ISSN 0024-9521
IJG Vol. 42, No. 2, December 2010 (105 - 118)
© 2010 Faculty of Geography Gadjah Mada Univ. &
The Indonesian Geographers Association

INDONESIAN JOURNAL OF GEOGRAPHY

ASSESSMENT OF SOIL PROPERTIES UNDER TEAK PLANTATATION IN ABIA – BADAGRY, LAGOS, NIGERIA

Ayo Omotayo
omotayo@yahoo.co.uk
Department of Geography and Planning, Lagos State University, Ojo

Ogundele, F.O
kunleoguns@yahoo.co.uk
Department of Geography and Planning, Lagos State University, Ojo

Akoteyon I.S
akoteyon@yahoo.co.uk
Department of Geography and Planning, Lagos State University, Ojo

ABSTRACT

This paper investigated whether the Teak plantation established a year ago by Lagos State Government Ministry of Agric and Co-operative at Abia-Badagry meet the soil and environmental requirement as obtainable in countries where Teak grows naturally. Also the study will also establish whether the establishment of Teak tree has changed the soil properties. Sampling design for this study was based on, the need to spread sample sites objectively over the study area. The entire plantation is 2.5ha and five soil samples were collected from the plantation using soil auger. From each of the five (5) holes dug, soil samples were randomly collected from two sampling depths 0 – 15 cm and 15–30cm, respectively. Soil samples were air-dried, sieved, and analyzed in the laboratory using standard techniques. The result of the soil analysis show that PH, EC, TOM, TOC, TN, Av.K, Av.P and Bulk Density ranges between,5.36-5.86,38.00-156.00,1.06-2.41,0.86-1.92,0.01-0.03,0.03-0.03,0.02-0.02 and 1.31-1.36 respectively. Among the examined variables,Ec has the highest mean (61.00) followed by pH (5.72) while TN/Av.P remained the least value (0.02). Also, EC recorded the highest Standard Deviation (46.73).this was followed by TOM (0.52) while Av.K/Av. Based on the empirical data and the analysis carried out on the Teak plantation and the site characteristics to find out the suitability or otherwise of the site for maximum Teak yield in the country, it was found that the site characteristics, especially, soil properties are similar to those of places where Teak grows naturally. Therefore it is recommended to Lagos State Ministry of Agric and Cooperative to increase the plantation size.

Keywords: teak plantation, sampling design, teak grows naturally

INTRODUCTION

Globally, forest plantations have witnessed a phenomenal growth since the middle of the 20th century, especially within the past three decades [*Evans and Turnbull,* 2004]. The global forest plantation estate, for example, increased from 17.8 million ha in 1980 to 43.6 million ha in 1990 and from 124 million ha in 1995 to 187 million ha in 2000 [*FAO*, 1992]. Originally, Nigeria natural forest accounts for about 360,000 km^2 of the countries total land area of 983,213 km^2 [*IUCN/-WWF*, 1987]. Meanwhile, with increasing demand for exotic timber materials, natural forest sizes have been declining at an alarming rate since the beginning of the 20^{th} century with an estimate of about 401,000 ha yr^{-1} in year 2000 [*FAO*, 2005; *FAO,* 2006].

It is on record that excessive clearing of natural forest for different land uses affects the ecological balance of the environment because the land's protective and regenerative properties are reduced, making the area susceptible to cataclysmic disasters such as soil erosion and nutrient exhaustion, especially in the Tropics. The response to the spate of declining fortune of the tropical forests in Nigeria as in other parts of the world is the establishment of forest plantations which began in the early 20^{th} century. Most of the species cultivated in the early stages of plantation establishment (1910 to 1930) were indigenous species like *Nauclea diderrichii, Entandrophragma spp, Khaya spp, Guarea* spp, *Melicea excelsa, Afzelia africana, Cedrela odorata, Albizia lebbek, Azadirachta indica Cassia siemea, Dalbergia sissoo*. The initial aim of plantation forestry in Nigeria was to stimulate natural forest through planting mixtures of indigenous species. This explains why majority of early plantations were mostly mixed stands of indigenous species. However, the aim has since shifted to meeting the anticipated challenges of wood deficit, fuel wood shortage and providing raw materials to feed the pulp and paper industries.

