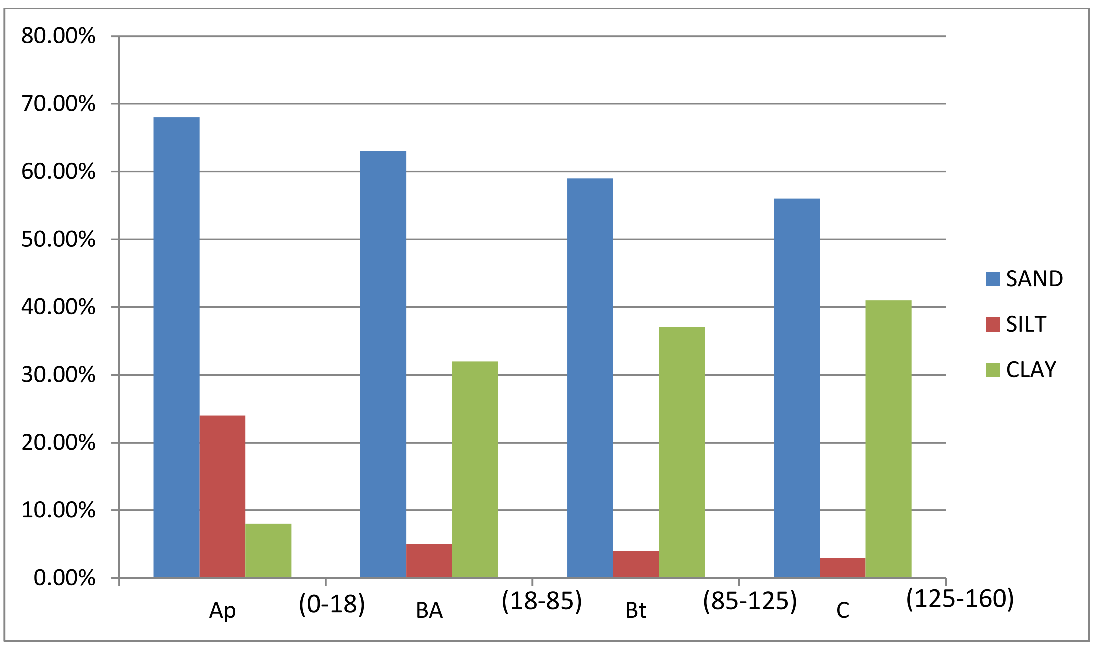

Fig. 4B. AS2 Horizons/Depth (cm) (Middleslope)

