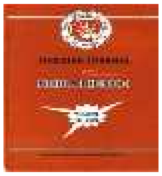
Nigerian Journal of Soil Science 23 (2013) 252 – 263

Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com



EVALUATION OF SOME SANDSTONE DERIVED SOILS OF SOUTHERN NIGERIA FOR RUBBER (*Hevea brasiliensis*) CULTIVATION

***Orimoloye J. R. and Akinbola, G. E.**
Department of Agronomy, University of Ibadan, Ibadan, Nigeria
*****Corresponding Author: Email: orimoloyej@yahoo.com

ABSTRACT

Some soils derived from crustaceous sandstones at Iyanomo, Edo State, Southern Nigeria were mapped, characterised and evaluated for rubber cultivation, using local, USDA Soil Taxonomy and FAO systems. Conventional parametric and non-parametric land suitability evaluation systems as well as weighted parametric approach in Geographic Information System (GIS) methods were used to generate suitability ratings for rubber cultivation. Dry rubber yield from existing plantations on the site obtained in the 2005/2006 and 2006/2007 cropping seasons were used to validate the suitability ratings. A total land area of 2070 ha was surveyed and the soils studied were classified as Alagba, Orlu, Kulfo and Ahiara series. The soils were in the Ultisol and Inceptisol soil orders of the Soil Taxonomy which covered 73.1 % and 26.9 % of the study area respectively. Parametric and non-parametric land suitability evaluation rated 73.1 % and 26.9 % of studied area as moderately suitable (S2) and marginally suitable (S3) respectively. The GIS method however rated 88.0 % of the site as highly suitable (S1) and 12.0 % as S2. Dry rubber yield obtained over a two year period correlated significantly (r = .929**) with the GIS suitability rating. Suitability evaluation using weighted parametric method in GIS was found to be better than conventional methods in rating the soils for rubber productivity and predicting yield of rubber.

Keywords: Rubber production, Soil classification, Land suitability evaluation,

INTRODUCTION

Land is the most important natural resource of any region or country. The soil constitutes the most vital component of the land because most of the complex biophysical and biochemical processes necessary for the sustenance of life and maintenance of the global ecosystem take place in the soil (Cârstea, 2010). Soil is the long-term capital on which nations build their resources (Wilding and Lin, 2006). Any serious attempt to use land judiciously for agriculture, engineering, urban development, pollution control, etc., must start with the knowledge of the nature, type and spatial distribution of soils existing in the regions as produced in land resource surveys (Ogunkunle, 1987; Brady, 2002; Thapinta and Hudak, 2003). Land evaluation is the interpretation of soil survey data in order that every hectare of land should be used in accordance with its capability, suitability and limitations (FAO (2007). The suitability of soils for a particular crop or a specific land use is indicated by the kinds and extent of soil limitations that may impede the cultivation of the crop. Land evaluation using a scientific procedure is essential to assess the potential and constraints of a given land parcel for agricultural purposes (Rossiter, 1996). The knowledge of soil limitations arising from land evaluation reports therefore aims at providing practical approaches to ameliorating such limitations before, or during the cropping period (Lin *et al.*, 2005). Great demands are being placed on tropical soils to meet the need for food and fibre of a rapidly growing population. This requires either intensifying cultivation to increase crop yield per unit area or opening up new areas of land for cropping. To minimize damages to the environment, the land needs to be properly classified according to its suitability for the proposed kind of use. This requires a proper organization of land and soil data in such a way that could be interpreted and applied for agricultural development.

Rubber (*Hevea brasiliensis*, Wild ex de Juss, Muell. Arg) popularly referred to as *Para rubber* is a quick growing, erect tree crop with a straight trunk and bark which is usually grey and fairly smooth. It is a lowland crop that thrives mainly in the Southern rainfall belt of Nigeria. It is exploited for its latex, which is valued for its isoprene content. Other bye-products of rubber such as wood and seed have various industrial applications and good market values. The wood is used in construction and paper industries while the seed produces Rubber Seed Oil (RSO) and cake used in the manufacture of alkyd resin, putty, ink and animal feed supplements (Aigbekaen and Nwagbo, 1999). Rubber production in Nigeria has great potentials as a dependable source of raw materials for local industries. Most soils of the conventional rubber growing area were reported to be loamy sand in surface texture, characterized by low pH, low nutrient status, low ECEC and low water holding capacity (Ojanuga *et al*., 1981; Eshett, 1991) but with great potentials for tree crop production (Ataga *et al*., 1981). This study was therefore carried out to identify and classify the soils of Rubber Research Institute of Nigeria (RRIN); determine the suitability or otherwise of the soils for rubber cultivation using conventional parametric and non-parametric systems in comparison to a weighted parametric overlay in a Geographic Information System (GIS) environmement.