Consequently, the choice of species changed from indigenous to fast growing exotic species. Between the 1920s and early 1940s, *Tectona grandis* and *G. Arborea* were tried and found to have impressive growth. By the mid 1940s, *Tectona grandis* plantations had been established in forest reserves in many parts of the country (Ilorin, Olokemeji, Mamu and Gambari, Omo, Oluwa, Akure, Onitsha, Umuahia, Obubra, Ikom, Ogoja, Auchi, etc). Apart from *Teak* and *Gmelina*, other exotic species tried in Nigeria included *Eucalyptus* spp, *Pinus* spp, etc. Teak (*Tectona grandis*) which is well-known is the focus of this research. It is a woody species, which is particularly suitable for rapid production of large volumes of timber, poles and fuel wood and is widely used as lumber for shipbuilding and general carpentry. It is originally found in Southeast Asia and is one of the most widely introduced species out side its natural zone. Around fifty African, Caribbean, Central American and other tropical countries have witnessed

successful introduction of teak. Today, teak ranks among the top five tropical hardwood species in terms of plantation area established worldwide [*Krishnapillay,* 2000]. The good timber characteristics of *Teak*, its fast growth rate and high productivity led to its adoption in the 1960s as the most favoured exotic species for electrical pole and timber production. This was followed by large - scale planting of *Teak* plantations in many forest reserves in Nigeria. By the end of the 1960s, *Teak* has become the most dominant plantation species, which it has maintained till date, accounting for over 50% of total plantations in Nigeria.

A few studies have reported the effect of chemical or physical soil characteristics on wood quality [*Aguilar - Rodriguez et al.,* 2006] while very few studies have been carried out on Teak plantations comprehending the relationship of wood properties with soil characteristics, most of them have been carried out by private companies and are still unpublished. The aim of the present study is to analyze the effect of Teak plantation establishment on the soils chemical and physical characteristics in South West Nigeria. Furthermore, comparative studies are important ways for understanding the nutrient cycle under trees [*Proctor et al., 1983; Vitousek and Sanford,* 1986]. The rate at which different plant species immobilize nutrients varies, and results of studies on the more economically important tree plants such as Teak and gmelina can provide a rational basis for managing the soil under every plant. This emphasizes the need to examine the cycling of nutrients under exotic tree stands in the rainforest areas.

In Nigeria , extensive studies have been carried out on the effects of soil properties on the growth pattern of many tree crops including cocoa [*Ekanade,* 1988, *Kola Nut Egbe,* 1977; *Ekanade and Egbe,* 1990], [*Rubber Pushiparajah,* 1969, 1977; *Aweto,* 1987], oil palm [*Aweto and Ekuigbo,*1999, 2000], cashew [*Aweto and Isola,* 1995], Gmelinea Aborea [*Onyekwelu,* 2001; *Onyekwelu , et al* 2006; *Onyekwelu, et al.,* 2008; *Moreover, Aborisade & Aweto,* 1990] found that on moist sites where teak and *Gmelina* were planted, total exchangeable basic nutrients in the topsoil showed a definite decrease over those in the primary rain forest. It is also a widely held view that forest plantations could improve physico-chemical soil properties through litter fall addition, decomposition, and soil microbiological processes such as nitrogen fixation and mycorrhizal activity on previously degraded lands [*Evans,* 1992].

Although, it is widely reported in the literature that Teak has been studied rather in detail, especially in relationship with soil nutrient dynamics in the major soil types in south west Nigeria, but non has investigated the suitability of soils at the fringe of hydro orphic environment in the study area. Also, most recent site quality assessments on Teak plantations rely primarily on management strategies rather than the site ecological parameters (i.e. parent materials) which is an important soil forming factor which varies over space. In addition, some evidences have also emerged regarding site changes that may be induced by Teak plantations.

Despite the increasing level of plantation in replacement of the degraded natural forest to cater for high demand for this exotic species, there has not been much success in satisfying the demand. This is mainly because most of the plantations were established without due consideration for the prerequisite conditions required for the optimal growth of the tree species. This has led to further soil degradation and loss of nutrients in most of the plantations. The study therefore aims to examine soil properties and other conditions under Teak plantation in a newly established plantation in comparison with these properties in other countries where Teak grows naturally in order to arrive at a bench mark of soil properties and others that will assist in monitoring the changes that will occur over time since the species is not indigenous to the study area. Also, the study with the control point will be able to establish if significant changes have occurred in the physical and chemical properties of the soil.