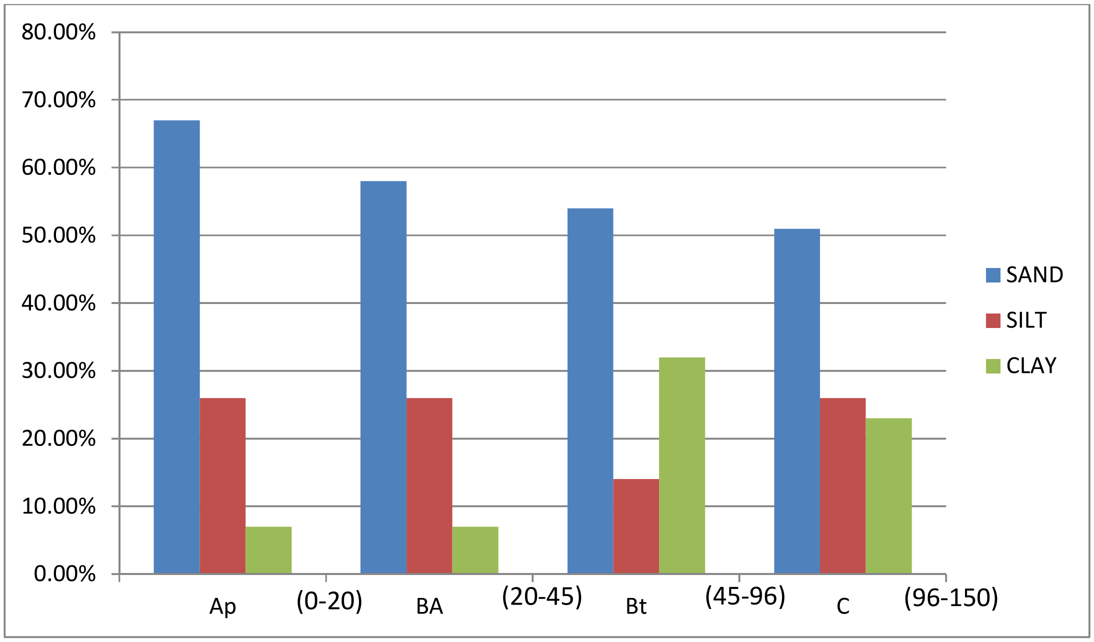

Fig. 4C. AS3 Horizons/Depth (cm)

Fig. 4A-4C. Particle size distribution for arable soils profile pits (AS1=AS3)

Table 5. Classification of soil textural classes (USDA System)

General terms Common Names	Texture	Basic soil textural Class Names
Sandy soils	Coarse.............................	Sand Loamy sands
Loamy soils	Moderately coarse......	Sandy loam Fine sandy loam[a]
	Medium.........	Very fine sandy loam[a] Loam Silt loam Silt
	Moderately fine............	Sandy clay loam Silty clay loam Clay loam
Clayey soils	Fine....................	Sandy clay Silty clay Clay

Adapted from Brady (2014).[a]not included in textural triangle

4. SOILS DATA INTERPRETATION FOR MANAGEMENT DECISIONS

Soil data interpretations predict behavior of soils for specified soil uses and under-specified soil management practices. Soil data interpretations provide users of soil information with prediction of soil behavior to help in the development of reasonable and effective alternatives for the use and management practices that are applied to soils such as irrigation of crop land or equipment use. Predictions of soil behavior results from the observation and record of soil responses to specific uses and management practices: such as seasonal wet soil moisture status. Soil interpretation use soil properties or qualities that directly influence a specific use or management of the soil. For the purpose of the present review, soil interpretation for agricultural ventures is assumed. The forest (FS), rubber (RS), and arable (AS) soils are predominantly sandy loams and sandy clay loams and are therefore classed as loamy soils (Tables 1, 2, 3, 5 and 6). The negligible changes in some soil horizons are because over long periods of time, pedologic processor such as illuviation and mineral weathering can alter the texture of certain soil horizons. Likewise, erosion and subsequent deposition downslope can selectively remove or deposit particles of certain sizes. These processes are corroborated because the soils are Ultisolswhich are very old and highly weathered soils with major pedogenic processes of illuviation and eluviation resulting in an argic horizon diagnostic of Ultisols [20]. The mean surface and subsurface bulk densities for forest (FS) soils were 1.18 and 1.37 Mgm^{-3}, rubber soil mean surface and subsurface bulk densities were 1.26 and 1.5 Mgm^{-3} and arable soils mean surface and subsoil bulk densities were 1.16 and 1.30 Mgm^{-3}. These bulk densities for the three land use types are within the accepted range for loamy soils of 1.4-1.5 Mgm-3 (Table 6) [19]. The properties imparted to the soils based on their loamy texture are that the soils are light to medium (Agricultural Class), fairly retentive of

Table 6. General characteristics/ fertility indices of the soil textural classes (USDA system)

S/N	Textural class	Proportion of: Sand (%)	Silt (%)	Clay (%)	Bulk density (Mgm^{-3})	Porosity (%)	Agric class	Gen. characteristics
1	Sandy soils(coarse) Sands Loamy sands	90 80	<10 10-20	<10 10-15	1.6-1.8	40-33	Very light	Poor dry soils, low water holding capacity.
2	Loamy soils				1.4-1.5	55-40		Fairly retentive of moisture. Good water holding capacity. Good drainage. Fertile soils and productive. Good for irrigation.
	i. Moderately coarse.							
	a) Sandy loam	50-80	Variable.	15-20			Light to medium.	
	b) Fine sandy loam.	40-70		20-30				
	i. Medium							
	a) Very fine sandy loam.	30-60	<50	5-10			Light to med.	
	b) Loam	<50	30-50	10-30			Medium.	
	c) Silt loam	Variable	>50	10-30			Heavy.	
	d) Silt	5-10	80-100	5-10			Heavy.	
	i. Moderately fine	<45	<30	20-30			Light to medium.	
	a) Sandy clay loam	Variable	>40	>10			Heavy.	
	b) Silty clay loam							
	c) Clay loam	20-40	Variable	20-40			Medium.	
3	Clayey soils (Fine)				1.0-1.3	62-57		Difficult to work: poorly drained usually not fit for irrigation but fertile and good for dry crops.
	a) Sandy clay	>45	Variable	30			Light to medium	
	b) Silty clay	Variable	>40	>10			Heavy.	
	c) Clay	<40	<40	>40				