MATERIALS AND METHODS

Description of Study Area:

The study was carried out within the conventional rubber growing belt of Nigeria at the Rubber Research Institute of Nigeria (RRIN) main station at Iyanomo (near Benin City), Ikpoba-Okha Local government Area of Edo State. The study area occupies a land area of 2070 hectares. It is situated about 29 kilometers Southeast of Benin City. The Area is located within longitudes 5º 34'E and 5º 38'E and latitudes 6º 08'N and 6º 11'N. It is bordered by Ogbekpen village (southwest); Benin Owena River Basin Development Authority [BORDA] (south east); Uhie village (Northeast) and Obayantor village (northwest). Vegetation in the study site is a multistoried high tropical rainforest characterized by a multiplicity of tree species. The climax vegetation has been tremendously altered by the impact of uncontrolled forest exploitation and cultivation. Several topical tree species such as *Chrotalaria exelsa, Cieba petandra* etc. are still present. The study site is underlain by the Southern Nigeria sedimentary basin and falls within the area described as the 'acid sands' of southern Nigeria (Udo and Sobulo, 1981). The area is specifically on what was described as the 'Benin Fasc' of the sedimentary (sandstone) deposits of the Pleistocene age (Ojanuga, 2006).

Field work

A detailed soil survey with 200 m x 200 m grid pattern was carried out. The choice of this grid pattern was borne out of: (i). Previous experiences and studies that showed that soils of the Coastal Plain Sands (especially the land system type of the study area) exhibit a level of homogeneity that will make smaller grid size unnecessary as it is not likely to yield more information. (Fapounda, 1986); and (ii). The total land area covers about 2,070 hectares, majority of which have been demarcated into 200 x 200 m blocks with paths and some motor-able earth roads.

Identification of the soils and their boundaries were made using soil auger borings at the intersections of the grids in each block, at the depths of 0 – 30, 30 – 60, 60 – 90 cm for physical and morphological properties such as colour, (using the Munsell Soil Colour Chart), texture and consistency by hand feel methods, effective soil depth, presence of concretions and soil drainage conditions, surface stoniness, slope gradients (%) and aspects. Slope properties and the coordinates of examination points were obtained with the use of Garmin Etrex Global Positioning System (GPS) handset. Variations in the observed morphological properties in the auger examination points were used to delineate the soils into Mapping Units. Each Mapping Unit and variants were further examined in detail by sinking standard modal profiles to depths ranging from 180 to 200 cm. A total of 10 soil profiles pits were dug and they were described according to FAO (1990), guidelines. Soil genetic horizons were sampled and processed for laboratory analyses.

Laboratory analyses

Particle size analysis was carried out using the Bouyoucous hydrometer method (Gee and Or, 2002), Soil bulk density of each horizon of the profiles as a ratio of the dry mass to volume; was determined in triplicates from undisturbed core samples (Grossman and Reinsch, 2002). Total porosity was derived from the relationship of particle density to the bulk density using the formula 1- [ρs/ρb] x100. Where ρs = particle density and ρb = bulk density. The average particle density of mineral soils (2.65 kg m^{-3}) was used for the computation.

Soil pH was determined potentiometrically in water and in KCl. In water, 10g of soil sample to 25ml of distilled water was added (ratio 1:2.5) while pH in KCl was also determined at a ratio of 1:2.5 soil to solvent and the readings were taken using the glass electrode (Methler) pH meter buffered at pH 7. Organic carbon was determined by the Walkley-Black wet oxidation method (Walkley and Black, 1934). Exchangeable bases (Ca, Mg, K, Na) were extracted with 1N NH_4OAC (pH 7). Exchangeable Ca and Mg were determined by atomic absorption spectrometer while K and Na by flame photometer (Black, 1965). Exchange acidity ($A1^{3+}$, H^+) was determined by titration of soil solution with 1 N KCI (Black, 1965). Extractable micronutrients, Mn, Zn, Cu and Fe were leached with 0.1N HCl using the method of Wear and Summer (1948), and were determined on the atomic absorption spectrophotometer. Effective CEC was computed by the summation of exchangeable bases (Ca, Mg, K and Na) and exchange acidity (Al and H).