To forestall planting trees in an environment where the edaphic factors do not match the site requirements of the species, this paper therefore aims to investigate whether the Teak plantation established a year ago by Lagos state government ministry of Agric and co-operative at Abia-Badagry meet the soil and environmental requirement as obtainable in countries where Teak grows naturally such as Laos Republic, and other countries where Teak dominate the world market such as Indonesia. Also the study will also establish whether the establishment of Teak tree has changed the soil properties. To do this, the site soil properties will be compared to the adjoining degraded secondary forest since the site was degraded before the establishment. The outcome of this investigation will help in formulating recommendations for the establishment of new plantations or extension of the current one.

Finally, recommendations on land management prior to planting and silviculture practices at planting and during the rotation length of the plantation stand will be formulated for establishing new Teak Plantations.

THE METHODS

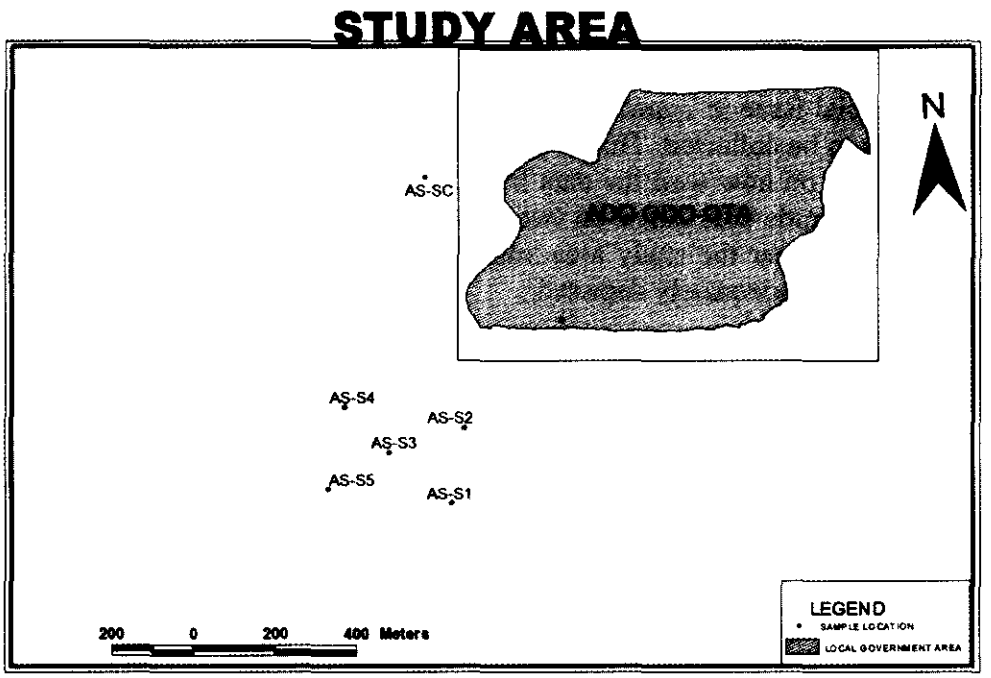
Sampling

A crucial issue in quantitative soil ecology is the selection of sample from which data is to be collected. This is because the reliability of the final conclusions depends largely on how well the data have been built [*Kershaw,* 1985]. Sampling design for this study was based on two premises: first, the need to spread sample sites objectively over the study area and second, the need to ensure that the site characteristics are adequately depicted.

The entire plantation is 2.5 ha and five soil samples were randomly collected from the plantation using soil auger .The sixth sample was collected from the adjoining degraded forest as a control since we do not have the soil status of the plantation before the establishment of the plantation.

