PROPERTIES AND AGRICULTURAL POTENTIALS OF KULFO SERIES FOR RUBBER CULTIVATION IN A HUMID LOWLAND AREA OF SOUTHWESTERN NIGERIA.

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Abstract

The morphology, physical and chemical properties of Kulfo series in a humid lowland area of Southwestern Nigeria were studied and evaluated for rubber cultivation. The available soil survey report was inspected and the pedon that was correlated with Kulfo series was dug. Soil samples collected from the genetic horizons of the pedon were analyzed using standard procedures. Generally the soil was fairly well drained, deep, absence of rock structure and sandy loam over sandy clay loam. Soil reaction was acidic (pH 5.2 – 5.5), ECEC was low (3.27 – 5.37 Cmol kg^{-1}) and base saturation was high (51.39 – 80.79%). The soil has udic moisture regime, cambic surface horizon and argillic subsurface horizons and was classified as Typic Eutrodept (USDA Soil Taxonomy) or Haplic Cambisol in WRB. A parametric approach was used to rate the suitability of the series for rubber cultivation and was found to be marginally suitable (S3). It was found that the soil had fertility limitations. Kulfo series has good physical properties. Adopting adequate soil management practices will improve the fertility of the soil and sustain it for rubber productivity.

Keywords: Rubber, sustainability, land use, Kulfo series and humid lowland.

Introduction

Dent and Young (1981) had defined soil series as a group of soils with the same parent material under similar external conditions. The soils within a series are essentially homogenous in all pedon characteristics except texture of the epipedon and some site features (Brady, 2002; Soil Survey Staff, 2014). Hence, soils of the same series nevertheless have the same potentials under similar management conditions. Soil series is a simple mapping or a taxonomic unit (Northcote, 1984) and therefore, each series as a rule, is given a name of a locality or feature from where it is first recognized.

Kulfo series was first described by Vine (1952) in Kulfo near Magamo in Niger State of Nigeria and later in Nigerian Institute for Oil Palm Research (NIFOR) in Edo State (Vine, 1956) as a loamy deposit occupying a lower slope as hill wash. Later, Moss (1957) described the series as soils formed in layered pedisediments, well drained, strongly leached without hard pan found on sedimentary rocks of western Nigeria. It is associated with Alagba series but differs by its greater depth of the sandy layers.

Aiboni (1988) observed that Kulfo series represents soils found in middle slope, freely drained, poor nutrient status and loamy sand topsoil with no recognizable diagnostic horizon, which she described as Typic Ustorthents. Ugba and Babalola (1989) noted that the primary roots of oilpalm were well distributed up to 105 cm depth in Kulfo series unlike in Alagba series where the primary roots declined after 60 cm depth. Ogunkunle (1993) described the Kulfo series in NIFOR near Benin as deep, dark brown loamy sand topsoil, deep and well drained and classified it as Typic Dystropept. Fasina *et al.* (2015) working in Ogun State classified the series as Typic Rhodoudalf that was well drained, deep and having loamy topsoil.

Kulfo series is of great agricultural importance in southwest Nigeria. Its poor fertility status, high rate of soil degradation and vulnerability have made the sustainability of the soils more important than ever (Aiboni, 1988; Fasina *et al.* 2015). The characteristics of Kulfo series and indeed, its agricultural potentials are not well documented and in particular in rubber husbandry. Therefore, the objectives of this work were to examine the properties and sustainability of Kulfo series of the study area for rubber cultivation under rainfed condition.

Material and Methods

Study area

The study area is in Rubber Research Institute of Nigeria, Benin City (RRIN) which is located within latitude 6° 08 ′ and 6° 11′ N and longitude 5° 34 ′ and 5° 38′ E. (Figure 1) and 39 m asl. Based on its meteorological data, the area is an Udic soil regime and isohyperthermic soil temperature. The mean total annual rainfall is 2,255 mm with an average total of 110 rainy days annually and could reach up to 140 rainy days in some years. The mean minimum annual temperature is 25^0C while that of the maximum temperature is 29^0C. The sunrays are almost vertical over the area resulting to a daily 3-6 hours of effective sunshine. The area is in the very humid coastal plain ecological zone, and the land is used mainly for rubber cultivation, although other crops such as mangoes oranges and wild oil palms are scattered within the area. What remains of the native vegetation is found in patches near the plantations and around the Okun dam.