Land Evaluation

Based on profile description and laboratory analysis, the soils were classified using the USDA Soil Taxonomy (Soil Survey Staff 2010), World Reference base for soil resources (FAO/IUSS, 2006) and at the series level using the system of Moss (1957), as modified by Ogunkunle (1983). The suitability of the pedons for rubber was evaluated using the revised FAO framework for Land Suitability Evaluation (FAO, 2007). Three suitability evaluation approaches were employed namely:

i. Conventional Non Parametric Approach in which Pedons were placed in suitability classes by matching their characteristics with the land requirements for rubber. The modified suitability criteria for rubber proposed by Van Ranst *et al*., (1996) was employed (Table 2) in the rating of the study sites in comparison with the classical rating of Sys (1985). The suitability class of a pedon is indicated by the most limiting factor.

ii. Parametric Approach: In the Parametric approach (Ogunkunle, 1993), the limiting characteristics of each pedon were rated as contained in Table 2. The index of suitability was computed using the equation:

IS = A x √B/100 x C/100 x …F/100

Where IS = Index of Suitability

A = the overall lowest characteristic rating B , C, …F = the lowest characteristic rating for each land quality group

In Table 1, five land quality groups: climate (c), soil limitations (s), Physiography (t), soil fertility (n) and wetness (w) are defined. Only one (the most limiting) member in each group was used because there are usually strong correlations among members of the same group. Potential Index of Suitability (ISp) is the envisaged suitability of land units for the Landuse (Rubber cultivation) after land improvements have been effected where possible or necessary (Ogunkunle, 1993; Senjobi, 2001).

iii. GIS weighted overlay approach: By interpolation tools of ArcGIS 9.3 (ESRI 2008), each parameter group was taken and evaluated at a time to produce a suitability sub-map (e.g. ECEC was used for the fertility (f) group in Table 1). The overall suitability map was obtained by weighted overlay of the suitability sub maps for each parameter land characteristic group. A weight was allocated to each sub-map of the various parameters to show the relative importance of the parameter. Weights assigned must all add up to 1 (or 100 %)

Yield validation

Rubber latex collections for two consecutive seasons were monitored in 2005/2006 and 2006/2007 in some selected plots of existing rubber plantations in the study site. A half-spiral alternating days tapping method (Saraswathyama *et al.*, 2000) was adopted. The yield potentials of the various clones under ordinary farmers' field conditions and the age of the plantation were used as baseline to validate the land evaluation for rubber in the various fields. The accuracy (practical value) of land classification was tested by comparing the actual yield obtained with the standard yield of the rubber clone in each field with each soil class using the following relationship:

Yield Index (YI) = Actual yield / Standard yield x 100.

Standard yield is the yield potential quoted by the authorities that released the rubber clone. The index obtained is then compared with the recommended yield class for rubber, for the suitability class of each Pedon as suggested by Sys (1985) and as modified by Watson (1989).

RESULTS AND DISCUSSION

Four mapping units were identified at the study site (Iyanomo). The soil map is presented in Fig. 1. The taxonomic classifications of the four pedons are presented in Table 3 while the relative position of the pedons on a typical toposequence in the study area is shown in Fig. 2. The Iyanomo soils were formed on sandstone parent materials belonging to the 'Benin Fasc' (Ojanuga, 2006). Ahiara and Kulfo Series were so classified according to their lower slope physiographic positions in the non-mottled and non- concretionary toposequence of 'red' soils in the 'Benin Fasc' with Ahiara occurring below Kulfo along the catena (Moss 1957).The soil type distribution of the study area was observed to have been influenced by the physiographic position. The spatial distribution of soils is widely agreed to be a function of the five soil forming factors with topography being the principal controlling factor at the local level. Mc Bratney *et al.*, (2003) and Rezaei and Gilkes, (2005), belief that the existence of a spatial correlation between the occurrence of soil types and landform position in the physiography is a basic premise of applied pedology. This characteristic and predictable relationship has been used successfully to map and characterise soils especially at Series level in Western Nigeria (Smyth and Montgomery, 1962). Younger soils (Entisols and Inceptisols) occur at valley bottoms while the older, more developed Ultisols occur at the hillcrests, upper and middle-slope positions at the site. Fasina (1997) , noted that the valley pedons of most toposequences of the coastal plain sand derived soils tend to have younger soils with no major diagnostic horizons but evidence of recent or continuous deposition compared with soils of the upper slope which are usually Alfisols, Ultisols or Oxisols. Alagba and Orlu series are located at the upper and middle slope positions of the same toposequence. The two soil series are closely related in colour and texture but the major difference is the depth at which the clayey texture (usually sandy clay) occurs. While the sandy clay texture is encountered at about 40 cm depth or less in Alagba series, it usually occurs at about 60 cm in Orlu series. Though, Moss (1957), suggested the discontinuation of Orlu series and instead be classified as the clayey subseries of the Kulfo series, Ogunkunle (1983), argued that Orlu series as earlier identified by Vine (1954), be upheld since the distinguishing characteristics are very relevant to soil management.

