

Research Article

Suitability Evaluation of Soils for the Cultivation of Coconut (*Cocos nucifera*) Along a Toposequence of Ogoni, Andoni and Opobo Unity Road, Rivers State, Southern Nigeria

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Abstract

A suitability assessment studies was carried out to assess the suitability of the toposequence along Ogoni, Andoni and Opobo unity road for the cultivation of coconut. Results obtained from the studies revealed sand fractions were high ranging from 81.6 – 84.6g/kg, followed by silt (11 – 17 g/kg) and clay (0.4 – 3.4) in that order. Soil reaction (pH) ranged from acidic to slightly acidic (5.62-6.53) with low organic carbon (0.1 - 0.99g/kg) and total nitrogen (0.009-0.005g/kg). The potassium contents were moderate; while exchangeable cations and available phosphorus were very low. The results also showed that pedon 1, 2 and 3 were moderately suitable (S2) for coconut cultivation but with limitation in fertility especially low organic carbon and soil physical characteristics in term of erosion hazard and flood. Therefore in optimizing and sustaining the soils for coconut production, appropriate management practices to remedy erosion and the poor drainage condition due to flood and fertility of the soils should be developed and applied to boost coconut production in the area. Planting of cover crops and application of organic residue should be considered especially in area due to the sandy texture of the soils for coconut cultivation. Furthermore, the study shows that coconut can be cultivated in the environment due to favourable climatic and edaphic condition in the study area.

Keywords

Actual Land Suitability, Climatic Condition, Coconut Palm, Permanently Not Suitable, Tree of Heaven

1. Introduction

Land evaluation is the process of assessment of land performance for specified purposes [14, 21]. Land suitability evaluation is the degree of the appropriateness of land for a certain use. Land suitability could be assessed for present condition (Actual Land Suitability) or after improvement (Potential Land Suitability) [12, 17, 21]. To assess the suitability of an agricultural land, land, the climate, topography, wetness, soil physical properties and fertility (crop require-

ments or needs) are to be evaluated before the land can be used [19, 12]. The result from land suitability evaluation can be highly suitable (S1), moderately suitable (S2), marginally suitable (S3) not suitable (N) currently not suitable (N1) and permanently not suitable (N2) as the case maybe. Most of problems the encountered in coconut production in most West Africa countries are nutrient (fertility) base and partly climatic elements [1]. In Nigeria Coconut palm, is at present grown in

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few states of the southern state, predominantly in coastal states such as Rivers, Delta, Lagos, Edo, Ondo, and Bayelsa. Under natural environments, coconut yield pattern has been found to follow seasonal cycles, just like the oil palm [1]. Rainfall, temperature and drought are among the climatic factors that influence coconut yield pattern [17, 20, 18]. Tree of heaven (coconut) is a useful tropical plant which plays a major role in the economy of Nigeria. The coconut palm is veritable source of income to boost the economy of the many nations where it is grown extensively.

Coconut provides sustainable source of employment to more than 10 million people; adding that it is widely used as raw materials to some industries to manufacture coconut oil, milk, cream, coconut water, desiccated coconut, coconut flour, oil cake, soaps, hair oil, cosmetics and coconut fibre [6]. Coconut adapt to a wide range of soils with good climate condition and elevation above sea level. Most at times, coconut and other tree crops such as rubber are widely grown and cultivated within coastal region because it serves as a good indicator against coastal erosion [16]. This research aimed at assessing the potentials of soils of the study area for the cultivation of coconut to meet up both the nutritional and economic need of the people and improve their standard of living. To achieve this goal, it is very necessary to have a more comprehensive approach to solving the soil nutritional needs and moisture requirement in ascertaining the suitability of the soils to promote the survival and cultivation of coconut as a tree crop in the area. Therefore, the main aim of this study or research, was to evaluate the suitability of soils along a toposequence of Ogoni, Andoni and Opobo Unity Road Rivers State for coconut cultivation.