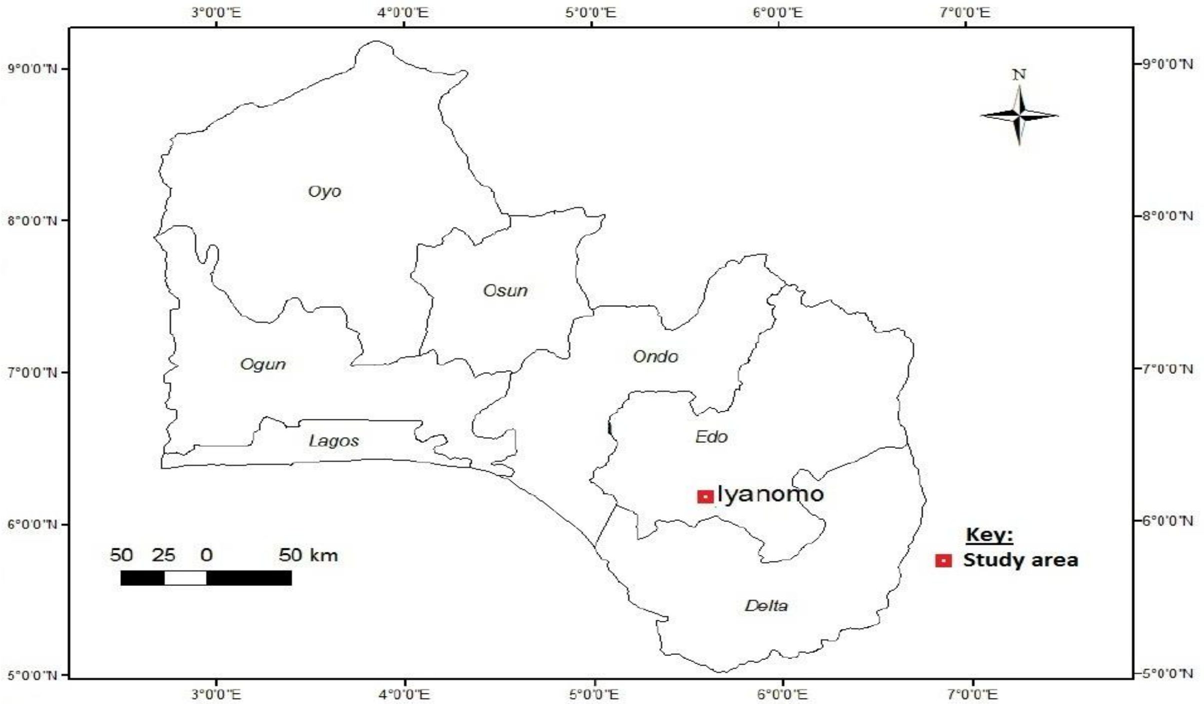

Figure 1: Map of southwestern Nigeria showing the study location.

Field Studies

The available soil survey report by Orimoloye and Akinbola (2013) was inspected in order to get dependable soil details. Pedon that was correlated with Kulfo series was then dug and geo-referenced using Handheld Global Positioning System (GPS) Receiver to co-ordinate the reference point. Morphological characterization was carried out according to FAO (1990) guidelines.

Laboratory Analyses

Soil samples got from the genetic horizons of the pedon were air-dried, crushed and sieved through a 2-mm sieve for laboratory analyses. Particle size analysis was determined by hydrometer method using sodium hexametaphosphate as dispersing agent (Okalebo *et al*, 2002), Bulk density was determined by collecting undisturbed core samples from each horizon using core sampler (216 cm^3). The untrimmed core samples were taken to the laboratory, trimmed with sharp knife and weighed. These were latter oven-dried at 105^0C to constant weight, and the bulk density determined as described by Grossman and Reinsch (2002). Total porosity (%) was derived from the relationship of particle density to the bulk density using the formula: percentage pore space = $(1 - D_b/D_p) \times 100$ Where; D_b = bulk density and D_p = particle density. The average D_p of mineral soils which is 2.65 Mg m^{-3} was used for computation.