Soil Sampling

From each of the five (5) holes dug, soil samples were randomly collected from two sampling depths 0 – 15 cm and 15 – 30 cm, hereafter referred to as topsoil and subsoil, respectively. The sampling was restricted to this zone because it provides the bulk of plant nutrients [*Russell,* 1978]. Soil samples were air-dried, sieved, and analyzed in the laboratory using standard techniques. Particle size composition was obtained by hydrometer method [*Bouyoucos,* 1962]. Soil pH was determined potentiometrically in 0.01m calcium chloride using a soil to calcium chloride solution ratio of 1:2 [*Peech,* 1965]. Organic carbon was determined by the Detjareff method [*Walkley and Black,* 1934]. The value of organic matter was obtained by multiplying organic carbon by 1.724. Extracts of soil sample leached with 1NB ammonium acetate were used to determine the concentrations of exchangeable cations, thereafter Ca, K and Mg were determined by atomic absorption and Na was determined by flame photometry. Exchange acidity was determined by extraction with barium acetate and titration with NaOH [*Jackson,* 1962]. Cation exchange capacity (CEC) was obtained by summation of exchangeable cations and exchange acidity. Total nitrogen was determined by the Kjedahl method and available phosphorus was determined by the Bray method [*Jackson,* 1970]. Base saturation was computed as the percentage of the total CEC occupied by cations. Extractable micronutrients (Zn, Cu, Ni, and Mn) were measured after extraction with 0.02M EDTA using atomic absorption spectrophotometer [*Isaac and Korber,* 1971].



The local government under which the study area is located covers an area of 1,460km$^{2.}$ It is bounded in the south and in the east by Lagos state, in the West by Ipokia and in the North by Yewa South and Ifo LG. The LGA falls within tropical climate with an average annual rainfall of 1540mm. It experiences an average daily temperature of 29^{0}C. The cover is dominated by evergreen rainforest. The state is located on sedimentary rock underlain by Ilaro geological formation. The topography is characterized by an undulating plain and rises gently from the Coastal plain to about 100m above sea level [*Onakomaiya et. al,* 2000]. Two types of seasons occur in the study area. The rainy season (between April - October) while the dry season occurs between November to March. The study area is endowed with fertile loamy soil which supports agricultural practices of different kinds. The study area is extensively cultivated for food crops such as cocoyam, cassava, maize and different types of vegetable and fruits. The population is about 526,565 [*NPC*, 2006] representing 14.12% of the state's population. The population is dominated by the Aworis, Egbas, Egun and Yewa sub-ethnic groups. The dominant human activities in the study area include farming, manufacturing, trading and fishing.

RESULTS AND DISCUSSION

Table 1: Results of soil sample analysis

Sample Code	Parameters Level Detected							
	pH	EC (μscm^{-1})	TOM (%)	TOC (%)	TN (%)	Av.K (%)	Av.P (%)	Bulk Density (g/cm3)
AS/SP_1	5.36	56	1.76	1.34	0.029	0.028	0.021	1.328
AS/SP_2	5.71	50	1.46	1.11	0.022	0.031	0.023	1.352
AS/SP_3	5.86	41	1.06	0.86	0.024	0.028	0.018	1.337
AS/SP_4	5.84	38	2.15	1.75	0.018	0.034	0.02	1.355
AS/SP_5	5.82	42	2.28	1.84	0.012	0.032	0.019	1.307
AS/SCP	5.72	39	2.41	1.92	0.021	0.029	0.022	1.341

Source: Fieldwork, 2009

Note: AS/S - Abia Soil Sampling Point, AS/SC - Abia Soil/Soil Control Point, EC - Electrical Conductivity, TOM - Total Organic Matter, TOC - Total Organic Carbon, TN - Total Nitrogen, Av.K - Available Potassium, Av.P - Available Phosphorus.

Table 2: Descriptive statistics of soil samples

	Mean	STD	C.V (%)	LCL	UCL
Ph	5.72	0.19	3.61	5.36	5.86
EC	61.00	46.73	76.61	38.00	156.00
TOM	1.85	0.52	28.11	1.06	2.41
TOC	1.47	0.43	29.25	0.86	1.92
TN	0.02	0.01	50.00	0.01	0.03
Av.K	0.03	0.00	0.00	0.03	0.03
Av.P	0.02	0.00	0.00	0.02	0.02
BD	1.34	0.02	1.49	1.31	1.36

Source: Fieldwork, 2009

LCL - Lower Confidence Level, LCL - Lower Confidence Level, UCL - Upper Confidence Level, C.V – Co - efficient of Variation, STD – Standard Deviation.UCL - Upper Confidence Level, C.V – Co - efficient of Variation - STD - Standard Deviation