2. Materials and Method

2.1. Description of Study Location

The study was conducted along a toposequence of the Ogoni, Andoni and Opobo unity road in Khana Local Government Rivers State. It lies between latitude 4.671 72N and longitude 7.34398E. The rainfall distribution in the study area ranged between 2000 — 2500 mm per annum [13, 15]. The monthly minimum and maximum temperature varies between 25 °C and 28 °C with relative humidity of 81- 87% depending on the season of the year [4]. The vegetation of the study area is the multistoried high tropical rainforest characterized by diversity of some tree species that has been seriously altered by the impact of crude oil pollution, unrestrained forest utilization and continuous land cultivation [15]. Some of the tropical trees species in the area are *Delinox regia*, *Chrotariaexelsa*, *Mahogany*, *iroko*, etc. Soils of the study area are well drained soils derived from coastal plain sand and alluvium of marine deltaic deposits commonly called Ogoni sands [13, 14].

2.2. Field Work

A pre-field visit was carried out to identify a toposequence along the Ogoni, Andoni and Opobo unity road. Three mapping units were identified as summit, middle slope and valley bottom along the toposequence in the study area. Geographical coordinates of each mapping unit was taken using the portable handheld Geographical Positioning System (GPS). One modal soil profile pit (2m×2m×2m) each was dug and described according to [15]. Soil samples were collected from each identified horizon in the soil profiles and was subjected to laboratory analyses using standard procedures at the Soil Science Laboratory, Department of Crop/Soil Science, Faculty of Agriculture, Rivers State University, Port Harcourt - Nigeria.

2.3. Laboratory Analysis

Soil particle size analysis was determined by hydrometer method as described by [25]. Textural class was determined using textural triangle, Bulk density was determined from the undisturbed core sampler [9]. Soil pH was determined in water by the pH meter electrode [23]. Total nitrogen was determined by the macro-kjedahl digestion distillation method [22]. Organic Carbon was determined by the [7] method. Available phosphorous was determined using [24] method. Exchangeable Bases (Ca^{2+} , Mg^{2+} , Na^{+} and K^{+}) were extracted by 1N NH_4OAc buffered at pH7 [26]. Ca and Mg were determined using Ethylene diamine tetra acid (EDTA) titration method, while the concentration of Na and K were measured with the flame photometer method. Cation Exchange Capacity was determined by the summation method of sodium (Na), potassium (k), magnesium (Mg) and Calcium (Ca) after determination of their exchange values [8,26] (Zhao, et al 2020). Effective Cation Exchange Capacity was determined by submission of exchangeable bases and total exchangeable acidity. Total Exchangeable Acidity was determined using the titration.

3. Results and Discussion

3.1. Morphological Characteristics

Table 1 shows the morphological characteristics of soils of the study area. The result indicated that the in pedon 1 (summit), soil colour varies between dark brown (7.5R $\frac{3}{4}$) at the surface to dark brown (7.5R $\frac{3}{4}$) at the sub surface when moist. Other soil morphological properties such as soil structures, consistence, drainage, boundary and roots differ from one pedon to another. In pedon 2 soil texture was loamy sand at the surface and sandy at the sub surface level. The soil colour matrix of pedon 2 (middle slope) ranged from very dark brown (7.5R 2.5/3) at the surface, to dark yellowish brown (10YR $\frac{3}{4}$) at the sub surface when moist; while soil texture in pedon 2 (middle slope) was loamy sand at both the

surface and subsurface level. Soil texture has been reported to directly influence the moisture status of low land soils [10]. This is because, it influences soil permeability and hence soil moisture redistribution and water holding capacity [11]. Pedon 3 (valley bottom) was characterized by strong brown

(10YR 2.5/3) at the surface soil level to brown (10YR 4/3) at the sub surface level and soil texture was loamy sand at the surface, and sandy loam to loamy sand at the sub surface level.

Table 1. Morphological Characteristics of soils of the study Area.