Soil pH was determined using a 1:1 soil to water suspension using glass electrode pH meter (Mclean, 1982). Organic carbon was determined by the method of Nelson and Sommers, (1982). While available P was extracted with Bray P-1 solution and measured using the molybdenum blue as indicator by the method modified by Olsen and Sommers (1982). Exchangeable acidity was extracted from a soil solution by 1N KCl (Thomas, 1982) and determined by titration with 0.5M NaOH using phenolphthalein as indicator. Exchangeable acidity was extracted from a soil solution by 1N KCl (Thomas, 1982) and determined by titration with 0.5M NaOH using phenolphthalein as indicator. Exchangeable bases (Ca, Mg, K, Na) were extracted within NH_4OAc buffered at pH 7; K and Na were read on ELE flame photometer and Ca and Mg by Atomic Absorption Spectrometer (AAS). Effective cation exchange capacity (ECEC) was determined by the summation of exchangeable base and exchangeable acidity. Also, the Percentage Base Saturation (BS%) was calculated as the sum of the exchangeable base divided by ECEC multiplied by 100. Available micronutrients were read using AAS and extracted using nitric acid and per-chloric acid for the various micronutrients (Lindsay and Norvell, 1978). Clay activity was calculated by dividing ECEC with the clay content of the soil through the relationship: ECEC × 100/% clay.

Soil Classification and Land Suitability Evaluation

The soils were classified based on the pedon description and laboratory analyses. The criteria used for the classification were the USDA soil Taxonomy (Soil Survey Staff, 2014) and world Reference Base of soil resources (WRB) (FAO/IUSS, 2006). The suitability for rubber production is by the parametric approach (Ogunkunle, 1993) using the limiting characteristics of the pedon which is rated in percentage as follows- None: 100 – 95 (S11), Slight: 94 – 85 (S12), Moderate: 84 – 55 (S2), Severe: 54 – 30 (S3), can be corrected: 20 – 20 (N1) and cannot be corrected (N2). The index of suitability of the pedon is then computed using the equation: IP =A√ B/1OO x C/100 … F/100

Where; IP = index of suitability

A= the overall lowest characteristic rating

B, C…F = the lowest characteristic of each land quality group.

The suitability classes S1(highly suitable), S2(moderately suitable), S3 (marginally suitable), N1 (currently not suitable) and N2 (potentially not suitable) are equivalent to IP (Index of Productivity) value of 100 – 75, 74 – 50, 49 – 25, 24 – 12.5 and 12.4– 0, respectively.

Sustainability of the Soil

The sustainability of the soil was that adopted from Ofem *et al.* (2015) and modified for tree crop production where soil data were combined into a cumulative rating index (C1) and weighting factors for 10 relevant indicators. In rating the indicators, I represented the best land use sustainability with the least limitation and 5 represented the worst land suitability with the highest limitation. Therefore, a relationship between soil sustainability and the cumulative index was established. Thus, soils that are sustainable to the present land use have the lowest cumulative rating index. The cummulatve rating was determined using the rating scheme of Planters Bulletin (1977) and Adaikwu and Ali (2013).

Results and Discussion

Morphology Properties

The soil occurs over younger, less consolidated sandstone, strongly leached non-concretionary, deep (>180 cm) and located towards the middle slope (0 – 6%) in the toposequence. It is coarse, weak with varieties of colours ranging from dark reddish (5 YR 3/2 moist) to strong brown (7.5 YR 4/6 moist) topsoil to yellowish red subsoil (5 YR 5/8 moist) (Table 1). The implication of this is that the hue is a mixture of 7.5 YR with a hue of 5 YR. The soil colour can be related to specific properties of the soil. For instance, the coating of iron oxides gives yellow, brown of red coloration (Soil Survey Staff, 2014). There are few, fine but distinct mottles at a depth of 44 – 90 cm, which are most likely to be due to redox condition in the soil matrix. The horizon boundary characteristics were clear, smooth to diffuse in the B – horizon. Faunal pedoturbation was active in the subsoil (90 – 114 cm) as seen by common ant holes and many fine roots. The soils are friable to loose when moist due to weak cohesion.