The result of the soil analysis show that pH, EC, TOM, TOC, TN, Av.K, Av.P and Bulk Density ranges between, 5.36-5.86, 38.00-156.00, 1.06-2.41, 0.86-1.92, 0.01-0.03, 0.03-0.03, 0.02-0.02 and 1.31-1.36 respectively. Among the examined variables, Ec has the highest mean (61.00) followed by pH (5.72) while TN/Av.P remained the least value (0.02). Also, EC recorded the highest Standard Deviation (46.73) this was followed by TOM (0.52) while Av.K/Av. P recorded the least value of (0.00). On the pattern of relative variation, the result of the Coefficient of Variation (C.V) shows that all the examined Soil parameters with the exception of EC are homogenous within the study area (see table 1).

Table 3: Relationship among parameters

		pH	EC	TOM	TOC	TN	Av.K	Av.P	BD
pH	C	1							
	P-Value								
EC	PC	-.954(*)	1						
	-Value	.003							
TOM	PC	.010	-.129	1					
	P-value	.985	.807						
TOC	PC	.088	-.193	.996(**)					
	P-Value	.868	.713	.000					
TN	C	-.699	.694	-.550	-.597				
	P-Value	.122	.126	.258	.211				
Av.K	PC	.493	-.475	.451	.483	.735			
	P-Value	.320	.341	.369	.332	.096			
Av.P	PC	-.439	.176	.204	.133	.261	.000		
	P-Value	.384	.739	.698	.801	.617	1.000		
BD	PC	.137	-.232	-.223	-.223	.316	.196	.456	
	P-Value	.796	.659	.670	.671	.542	.710	.363	

Source: Fieldwork, 2009

** Correlation is significant at the 0.01 level (2-tailed).

PC-Pearson Correlation

The correlation analysis shows that there is significant positive Correlation between pH and Electrical Conductivity (EC).Also Total Organic Matter (TOM) exhibited a significant Correlation with Total Organic Carbon (TOC).Similarly; there is significant Correlation between Available Potassium (Av.K) and Available Phosphorus (Av.P) table 3.

The physical and chemical properties of soils under Teak plantation are shown in Tables 1 and 2. The soil contain a high proportion of sand (greater than 60% of the mineral fragments) but with low proportion of loamy (about 20%), hence the soil of this area is sandy-loamy. The electrical conductivity of the soil is high. Electrical conductivity is a measure of the rate of water transmission in soils; therefore, the high value obtained in this study may be due to the sandy texture of the soils, which enhances free water flow [*Lombin*, 1986]. Soil pH reveals that the soil is mildly acidic with mean value of 5.7. This condition in soil is favorable to nutrient uptake by plants [*Tisdale and Nelson*, 1975]. Organic matter content especially is the topsoil is moderate with a mean value of 1.85.

The exchangeable cations occur in moderate concentrations. The level of exchangeable cations in this soil is adequate compared to the values which [*Jones and Wild*, 1975], reported are required for high fertility in Savanna soils. Total nitrogen and available phosphorus are also high, especially in the topsoil layer. The topsoil properties accounted for between 80.4 and 100 percent of the total variance in the growth parameters. Topsoil properties, which are very crucial to the growth of this tree crop, are soil pH, organic matter, extractable zinc and nickel. A corresponding analysis of the subsoil relationships reveals that electrical conductivity total nitrogen, available phosphorus, and extractable nickel are crucial to the growth and productivity of this tree crop.

The importance of organic matter, nitrogen, and available phosphorus is not in doubt. While nitrogen and phosphorus are essential organic nutrients necessary for plants growth, organic matter is a storehouse of these nutrients. Nitrogen is a major constituent of all proteins and, hence, all protoplasm, it causes increase in leaf growth [*Woomer and Swift*, 1994]. Phosphorus is also a vital ingredient for many enzymic reactions that depend on phosphorylation and it is necessary for the development of meristern tissues [*James*, 1973].

On the objective which investigated whether the soil properties of the study area is in any way similar to that of the countries where Teak grows naturally. It is widely known that apart from India, which is one of the countries hosting the natural habitat of Teak. Indonesia becomes both a veritable producer and consumer of teak. In the worldwide distribution, the pattern of Nigeria as Teak producer is still relatively insignificant compare to the whole production worldwide. However, Nigeria in the next few years will become a key player in the production and consumption of the tree .It is therefore, the soil physicochemical properties must be compared with the natural habitat of the species to be able to establish the constraints in the area of edaphic factors affecting the growth and production of the tree.