The non-parametric and parametric suitability ratings of the pedons at Iyanomo are shown in Tables 4 and 5 respectively while the suitability rations obtained from weighted overlay GIS analysis is presented in Table 6. The yield validation and suitability rating based on the yield index of rubber is shown in Table 7, while rank correlation co-efficient of evaluation procedures and rubber yield is given in Table 8. The suitability class of a pedon is determined by the lowest or least characteristic/quality rating for any suitability criterion. A combination of two or more limitations may effect a downgrading in the suitability classification of soil series as the system is based on the Leibig's law of minimum. The parametric and non-parametric suitability ratings of the pedons at Iyanomo agreed very strongly (r = .964**). However, actual yield in both 2005/2006 and 2006/2007 cropping seasons were not significantly related to the ranking of the pedons. When yield index which takes into account the potential yield of the rubber clones were involved, there were significant correlations (r = .964** and .929 **) for Non-parametric and parametric evaluation methods respectively) between the rankings of the soils and yield index in 2006/2007 season. This implies that, in evaluating the yield of rubber, it should be considered that each rubber clone has different yield abilities even when all other variables are held constant. The flaw with the LSE in crop yield prediction can be attributed to the high class limit set for the characteristics used for evaluation (Oluwatosin and Ogunkunle 1991). The class limit set for rubber, especially on surface and subsurface texture and fertility confines all the soils in the study area into marginal or at best, moderate suitability classes. For instance, a soil that has pH less than 5.0 is considered too strongly acidic for rubber, whereas optimal rubber performance at pH of between 4 and 4.5 have been reported (Watson, 1989; VanRanst *et al.*, 1996).

Whereas, LSE placed the soils at Iyanomo as S2 and S3 categories, with weighted overlay analysis in the GIS, 88.01 % and 11.98 % of the land area were highly suitable (S1) and moderately suitable (S2) respectively at Iyanomo. This is possibly so because all the criteria were allocated equal weight in the overlay analysis. The fertility criteria though contributed substantially but did not affect the classification as they did in the parametric and non-parametric LSE methods. One peculiar feature of the GIS overlay analysis is that each point was rated on its own merit; therefore suitability class did not strictly follow pedogenic classes. For instance, part of Kulfo series was in class S1 while some were in S2 at Iyanomo.

When the yield indices were used to place the pedons in suitability classes, larger proportions of the soils at Iyanomo produced yield indices that are expected of S1 soils. The implication of this is that yield index is a better assessment of yield in evaluating land suitability. Weighted overlay analysis gives a better interpretative evaluation for rubber when dry rubber yield is the object of interest.

CONCLUSION

The sandstone derived soils of Southern Nigeria are very suitable for rubber cultivation. Yield index rather than actual yields of rubber is a better yield performance indicator of land classification especially when varying rubber clones are involved. The parametric overlay analysis executed in GIS is a better instrument than both conventional parametric and non-parametric suitability evaluation methods in predicting yield of rubber.

Table 1: Land suitability requirements for rubber based on land qualities (Modified from Sys, 1985)

Land Qualities	**Sutability classes**				
	S1	**S2**	**S3**	**N1**	**N2**
Climate (c)					
Annual rainfall	>2000	1500-2000	1250-1500	-	< 1250
Dry season (months)	1-2	3-4	5	>5	-
Mean annual max temp. (ºC)	29	25-29	22-25	-	< 22
Mean annual min. temp. (ºC)	>20	16-20	14-16	12-14	< 12
Relative humidity (%)	>75	65-75	60-65	-	< 65
Permanent soil limitations (s)					
Effective soil depth (cm)	200	150-200	100-150	50-100	50 or less
Texture §	SC, CL, SiCL	LC, fine SC, SiC	Coarse SCL, CL, SL	LS	S
Gravel (%) 0-15 cm	< 3-10	10-35	35-60	60-90	> 90
Physiography (t)					
Slope gradient (%)	0-3	3-8	8-20	20-35	> 35
Altitude (m)¶	< 200	200-500	500-600	600-800	> 800
Soil fertility (f)					
Subsoil pH	5-6	4.5-5	4-4.5	6.5-7	7.0
ECEC (cmol kg^{-1})	> 10	5-10	< 5	-	-
Base Saturation (%)	> 45	30-45	15-30	< 15	-
Available P (Bray P1) (mg kg^{-1})	> 15	10-15	5-10	< 3	-
Organic Carbon (%)	> 1.2	0.8-1.2	< 0.8	-	-
Wetness (w)					
Drainage	Well drained	Well drained	Mod – imperfect	Poorly	poorly drained
Depth to water table (cm)	> 200	150-200	-	-	-

Table 2: Ratings of limiting factors of land quality for Parametric Suitability evaluation for rubber

Degree of limitation	Rating (%)	Suitability Class
Slight - None	100 -95	S11
Slight	94-85	S12
Moderate	84-55	S2
Severe	54-30	S3
Can be corrected	29-20	N1
Cannot be corrected	19-0	N2