Adapted from: Savalia et al. [19].

moisture, good Water Holding Capacity (WHC), good drainage, fertile soils, productive and good for irrigation. Growth of plant roots and aeration is less on 1.5-1.6 Mgm-3 bulk densities and growth of plants roots is totally stopped at 1.7-1.9 Mgm-3 bulk densities. In terms of bulk densities and their loamy textures the soils are well endowed for agricultural production. Loamy soils exhibit properties intermediate between sand and clay soils. Sandy soils exhibit minimal cohesive and adhesive properties and are so easily deformed that automobiles easily get stuck and on the other hand, clay soils can be so sticky when wet as to make hoeing or ploughing difficult. Loamy soils are considered best for agricultural production because they hold more water and nutrients than sandy soils and have better drainage, aeration and tillage properties than clay soils. They have slight plastic and sticky workable soil ideal for crop growth and crop productivity [19].

5. MANAGEMENT DECISION

After the properties of the soils are determined from their mechanical composition and textures (Tables 1, 2 and 3) and their response to various alternative uses and management predicted, the broad indications of the kinds of land uses and their requirements will need to be reconciled with the precise information on the soil quality. This process of mutual adaptation and adjustment of the description of land use and the increasingly known soil qualities is termed matching. In its simplest form, matching is confirmation of the physical requirements of specific crops, trees or grasses etc. with soil conditions to give a prediction of crop performance. Land use decisions can thus be taken in the field on-site because we know the mechanical composition of the soils ipso facto its texture. The mechanical composition or particle size and hence texture of soils impart certain unique characteristics to soil and are indications of the type of management needed for plant growth and engineering [5,1,19]. From the data on chemical properties for the soils (FS, RS and AS) in Tables 7, 8 and 9 respectively it is observed and corroborated that the loamy soils are well endowed to support a variety of land uses. Since soil management is the use to which we put soils and how we manage the soils under that use a good management option will be to select land-use by confirmation that the physical requirements of specific crops match the soil conditions in the field.

Table 7. Chemical properties of soils under forest of Agoi-Ibami

Elev	Profile No.	Horizon	Depth (cm)	pH	OC	TN	Av. P	EXC, Bases				Exc. A		ECEC	BS
								Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+	Al^{3+}		
					%	%	Mg /kg	←	Cmol/kg				→		%
135	FS1	Ap	0-20	4.8	5.5	0.15	6	1	0.4	0.3	0.1	0.1	0.6	4.4	4.09
	Crest	Bt	20-68	4.6	0.75	0.07	4	0.6	0.25	0.2	0.1	0.1	0.8	5.45	21.1
		C	68-105	4.4	0.4	0.06	2	0.42	0.15	0.15	0.1	0.1	2.3	8.72	9.4
	RS2	AP	0-15	4.9	3.5	0.1	4	0.7	0.25	0.2	0.2	0.2	0.8	5.65	23.9
	Mid. Sl.	BA	15-56	4.7	0.68	0.07	3	0.4	0.15	0.1	0.1	0.1	1.2	9.15	8.19
		Bt	56-103	4.5	0.45	0.05	3	0.4	0.15	0.1	0.1	0.1	5.3	18.05	4.1
		C	103-150	4.4	0.45	0.03	2	0.1	0.1	0.08	0.1	0.1	8.5	23.88	1.5
	RS3	AP	0-20	4.9	4	0.25	8	1.3	0.75	0.15	0.2	0.2	0.75	3.9	61.5
		Bt	20-51	4.7	0.85	0.08	3	0.3	0.4	0.12	0.1	0.1	3.0	3.92	23.5
		Btg	51-89	4.5	0.65	0.05	2	0.2	0.3	0.1	0.1	0.1	2.5	5.9	11.9
	Surface	Mean		4.9	4.33	0.16	6	1	0.47	0.22	0.17	0.17	0.72	4.65	42.1
		Min.		4.8	3.5	0.1	4	0.7	0.25	0.15	0.1	0.1	0.6	3.9	23.9
		Max.		4.9	5.5	0.24	8	1.3	0.75	0.3	0.2	0.2	0.8	5.65	61.5
	Subsurface	Mean		4.5	0.6	0.06	2.7	0.35	0.21	0.12	0.1	3.37	7	10.7	11.4
		Min		4.4	0.4	0.03	2	0.1	0.1	0.08	0.1	0.8	2.7	3.9	1.5
		Max		4.7	0.85	0.08	4	0.6	0.4	0.2	0.1	8.5	15	23.58	23.5