The Climatic parameters of the natural habitat of Teak are summarized below to see similarities and differences with the climate in the area under study.

Table 4: Climatic variables of different tropical countries / areas under which teak occurs naturally and /or as forest plantations

COUNRY	Mean Annual Rainfall (mm)	Mean Annual Temp. (OC)	Above Mean Sea Level (m)
Natural Habitat	1250-3750	mm 13-17 max 39-43	NA
Indonesia (Eastern Java)	1511-2108	30-32	100-1000
India (Central)	1600-1800 >2500	25 Min 19 max 35	NA 100-150
India (Nilabur south)			
Eastern Panama	2300	23-27	NA
NW Costarica	2900	26-29	90
Benin Republic	1100-1150	25-29	40-80
Liberia	2223-3221	25-27	NA
Togo	1200-1500	Na	NA
SW Cote - D'voire	1700-2100	28-35	110-200
Southern Sudan	1350-1600	28-35	800-1000
Western Nigeria	1100-1300	25-28	20-60

Source: Modified from Ombina, 2008
Note: NA-Not Available).

Within these boundaries, teak occurs naturally in moist and dry deciduous forest below 1000 m elevation in localities with annual rainfall of 1250 - 3750 mm, minimum temperature of 13°C to 43°C (Pndey & Brown, 20020 some climatic data from different countries managing Teak plantations are grouped in Table 4 above. The table revealed that the mean annual rainfall generally varies between 1100n mm and 3750 mm with the lowest mean being recorded in Tropical Africa (Benin) and the highest in the countries hosting the natural habitat of Teak (Myanmar and Thailand). The minimum and maximum mean annual temperature range from 19 to 43oC respectively. The hottest areas host the natural habitat of Teak. Due to the fact that climatic elements such as rainfall and Temperature among others are edaphic factors have impacts on plant physiological development and the life of micro-fauna which are responsible for tree litter decomposition resulting in the formation of soil organic matter, it is necessary to consider these factors during the process of establishing a site's suitability. It is revealed that there is not much difference in the climatic parameters of the natural habitat of Teak and that obtainable in the study site.

According to [*Mallpurreddi,* 2002], the prime controlling factors for development of organic matter is climate through its influence on litter production and its decomposition. However, the substratum on which plants are established also plays a crucial role not only because it anchor plant root system but also because it supplies mineral nutrients. The suitability of growing Teak in the Tropics, can be seen in Table 5 below showing the soil properties of countries and areas where Teak grows naturally.

Teak grows well on sandy loam soil implying good water drainage with a depth>90cm and near neutral status: PH of between 6.5 and 7.5 [*Zanin,* 2005]. The main soil physical characteristics for teak suitability are those of sandy loamy texture on a parent material derived from plutonic 9granite0 and metamorphic (gneiss). The PHs values cover a wide range but when considering the recorded data of India and Myanmar, the PH interval of 6-8 measured in H2O can be regarded as the best optimum.

Table 5: Soil characteristics data of different countries under teak plantation area

Country	Soil texture	Soil type	Parent rock	PH
Indonesia (Eastern Java)	NA	Karts, grim sol	NA	NA
India	Clay	Vertisol	Basalt,Sandstone	NA
(central)India	Sandy loam	NA	Alluvium	7.9
(south) Nillabur		NA	Literate	NA
NW Coastal Rica	Clay loam	Eutric, Calac vertisols	clay	5.5-8
LIBERIA	NA	Ferrasols, Cleysols	Granite,Gnesis,Diorrite	NA
Cote D"voire	Clay loam	NA	Granite,Gneisis	NA
Western Nigeria	Sandy loamy	Sandy loamy	Sandstone, Alluvium	5.72

Source: Modified from Ombina, 2008

CONCLUSION

Based on the empirical data and the analysis carried out on the Teak plantation and the site characteristics to find out the suitability or otherwise of the site for maximum Teak yield in the country, it was found that the site characteristics, especially, soil properties are similar to those of places where Teak grows naturally or where they have it in large plantation over the world.