Table 3: Taxonomic Classification of the rubber growing soils at Iyanomo

Pedons	Local classification (Moss 1957)	Soil taxonomy (Soil survey staff, 2010)	WRB* (FAO/IUSS, 2006)	Coverage Area (Ha)	Coverage Area (%)
A	Ahiara Series	Typic Dystrudept	Haplic cambisol (Eutric)	152.55	7.34
B	Kulfo series	Oxic Dystrudept	Haplic cambisol (Chromic)	406.54	19.59
C	Orlu Series	Typic Rhodudult	Acric Nitisol (Dystric)	1254.80	60.42
D	Alagba Series	Typic Rhodudult	Lixic Nitisol (Eutric)	262.78	12.65

***** WRB = World Reference Base for soil resources

Table 4: Land quality and Suitability (Non Parametric) classification for rubber at Iyanomo

Land characteristics*		Ahiara Series	Kulfo Series	Orlu Series	Alagba
c	Months of Dry season	3-4 (S2)	3-4 (S2)	3-4 (S2)	3-4 (S2)
	Annual Rainfall	1952 (S2)	1952 (S2)	1952 (S2)	1952 (S2)
	Max Temp. °C	32.72 (S1)	32.72 (S1)	32.72 (S1)	32.72 (S1)
	Min Temp. °C	23.55 (S1)	23.55 (S1)	23.55 (S1)	23.55 (S1)
	Relative Humidity (%)	78.2 (S1)	78.2 (S1)	78.2 (S1)	78.2 (S1)
s	Effective soil depth (cm)	150-200 (S2)	>200 (S1)	>200 (S1)	>200 (S1)
	Surface Texture	LS (S2)	LS (S2)	SL (S1)	L (S1)
	Subsurface texture	SL (S3)	SL (S3)	SCL (S2)	SC (S1)
	Gravel & Stones (%)	0 S1	0 S1	0 S1	0 S1
t	Altitude (m)	38 (S1)	42 (S1)	48 (S1)	51 (S1)
	Slope (%)	1-2 (S1)	3-4 (S1)	3 (S1)	2 (S1)
f	Soil Reaction (Subsoil pH)	4.97 (S2)	4.59 (S2)	5.22 (S1)	5. 9 (S1)
	(ECEC) (c mol kg^{-1})	4.75 (S2)	3.08 (S2)	2.87 (S2)	7.23 (S1)
	B. Saturation (%)	91.30 (S1)	92.21 (S1)	91.63 (S1)	83.46 (S1)
	Avail P (mg kg^{-1})	18.77 (S1)	21.11 (S1)	26.98 (S1)	24.04 (S1)
	Organic Carbon (g kg^{-1})	18.00 (S1)	19.40 (S1)	16.50 (S1)	30.00 (S1)
w	Drainage	Mod Well drained (S2)	Well Drained (S1)	Well Drained (S1)	Well Drained (S1)
	Depth to Water Table	150 - 200 (S2)	> 200 (S1)	> 200 (S1)	> 200 (S1)
suitability Class **					
	Actual	S3sw	S3sc	S2cs	S2c
	Potential	S3s	S3sc	S2c	S2c

*	**
c = climate	S2 = moderately suitable
s = soil parameters	S3 = marginally suitable
t = topography	
f = soil fertility	
w = wetness	

Table 5: Parametric suitability evaluation for rubber at Iyanomo study site

Land characteristics		Ahiara Series	Kulfo Series	Orlu Series	Alagba Series
	Months of Dry season	S12 (85)	S12 (85)	S12 (85)	S12 (85)
	Annual Rainfall	S11 (95)	S11 (95)	S11 (95)	S11 (95)
c	Max Temp. ºC	S11(100)	S11(100))	S11(100)	S11(100)
	Min Temp. ºC	S11(100)	S11(100)	S11(100)	S11(100)
	Relative Humidity (%)	S11(100)	S11(100)	S11(100)	S11(100)
	Effective soil depth (cm)	S12 (85)	S11 (100)	S11 (100)	S11 (100)
s	Surface Texture	S12 (85))	S12 (85)	S11 (95)	S11 (100)
	Subsurface texture	S2 (60)	S2 (75)	S12 (85)	S11 (100)
	Gravel & Stones (%)	S11 (100)	S11(100)	S1 (100)	S1 (100)
t	Altitude (m)	S11 (100)	S11 (100)	S11 (100)	S11 (100)
	Slope (%)	S11 (100)	S11 (100)	S11 (100)	S11 (100)
	Soil Reaction (Subsoil pH)	S2 (85)	S2 (85)	S11 (95)	S11 (95)
	(ECEC) (c mol kg^{-1})	S2 (75)	S2 (60)	S2 (75)	S12 (90)
f	B. Saturation	S11 (100)	S11 (100)	S11 (100)	S11 (100)
	Avail P (mg kg^{-1})	S11 (100)	S11 (100)	S11 (100)	S11 (100)
	Organic Carbon (g kg^{-1})	S11 (100)	S11 (100)	S11 (100)	S11 (100)
w	Drainage	S12 (90)	S11 (100)	S11 (100)	S11 (100)
	Depth to Water Table	S11 (100)	S11 (100)	S11 (100)	S11 (100)
Aggregate suitability Class**					
	Actual	S3 (45.44)	S3 (42.75)	S2 (63.75)	S2 (82.98)
	Potential	S3 (49.78)	S3 (55.48)	S2 (76.50)	S2 (82.98)