FS= Forest soils; OC= Organic carbon; Total N= Total nitrogen; AP= Available phosphorous; ECEC= Exchangeable cation exchange capacity; BS= Base saturation

Table 8. Chemical properties of soils under rubber at Agoi-Ibami

Elev.	Profile No.	Horizon	Depth (cm)	pH	OC	TN	Av. P	EXC, Bases				Exc. A		ECEC	BS
								Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	H^{+}	Al^{3+}		
					%	%	Mg /kg	←			Cmol/kg			→	%
135	RS1	AP	0-30	4.9	1.93	0.2	3.25	0.75	0.25	0.33	0.1	0.5	3	4.93	29.0
	Crest	BA	30-68	4.8	0.8	0.16	0.4	0.55	0.33	0.25	0.1	1.6	7	9.83	12.5
		Bt	68-110	4.7	0.75	0.09	0.2	0.42	0.4	0.12	0.1	3.4	8.4	12.84	8.09
86	RS2	C	110-150	4.6	0.7	0.06	0.12	2.2	0.45	0.1	0.1	4.5	13	18.75	15.2
	Mid. Sl.	AP	0-20	4.8	1.75	0.21	2.5	0.45	0.15	0.2	0.2	1.4	4.5	6.9	14.5
		Bt1	20-55	4.7	0.63	0.15	0.45	0.3	0.2	0.15	0.1	2	7	9.67	6.93
		Bt2	55-90	4.6	0.33	0.07	0.32	0.25	0.18	0.1	0.1	2.5	8.5	11.55	4.76
52	RS3	C	90-150	4.6	0.27	0.04	0.2	0.25	0.2	0.1	0.1	9.5	12	21.65	3.0
	Lower sl.	AP	0-25	4.9	2.75	0.27	2.55	0.85	0.2	0.35	0.2	0.6	4	6.6	24.2
		Bt1	25-90	4.7	0.5	0.07	1.2	0.64	0.25	0.25	0.1	2.3	8.3	11.84	10.4
		Bt2	90-110	4.6	0.29	0.05	0.6	0.56	0.36	0.15	0.1	2.1	15	18.57	6.3
		Ctg	110-150	4.5	0.21	0.03	0.45	0.37	0.36	0.12	0.1	7.6	12	20,95	4.5
	Surface	Mean		4.9	2.1	0.23	2.8	0.68	0.2	0.29	0.17	0.83	3.8	6.1	22.6
		Min.		4.8	1.75	0.2	2.5	0.55	0.2	0.2	0.1	0.5	3	4.93	14.5
		Max.		4.9	2.75	0.27	3.25	0.85	0.25	0.35	0.2	1.4	4.5	6.9	29.0
	Subsurface	Mean		4.6	0.5	0.08	0.4	0.6	0.3	0.15	0.1	3.9	10	15.1	8.0
		Min		4.5	0.21	0.03	0.12	0.25	0.12	0.1	0.1	1.6	7	9.67	3.0
		Max		4.8	1.2	0.16	1.2	2.2	0.45	0.25	0.1	9.5	15	21.65	15.2