Table 1: Morphological properties of the soil.

Horizon	Depth (cm)	Colour (moist)	Structure	Consistency (moist)	Texture (field)	Roots	Mottles	Boundary
Ap	0-18	5 YR 3/2	1,c,sbk	l	LS	vf,m	-	s,c
AB	18-46	7.5YR 4/6	1,c, sbk	fr	SL	vf,m	-	s,c
Bt_1	46-90	7.5YR 5/6	1,m,sbk	fr	SL	f,co	c,f,fe	s,g
Bt_2	90-114	7.5YR 5/8	1,m,sbk	fr	SL	m,fe	-	s,g
Bt_3	114-148	5 YR 4/6	2,f, sbk	f	SCL	m,vf	-	s,d
Bt_4	148-183	5 YR 5/8	2,f,sbk	f	SCL	m,vf	-	-

Key:

structure -1= weak, 2 = moderate, m = medium, c = coarse, cr = crumb, f = fine, sbk = sub angular blocky.

consistency - f = firm, fr = friable.

Texture -LS = loamy sand, SL = sandy loam, SCL = sandy clay loam.

Boundary - S = smooth, d = diffuse, g = gradual, c = clear

Roots – f = fine, vfe = very few, vf = very fine, m = many, co = common

Mottles - f = fine, fe = few.

Physical Properties

Table 2 shows the physical properties of the soil. The distribution of sand fraction ranges from 872 g kg^{-1} on topsoil to 692 g kg^{-1} in the subsoil. This distribution of sand is similar to that of Orlu series (Moss, 1957) but the difference is the lesser depth of the sandy layer in Orlu series. The bulk density is 1.44 Mg m^{-3} in the topsoil and increases in value with depth up till 180 cm. The high values of bulk density at the subsoil may be attributed to low content of organic matter down the profile. The total porosity decreases from 45.66 % in topsoil to 33.58 % in subsoil indicating that there may be come restricted rubber root penetration in the subsoil. The soil texture varied from sandy loam to sandy clay loam. An inspection of the table showed that the texture became finer with depth. This increase in clay with soil depth is an indication of clay migraton by the process of illuviation. Similar results were obtained by Ugwa *et al.* (2005) and Ajiboye *et al.* (2015). The soil cannot be described as clayey because of the dominance of the sand features in the site. The soil therefore, is well drained. There is an irregular depth distribution of the silt fraction.

Table 2: Physical properties of the soil.

Horizon	Depth (cm)	Clay (g kg^{-1})	Silt (g kg^{-1})	Sand (g kg^{-1})	Silt/ clay ratio	Clay activity	Texture	Bulk density (Mg m^{-3})	Total porosity (%)
Ap	0-18	88	40	872	0.45	40.2	SL	1.44	45.66
AB	18-46	228	40	732	0.18	16.8	SCL	1.54	41.88
Bt_1	46-90	288	20	692	0.07	11.4	SCL	1.67	36.98
Bt_2	90-114	308	20	672	0.07	11.7	SCL	1.66	37.35
Bt_3	114-148	288	20	692	0.07	13.8	SCL	1.75	33.96
Bt_4	148-183	288	20	692	0.07	18.7	SCL	1.76	33.58

Key: SL=sandy loam; SCL= Sand clay loam

In general, the silt fraction is low in all the horizons of the Kulfo series an indication of advanced weathering. Silt may have undergone transformation into clays to have been so low in all the horizons. Silt/clay ratio is as high as 0.45 at the epipedon and 0.07 at the endopedon with evidence of clay accumulation. These values show that a lot of weathering is taking place in the topsoil. It also shows the stages of development of the soils. Ayologha (2001) and Ajiboye *et al.* (2015) reported that silt/clay ratio of >0.15 indicated low weathering intensity. Hence, the silt/clay ratio of 0.45 showed that the soil at the surface was the most recent deposits. The clay activity is 40.2 in topsoil and 18.7 at the subsoil. Westin and de Brito (1969) had reported that clay activity is an index of weathering. Also, the soil has some evidence of eluviation (Figure 2), and is weathering within the upper horizon judging from its clay activity. Although the values of silt/clay ratio were lower than those of the clay activity the trend seems similar in all the horizons. Apparently, the clay activity presented a better picture of the weathering index of the Kulfo series.