*	**
c = climate	S2 = moderately suitable
s = soil parameters	S3 = marginally suitable
t = topography	
f = soil fertility	
w = wetness	

Table 6: Area coverage of GIS suitability analysis at Iyanomo study site

Pedons	Suitability class			
	S1		S2	
	Area (ha)	Coverage (%)	Area (ha)	Coverage (%)
Ahiara	-	-	152.55	7.34
Kulfo	310.93	14.94	95.61	4.64
Orlu	1254.80	60.42	-	-
Alagba	262.78	12.65	-	-
Total	1822.43	88.02	248.16	11.98

Table 7: Actual yield and yield index of rubber at Iyanomo in 2005/2006 and 2006/2007 seasons

Soil Series	Field/ Location	Rubber clone	Actual yield (kg/ha/year)		Yield Index	
			2005/2006	2006/2007	2005/2006	2006/2007
Ahiara	L12	NIG 800	2024.67	2018.72	74.28 (S2)	73.33 (S2)
Kulfo	M16	RRIM 600	2728.97	2182.14	124.04 (S1)	99.18 (S1)
Orlu	OP8	GT 1	2295.38	2513.19	109.37 (S1)	136.58 (S1)
Alagba	QR 16	RRIM 628	2012.50	1988.34	197.49 (S1)	195.09 (S1)

Table 8: Spearman's rank correlation co-efficient among land classification procedures and rubber yield

	Non Parametric		Parametric		Actual rubber yield		Rubber yield index	
	Actual 1	Potential 2	Actual 3	Potential 4	2005/2006 5	2006/2007 6	2005/2006 7	2006/2007 8
1	1.00							
2	1.00**	1.00						
3	.964**	.964**	1.00					
4	.964**	.964**	1.00**	1.00				
5	.714ns	.714ns	.643ns	.643ns	1.00			
6	.750ns	.750ns	.679ns	.679ns	.964**	1.00		
7	.714ns	.714ns	.643ns	.643ns	.464ns	.429ns	1.00	
8	.964**	.964**	.929**	.929**	.607	.643ns	.786*	1.00

*, ** correlation significant at 0.05 and 0.01 levels respectively.