RS= Rubber soils; OC= Organic carbon; Total N= Total nitrogen; AP= Available phosphorous; ECEC= Exchangeable cation exchange capacity; BS= Base saturation

Table 9. Chemical properties of soil under arable at Agoi-ibami

Elev.	Profile No.	Horizon	Depth (cm)	pH	OC	TN	Av. P	EXC, Bases				Exc. A		ECEC	BS
								Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	H^{+}	Al^{3+}		
					%	%	Mg /kg	←			Cmol/kg			→	%
152	AS1	AP	0-30	5	0.72	0.4	11.25	2	1.6	0.1	0.1	0.12	0.5	4.46	85.2
	Crest	AB	30-49	4.9	0.52	0.16	4.32	1	0.9	0.19	0.05	0.54	0.8	3.51	60.9
		Bt	49-85	4.8	0.44	0.12	5.75	2.6	0.5	0.16	0.05	0.72	1.0	4.98	66.8
157	AS2	C	85-150	4.8	0.32	0.06	1.25	2.8	2	0.14	0.04	0.88	1.7	7.51	66.3
	Mid. Sl.	AP	0-18	4.9	0.16	0.04	11.62	2.4	1.4	0.12	0.06	0.15	0.2	4.33	91.9
		AB	18-85	4.9	0.32	0.06	6.5	0.8	1.6	0.24	0.06	0.23	0.3	3.23	83.6
		Bt	85-125	4.8	0.18	0.02	1.75	1.4	1.8	0.14	0.05	0.45	0.5	4.34	78.1
52	AS3	C	125-160	4.8	0.08	0.01	2.75	1.6	2	0.11	0.05	0.56	1.5	5.82	64.6
	Lower sl.	AP	0-20	4.8	0.84	0.3	13.87	3.4	1.5	0.3	0.1	0.24	0.4	5.89	89.9
		AB	20-45	5.1	0.44	0.17	8.75	1.4	1.8	0.2	0.1	0.29	0.5	4.24	82.5
		Bt	45-96	4.8	0.24	0.07	4.75	1.4	1.6	0.15	0.1	0.6	0.7	4.55	71.4
		C	96-150	4.8	0.24	0.05	4.5	1.6	1.8	0.15	0.1	0.85	1.9	6.35	57.5
	Surface	Mean		4.9	0.57	0.19	12.34	2.6	1.5	0.173	0.09	0.17	0.4	4.89	89.0
		Min.		4.8	0.16	0.04	11.25	2	1.4	0.1	0.06	0.12	0.2	4.34	85.2
		Max.		5.1	0.84	0.3	13.87	3.4	1.6	0.3	0.1	0.24	0.5	5.89	91.2
	Subsurface	Mean		4.9	0.31	0.1	4.45	1.6	1.6	0.2	0.1	0.6	0.1	4.1	70.1
		Min		4.8	0.08	0.01	1.25	0.8	0.5	0.11	0.04	0.23	0.3	3.23	57.5
		Max		5.1	0.52	0.17	8.75	2.8	2	0.24	0.1	0.88	1.9	7.51	83.6

AS= Arable soils; OC= Organic carbon; Total N= Total nitrogen; AP= Available phosphorous; ECEC= Exchangeable cation exchange capacity; BS= Base saturation

6. CONCLUSION

The mechanical composition and texture of soils are a basic aspect of their physical investigation. These parameters not only determine to a large extent the physical and chemical behavior as well as the biological potential but also indicators of the type of management needed for good plant growth and for engineering purposes. The soils at Agoi-Ibami were therefore analyzed for their mechanical and textural composition as a case study for evaluating the fast, cost-effective and cheap on-site soil data interpretation and management decisions for small scale, subsistence farmers with limited access to external farm-inputs in developing and or sub-Saharan Africa. It was observed that the soils were predominantly loams and their accompanying properties can be predicted (Tables 4 and 6). Armed with the mechanical and textural composition determined in the field, land use and management decisions can be undertaken on-site during field studies without recourse to rigorous, expensive and time consuming laboratory analysis which are beyond our resource poor farmers. Land use and management decisions are undertaken by mutual adaptation and adjustment of the description of land use and the increasingly known soil qualities imparted by their texture and mechanical composition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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