Therefore it is recommended to Lagos state ministry of Agric and cooperative to increase the plantation in area size especially the degraded forests. After the establishment, the growth of annual crops especially those that require the nutrient given by Teak and those that will give the minerals required by Teak. Furthermore, good growth and yield of this crop can be maximized through agronomic practice, which would enhance the level of organic nutrients and reduce soil acidity.

REFERENCES

Aweto, A.O (1987), Physical and Nutrient Status of Soil under Rubber (Hevea brasiliensis) of Different Ages in South Western Nigeria. *Agricultural Systems, 23,* 63-72.

Aweto, A.O. and Ekuigbo U.E (1994), Effects of Oil Palm Plantations on Tropical Forest Soils in South Western Nigeria. *The Indonesia Journal of Geography 26,* 51-59.

Aweto, A.O. and Ishola, M.A (1995), The Impact of Cashew (Anacardium occidentale) on Forest Soils. *Experimental Agriculture*, 30, 337-341.

Bouyoucos, G.J. (1962), Estimation of Colloidal Material in Soils. *Science, 64*,632.

Egbe, N.E (1973). Soil of Kola (Cola nitida. Vent, Sciott and Endlicher) groves in Western Nigeria.*Ghana Journal of Agric. Science, 6*, 149-153.

Ekanade, O. & Egbe, N.E (1990), Analytical Assessment of Agro forestry Practices Resulting from Interpolating Cocoa and Kola on Soil Properties in Southwestern Nigeria. *Agriculture, Ecosystem and Environmental, 30,* 337-346.

Ekanade, O (1985a), the Impact of Cocoa Cultivation on Soil Properties in South Western Nigeria. Unpublished PhD Thesis, University of Ife 305pp.

Ekanade, O (1988), the Nutrient Status of Soils under Peasant Cocoa Farms of Varying Ages in Southwestern Nigeria. *Biological Agricultural and Horticulture, 5,* 155 - 167.

Evans, J (1999), Sustainability of forest plantations: a review of evidence and future prospects. Int. *Forestry Rev. 1 (3),* 153–162.

Evans, J., Turnbull, J.W (2004), Plantation Forestry in the Tropics, third ed. Oxford University Press, 467 pp.

FAO (2005), State of the World's Forests 2005. FAO, Rome, 153 pp.

FAO (2006), *Global planted forest thematic study: results and analysis*, by Del Lungo, J.B. & Carle, J. Planted Forests and trees: Working paper 38. Rome.

FRA (2000), Global Forest Resources Assessment 2000. FAO Forestry Papers 140. FAO, Rome.

IUCN/WWF (1987) Centres for plant diversity. A guide and strategy for their conservation. IUCN Threatened plant unit/WWF plants conservation programme, Kew, London, UK.

Jackson, M.L (1970), *Soil Chemical Analysis, Prentice Hall, Englewood, Cliffs, New Jersey.*

James, W.G (1973), *an Introduction to Plant Physiology*. 7th edition, Oxford University Press, London. Pg.181.

Jones, M.J. & Wild, a (1975), Soils of the West African Savanna. *Techno. Comm. No 55* Comm. Bureau of Soils. Harpenden. Krishnapillay, B. 2000. Silviculture and management of teak plantations. Internet document. http://aginfo.snu.ac.kr/research/unasylva/pdf/ 201_03.pdf.

Lombin, G (1986), *Introduction to Tropic Palm Agriculture*. London, Longman.

Muciler-Dombois, D. & Ellenbery, H (1974), Aims and Methods of Vegetation Ecology Wiley, London.

Peech, M (1967), Hydrogen ion activity, In Black, C.A. (ed) *Methods of Soil Analysis Part 2*, p: 914 – 926 S.A. Madison Wisconsin.

Pushiparajah, E (1969), Nutrient and fertilizer use in Hevea brasiliensis and associated covers, in peninsular Malaysia, *Research Inst. Srilanaka 54*, 270-283.

Pushiparajah, E (1969), Response in growth and yield of Hevea brasiliensis to fertilizer application on Regnam soil series, *Journal Rubber Res. Inst. Malaya 21*. 165-174.

Russel, E.W (1967), Soil condition and Plant Growth, 9th edition Longman London 688pp.

Tisdale, S.L. & Nelson, W.L (1975), *Soil Fertility and Fertilizers*. Long.