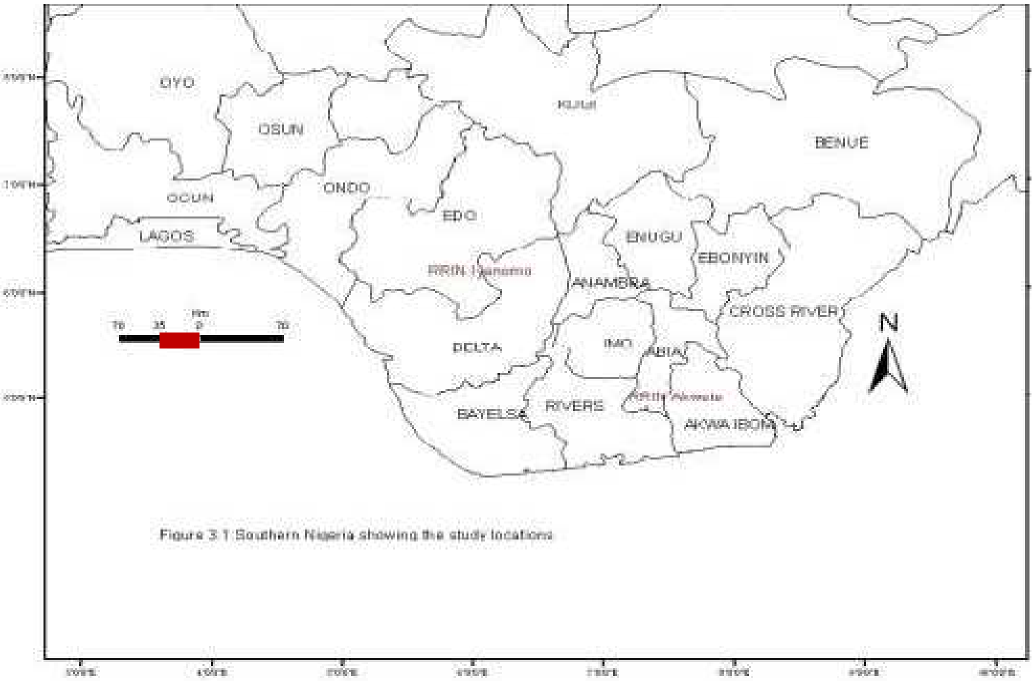
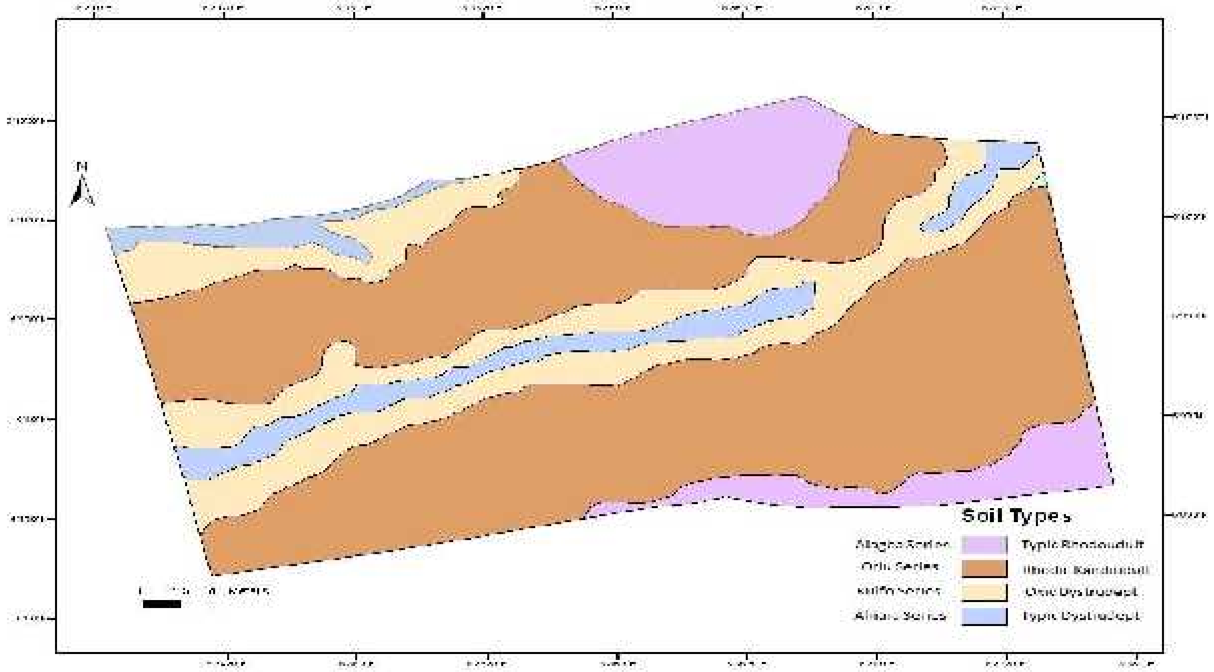


Figure 3.1 Southern Nigeria showing the study locations

Fig.1: Soil map of the study site (Rubber Research Institute of Nigeria, RRIN Mainstation) Iyanomo, near Benin City.



ACKNOWLEDGEMENTS

The assistance and conducive environment for this study provided by the Executive Director of RRIN is gratefully acknowledged. Also the contributions of the field and laboratory staff Soil and Plant Nutrition (SPN) Division, RRIN is well appreciated,

REFERENCES

Aigbekaen, E. O. And Nwagbo, E. C. (1999) An analysis of costs and returns of natural rubber production in Nigeria. *Indian Journal of Natural Rubber Research* 12 (1&2): 77-85

Ataga, D. O., Omoti, U. and Uzu, F. O. (1981). Management of the “acid sands” in Nigeria for tree crop production. In: E.J. Udoh & R. A. Sobulo (Eds), ‘Acid sands’ of Southern Nigeria. Soil Science society of Nigeria. *Monogramme No 1*, 86-150

Black C.A. (1965) method of soil analysis Agronomy No 9 part 2 American society Agronomy Madison Wisconsin.

Brady, N. C. (2002) The nature and properties of soils. Tenth Edition, Prentice-Hall of India. 621p.

Cârstea, S. (2010). Pedogeographogenetic and Pedomorphogenetic Concepts in Soil Surveys. *IUSS Bulletin* 116: 14-17ESRI 2008.

Eshett, E. T. (1991). General properties of iron and aluminium status of selected rubber growing soils of Southern Nigeria. *Indian Journal of Natural Rubber Research* 4(1): 8-15.

ESRI (2008). ArcGIS 9.3 Tutorials. Environmental Systems Research Institute, Redlands, California.

FAO (1990). Guidelines for soil profile description. Soil resources management and conservation service, FAO, Rome.

FAO (2007). Land evaluation: towards a revised framework. Land and water discussion paper 6. FAO, Rome.

FAO/IUSS (2006). World reference base for soil resources 2006. 2nd edition, World Soil Resources Reports No 103. FAO, Rome.