Pedon designation	Horizon Depth (cm)	Colour (moist)	Tc	Structure	consistence	Drainage	Bound-ary	Roots
Pedon 1 Summit								
AB ₁	17-35	7.5R ¾ db	Loamy Sand	FG	F	WD	Cs	M ₁ rts
AB ₂	35-78	7.5R 2./3 vdb	Sandy loam	FG	F	WD	DF	CL rts
Ah	0.17	57R 2.5/2 drb	Loamy Sand	FG	F	WD	DF	F1 rts
B	78-200	7.5R 2.5/2 db	Sandy loam	Crumby	F	WD	DF	VF1 rts.
Pedon 2 (Middle Slope)								
A	0.23	7.5R 2.5/3 vdb	Loamy Sand	SBK	FI	WD	CS	VF1 rts
B	23-69	7.5R 5/8 sb	Loamy Sand	SBK	FI	WD	CS	VF1 rts
AB1	69-200	10YR 3/4 dyb	Loamy Sand	SBK	F1	WD	AW	VF1 rts
Pedon 3 (Valley Bottom)								
AB ₁	0-26	10YR 2.5/3 sb	Loamy Sand	SBK	F11	WD	CS	M1 rts
AB ₂	26-78	10YR 3/4 dyb	Sandy loam	SBK	F1	WD	CS	M rts
Ah	78-20	10YR 4/3 b	Loamy sand	SBK	F1	WD	CS	M2 rts

3.2. Physical Characteristics of Soils of the Study Area

Table 2 also shows the physical characteristics of the soils in pedon 1 – 3. Sand fraction dominates the particles size distribution ranging from 816 – 846 g/kg, silt (120 – 170 g/kg) and clay (4 – 34 g/kg); while soil bulk density in pedon 1 ranged from 1.5 – 1.78 g/cm³ and total porosity that varied from 38.28 – 42.41%. The results obtained as shown in Table 2 indicated that in pedon 2, sand fraction also ranged from 826 – 846 g/kg I, the middle slope, 110 - 160 g/kg (silt), 14 – 34 g/kg (clay). Soil bulk density ranged from 1.60 – 1.80 g/cm³; while total porosity ranged between 34.84 – 40.01%. The result also indicated that in the pedon 3 (valley bottom), sand fraction was also higher (816 – 846 g/kg) followed by silt (130 – 160 g/kg) and clay fraction had the

lowest (14 – 24 g/kg). Pedon 3 (valley bottom) had bulk density of 1.52 – 1.79 g/cm³ and total porosity of 38.28 – 42.8%. There was an increased in sand fractions at surface soil level but decreased down the depth of the profile, while clay increased down the soil profile. The high level of sand fraction in the particle size distributions is an evidence of the type of parent materials from which the soils were formed and the coastal nature of the study area (Peter *et al*, 2019). Low clay content in pedon 2 (middle slope) in the B horizon could be due to erosion and in pedon 3 (valley bottom), especially in the AB1 horizon, was due to seasonal water logging which could hinder pedogenic processes and loss of clay when the soils are flooded during the rainy season [3, 5, 15]. Silt content was high in pedon 1 and varied from 14 – 16g/kg. The bulk density of the soil ranged from 1-61 to 1-78g/cm³ and fluctuated with increasing depth.

Table 2. Physical Characteristics of soils of study area.

Pedon Designation	Horizon depth (cm)	Sand	silt	clay	BD (g/cm ³)	Tp (%)	Tc
		→ g/kg ←					
Pedon 1 (summit)							
AB ₁	17-35	83.6	14	2.4	1.6	40.2	Loamy Soil
AB ₂	35-78	82.6	17	0.4	1.72	38.28	Sandy loam
Ah	0-17	84.6	12	3.4	1.521	39.24	Loamy soil
B	78-200	81.6	16	2.4	1.78	42.41	Sandy loam
Pedon 2 (Middle Slope)							
A	0-23	84.6	11	3.4	1.71	38.24	Loamy Soil
AB	23-69	82.6	16	1.4	1.60	40.01	Loamy Soil
B	69-200	83.6	14	2.4	1.80	34.84	Loamy Soil
Pedon 3 (Valley Bottom)							
ABI	26-78	82.6	16	1.4	1.72	38.275	Loamy Soil
AB2	78-200	81.6	16	2.4	1.79	42.8	Sandy loam
Ah	0-26	84.6	13	2.4	1.52	39.23	Loamy Soil

Structure: FG= Fine Grain, SBK= Subangular blocky. Consistency: F= Friable, F1= Firm, Drainage: WD= Well drain. Boundary: CS= Clear smooth, DF= Diffused, AW= Abruptly wavy, Root: MF₂rts= many fine roots, CL= Common fine roots