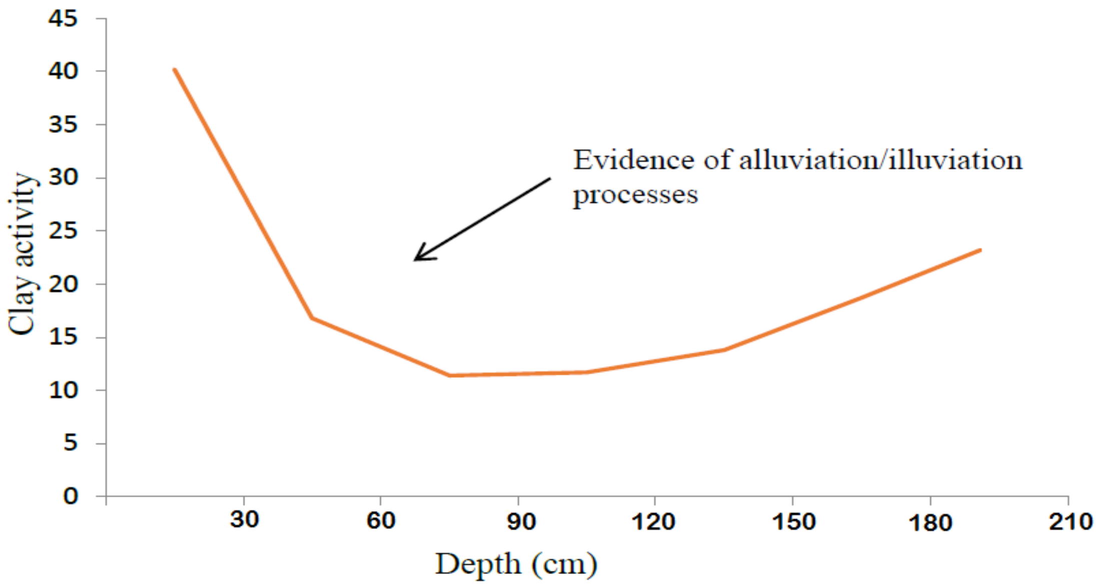

Figure 2: Clay budge in the soil profile

Chemical Properties

Detailed chemical properties of Kulfo series is presented in Table 3. Rubber has been known to tolerate pH of 4.0 to 6.5 (Ugwa *et al.*, 2005). The pH ranging from 5.2 to 5.5 recorded in the series does not pose any problem to the nutrients for the tree crop. Total N is directly related to the organic matter. It ranges from 0.93 g kg^{-1} in topsoil to 1.55 g kg^{-1} in the subsoil and this is moderate. This might be due to the intercropping practiced or due to organic matter regeneration in the site. There seems to be no clear trend in the distribution of the macronutrients within the solum except with P. In addition P is considered to be moderate while other macronutrients are low. These may be due to the high degree of leaching occasioned by the high rainfall regime of the site (2,255 mm per annum). Phosphorus is one of the nutrients required mostly by rubber and it varies from 10.76 mg kg^{-1} in topsoil to 9.18 mg kg^{-1} in the subsoil. The ECEC range from 3.54 to 5.37 Cmol kg^{-1} and it is within the range reported by Esekhade *et al.*(2003). Ojo-Atere *et al.* (2011) attributed this low ECEC range to kaoinitic nature of the parent material of the area.

Table 3: Chemical properties of the soil.