Fapohunda, F. A. (1986). Variability studies on a soil map produced from remotely sensed data of the coastal plain sands of Nigeria. PhD Thesis, University of Ibadan, Nigeria.

Gee, G. W. and Or, D. (2002). Particle size analysis. In: Dane J.H. and Topp G.C. (Eds.). Methods of soil analysis, Part 4, Physical methods. Soil Science Society America Book series No. 5 ASA and SSSA, Madison, WI. p 255-293.

Grossman, R. B. and Reinsch, T. G. (2002). Bulk density and linear extensibility. In: Dane J.H. and Topp G.C. (Eds). Methods of soil analysis, part 4, physical methods, Soil Science Society of America Book Series No. 5 ASA and SSSA Madison, WI. pp 201-228.

Lin, H., Bourma, J., Wilding, J., Richardson, L., Kutilek, M and Nielson, D. R. (2005). Advances in hydropedology. *Advances in Agronomy*. (85): 1-89.

Mc Bratney, A. B., Mendocasantos, M. L. and minasny, B. (2003). On digital soil mapping. *Geoderma* 117: 3-52.

Moss, R. P. (1957). Report of classification of soils formed over sedimentary rocks in Western Nigeria. Dep. Rep, MANR; Ibadan.

Ogunkunle A. O. (1983). Updating the classification of acid sand soils with particular reference to the soils on the NIFOR main station. *Journal of the Nigerian Institute for Oil Palm Research* 6: 234-255.

Ogunkunle, A. O. (1987). Soil resource inventory and agricultural productivity in Nigeria. *Proceedings*, National productivity workshop. Owerri, Dec. 1-3, 1987.

Ogunkunle A. O. (1993). Soil in land suitability evaluation: an example with oil palm in Nigeria. *Soil Use and Management* 9: 35-40.

Ojanuga A. G., Lekwa, G. and Akamigbo, F. O. R. (1981). Survey, classification and genesis of acid sands. In: Acid sands of Southern Nigeria. SSSN Monograph No 1. Pp 1-18.

Ojanuga A. G. (2006). Agro ecological zones of Nigeria manual (F. Berding and V. O. Chude: Eds.) NSPFS/FAO/ FMA&RD, Abuja, Nigeria. 128pp.

Oluwatosin, G. A. and Ogunkunle, A. O. (1991). Suitability rating of some soils of the Savannah Zone of Southwestern Nigeria for rainfed maize. *Nigeria Journal of Soil Science* 10: 1-24.

Rezaei, S. A. and Gilkes, R. J. (2005). The effects of landscape attributes and plant community on soil chemical properties in rangelands. *Geoderma* 125: 167-176.

Rossiter, D. G. (1996). A theoretical framework for land evaluation. *Geoderma* 72: 165-190

Saraswathyama, C. K., Licy, J. and Marattukalam, J. G. (2000). Planting materials, In; George, P. and Kuruvilla Jacobs, C. (Eds). Natural rubber: Agromanagement and crop processing. Rubber Research Institute of India, Kottayam, India. Pp 59-74.

Senjobi, B. A. (2001). Parametric and conventional approaches for soil potential evaluation in three ecological zones of Southern Nigeria. *Moor Journal of Agricultural Research* 2: 91-102.

Smyth, A. J. and Montgomery, R. F. (1962). Soils and land use in central Western Nigeria. Government Press, Ibadan. 265.

Soil Survey Staff, (2010). Keys to soil taxonomy (Eleventh Edition). USDA Natural Resources Conservation Service, Washington, D.C.

Sys, C. (1985). Land Evaluation. International Training Centre for postgraduate soil Scientists Vol I & II. State University, Ghent.

Thapinta, A and Hudak, P. F. (2003). Use of Geographic Information Systems for assessing groundwater pollution potential of pesticides in central Thailand. *Environmental International* 29: 87-9.

Van Ranst, E, Tang, H., Groenemans, R. and Sinthura, S. (1996). Application of fuzzy logic to land suitability for rubber in Peninsular Thailand. *Geoderma* 70: 1-19.

Vine, H. (1954). Latosols of Nigeria and some related soils. *Proceedings* of 2nd Inter-African Soils conference. Pp 295-308.

Walkey, A., and Black, I. A. (1934). An examination of Detjareff method for determining soil organic matter and proposed modification of chromic acid titration method. Soil Science 37:29-38.

Watson, G. A. (1989). Nutrition: Rubber. C.C. Webster and W.J.Baulkwill (Eds). Longman Scientific and Technical, New York.

Wear, J..I. and Sommer, A.L. (1948). Acid extractable zinc of soils in relation to the occurrence of zinc deficiency symptoms of corn: A method of analysis. *Soil Sci. Soc. Am. Proc.*, 12:143- 144.

Wilding, L.P. and Lin, H. (2006). Advancing the frontiers of soil science towards geosciences. *Geoderma* 131: 257-274.