Horizon	Depth (cm)	*pH* H_2O	Org. C	TN	Avail. P	EA	Ca	Mg	K	Na	ECEC	BS	Mn	Fe	Cu	Zn
			(gkg^{-1})		(mgkg^{-1})	(C mol kg^{-1})						(%)	(mgkg^{-1})			
Ap	0 – 18	5.5	9.0	0.93	10.76	0.68	0.34	0.23	0.99	1.30	3.54	80.79	5.4	296.0	9.46	1.63
AB	18 - 46	5.4	12.4	1.29	11.20	1.05	1.27	0.17	0.99	1.35	3.83	72.58	1.6	227.0	11.12	1.45
Bt_1	46 – 90	5.4	8.0	0.83	10.56	1.45	1.28	0.14	0.10	1.39	3.27	55.66	2.5	156.0	10.25	1.26
Bt_2	90 - 114	5.2	8.6	0.89	11.78	1.75	1.23	0.13	0.01	1.48	3.60	51.39	2.0	60.1	10.46	1.44
Bt_3	114 – 148	5.5	4.4	0.47	9.46	1.15	1.34	0.13	1.00	1.35	3.97	71.03	2.3	30.0	10.74	1.58
Bt_4	148 - 183	5.4	14.9	1.55	9.18	1.45	1.43	0.11	0.99	1.39	5.37	73.00	1.4	19.9	10.97	1.43

The base saturation is higher than 50%. Previous work showed that soils in this area had base saturation of 92% (Orimoloye and Akinbola, 2013) and this was associated with weatherable minerals. Apart from Cu and Mg that increase with soil depth the other micronutrient do not have a definite pattern. They seem to be sufficient when compared with the critical levels except Fe content which is high (Amhakhian and Osemwota, 2012). They occur in the order as Fe>Cu>Mn>Zn.

Soil Classification

The pedon has loamy sand, aquic condition within 50 cm of the soil surface and absence of rock structure. There are no other distinguishing diagnostic horizons except cambic B. The geomorphic surface is young and nutrients are leached. The soil meets the requirements for placement in Inceptisol order. The suborder is Udept as the moisture regime is Udic. The base saturation by NH_4OAc (pH 7.0) qualifies it to be Eutrudept in Great group. At the subgroup level, it has some properties that represent its central concept which classified it as Typic Eutrodept. Based on the WRB, FAO/IUSS, (2006) the pedon may be classified as Haplic Cambisol (Chromic) since the hue is 7.5 YR and the chromic > 4 in between 30 to 100 cm in the subsoil.

Soil Suitability, sustainability of the land use and related management

Many authors have argued on the best method of assessing the land suitability evaluation of an area (Ogunkunle, 1993; Senjobi, 2001; Ritung *et al.*, 2007). However, Oluwatosin and Obatolu (2005) are of the opinion that any method would provide practical land suitability estimate of any tree crop under study. Table 4 therefore, shows the individual scores of the land characteristic and the suitability classifications under the current and potential evaluation by the parametric approach for rubber cultivation. Current suitability is the suitability of land under low input management regime while potential suitability is the land suitability that is attained after the land has been improved (Ritung, *et al.*, 2007).

The current suitability rating (IPc) and potential suitability rating (IPp) for Kulfo series were 47.91 and 69.15, respectively. Generally, the soils have been rated as marginally suitable (S3) in terms of low input management regime. The rating seems to be influenced by subsoil texture and soil fertility limitations. The S3 rating of the soil implies that the soil needs to be improved in productivity by erosional control measure as well as by manuring such as the applications of rock phosphate and/or limestone which are likely to release fixed P and subsequently boost the levels of Ca and Mg. This may probably raise potential rating of the soil to suitable (S2) and by so doing ensure both social and economic potential of the rubber farmers.

Table 4: Parametric suitability evaluation for rubber at Kulfo Series.

Land characteristics *		**Kulfo Series**
C	Months of Dry season	S12 (85)
	Annual Rainfall	S11(95)
	Max Temp. ^oC	S11(100)
	Min Temp. ^oC	S11(100)
	Relative Humidity (%)	S11(100)
S	Effective soil depth (cm)	S11 (100)
	Surface Texture\	S12 (85)
	Subsurface texture	S2 (75)
	Gravel & Stones (%)	S11(100)
T	Altitude (m)	S11 (100)
	Slope (%)	S11 (100)
F	Soil Reaction (Subsoil pH)	S11 (95)
	ECEC (c mol kg^{-1})	S2 (60)
	Base. Saturation	S11 (100)
	Avail P (mg kg^{-1})	S2 (80)
	Organic Carbon (g kg^{-1})	S11 (100)
W	Drainage	S11 (100)
	Depth to Water Table	S11 (100)
Aggregate suitability Class		
Current (IPc)		S3 (47.91)
Potential (IPc)		S2 (69.15)

*: c = climate, s = physical soil characteristics, t = topography, f= soil fertility, w= wetness

The sustainability of the soil is indicated in Table 5. With the exception of the soil pH, the soil generally has both fertility and soil compaction limitations.

Table 5: Cummulative index ratings and sustainability of the soil (modified after Ofem *et al.* 2015)

Soil Indicator	Relative Weighting factor	Limitation*
Physiography **		
Slope gradient (%)	6 (2/5)	Slight
Physical attribute		
Effective rooting (cm) *******	183 (1/5)	None
Texture (Subsoil) *******	SCL (2/5)	Slight
Stoniness/rock outcrop (%) ******	few (2/5)	Slight
Bulk density (mg m^{-3}) *******	1.66 (3/5)	Moderate
Drainage ******	Fairly (2/5)	Slight
Soil fertility ****		
Soil Ph	5.2 (2/5)	Slight
Organic carbon (g kg^{-1})	8.6 (4/5)	Severe
Available P (Bray 1)	11.78 (3/5)	Moderate
ECEC (C mol kg^{-1})	3.6 (5/5)	Extreme
Cumulative index (C1)	26/50	

Limitation*: I = None; 2 = Slight;3 = moderate; 4 = severe; 5 = extreme.
Sustainability of land use: Highly sustainable = <20; sustainable = 20 – 25; sustainable with high input = 25 – 30; sustainable with another landuse = 30 – 40; unsustainable >40.
******FAO (1990)
******* Planters Bulletin (1977)
********Adiukwu and Ali (2013)

The cumulative Index (C1) of the soil is 26/50 which rates the soil as sustainable with high farm inputs. This may be achieved by encouraging returns of organic residues into the soil such as planting and incorporating leguminous plants. Manuring the soils is another good husbandry in improving the fertility of the soil. The penetration of rubber roots into the soil is severely affected by high bulk density (Planters Bulletin, 1977) perhaps, as a result of the poor space, air water and low organic matter in the subsoil. The use of chain saw to clear the tree and stumps in the area is recommended in order not to expose the subsoil to erosion and compaction. Apart from the low basic cations, the effective soil depth, soil texture with friable and firm consistency and good drainage class, the study area falls within the moderate range of grading the soil suitable for rubber cultivation as defined by Planters Bulletin (1977) and Ugwa *et al.*,(2005).

Summary and Conclusion

Kulfo series consists of coarse, weak dark reddish (5 YR 2.5/2 moist) over strong brown (7.5 YR 5/6 moist). topsoil to yellowish red (5 YR 5/8 moist) subsoil. The texture varies from sandy loam in the first 18 cm transiting to sandy clay loam. The soil is deep, moderately acidic, situated in the middle gently slope (0-6%) site. The series is developed on young less consolidated sand stone, non-concretionary of the Miocene – Pleistocene age and are found in association with Ahiara and Orlu series.

The soils have been adjudged to be marginally suitable and sustainable with high farm input for rubber cultivation. Full potential of the area may be achieved if it is not mechanically worked on because of the fragile nature of the soils.

Although suitability of soil has been rated currently as marginally suitable (S3) and can potentially be improve to moderate suitable (S2), with the use of organic based manure the trend was similar to the approach by the cumulative Index of 26/50. It seems however, that the two approaches produce same result, namely: IPp and C1 values were 69.15 and 52 (26/50) respectively, which falls into S2 rating (50 – 74). It appears that parametric approach of land suitability evaluation presents a better picture of rating the soil.

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