3.3. Chemical Characteristics of Soils of the Study Area

Results obtained on chemical properties of the soils are presented in Table 3. Soil reaction (pH) were strongly acidic to slightly acidic (pH5.05 - 6.53). Acidification or lowering of soil pH has negative impact on most crop growth (Horneck et al., 2011). Organic carbon contents was low between (0.10-1.21kg/kg). The organic matter (OM) content of the soils ranged between 0.87-2.08g/kg. The highest value occurred in

the surface soil of pedon 2 (middle). This could be attributed to the influx of organic materials into the middle slope as a result of the kind of rainfall experienced in the area [18]. It was an indication of accumulation of plant litters (leaves, stems) transported by erosion and deposit from the upper slope. The total nitrogen value were very low (0.001-0.208/kg). The low content could be as a result of leaching, rapid microbial activities and crop removal, leading to nitrate loss in the soil environment [1]. This is an obvious reason to expect a decreased level of the nitrogen content of the soil as OM is essentially the main source of nitrogen.

Table 3. Chemical Properties of soils of the study area.

Pedon Des-ignation	Horizon Depth (cm)	Ph (H ₂ O)	OC g/kg	OM	TN	AIV.P Mg/kg	Ca	Mg	K	Na	EA	EH	TEA	ECEC	CEC	BS%
							Cmol/kg	Cmol/kg	Cmol/kg	Cmol/kg	Cmol/kg	Cmol/kg	Cmol/kg			
Pedon (summit)																
AB ₁	17-35	5.62	0.10	1.21	0.009	14.0	1.20	0.40	0.80	0.26	0.49	0.51	1.00	2.98	1.94	65
AB ₂	35-78	5.50	0.70	1.21	0.008	29.8	0.20	0.6	0.19	0.26	0.60	0.62	1.22	2.29	1.25	54
Ah	0-17	5.38	1.21	2.08	0.208	42.1	0.6	1.8	0.19	0.18	0.25	0.25	0.50	3.77	2.77	73
B	78-200	5.81	0.51	0.87	0.015	33.2	1-00	0.6	0.16	0.18	0.31	0.35	0.66	3.06	1.94	63
Pedon 2 Middle Slope																

Pedon Designation	Horizon Depth (cm)	Ph (H ₂ O)	OC g/kg	OM	TN	AIV.P Mg/kg	Ca Cmol/kg	Mg	K	Na	EA Cmol/kg	EH	TEA	ECEC	CEC	BS%
A	0-23	5.05	1.21	2.08	0.012	28.0	1.8	0.80	0.23	0.17	0.21	0.18	0.39	3.87	3.00	77
B	23-69	5.25	0.51	0.87	0.001	45.6	0.8	0.20	0.08	0.14	0.52	0.56	1.08	2.30	1.22	53
AB1	69-200	0.66	0.66	1.14	0.002	49.1	0.2	0.60	0.09	0.14	0.47	0.53	1.00	2.15	1.03	48
Pedon 3 valley Bottom																
AB1	26-78	6.38	0.59	1.01	0.005	59.5	1.2	0.40	0.08	0.17	0.48	0.05	0.53	1.95	1.85	95
AB2	78-200	5.94	0.55	0.94	0.001	59.5	0.6	1.20	0.12	0.15	0.44	0.04	0.48	2.17	2.07	95
Ah	0-26	6.53	0.99	1.68	0.005	42.1	0.8	1.00	0.09	0.18	0.35	0.50	0.85	3.51	2.07	59

Table 4. Land and climate characteristics for suitability classes for coconut (*Cocos nucifera* L.).

Land use requirement/characteristics	Land Suitability class		
	P1	P2	P3
Annual mean temperature (tc)			
Annual mean temp	25-28 °C (S1)	25-28 °C (S1)	25-28 °C (S1)
Mean annual rainfall (mm)	2000-2500mm (S1)	2000-2500mm (S1)	2000-2500mm (S1)
Dry months (month)	2 months (S1)	2 month (S1)	2 month (S1)
Humidity (%)	81-90% (s1)	81-87 (S1)	81-87 (S1)
Drainage	WD (S1)	WD (S1)	WD (S1)
Soil texture	Vft (S1)	fine medium (S1)	Fine medium (S1)
Soil depth (cm)	200 (S1)	200cm (S1)	200cm (S1)
Thickness (cm)	52 (cm) (S1)	52 (cm) (S1)	52 (cm) (S1)
Base saturation (%)	65 (S1)	77-(S1)	95- (S1)
pH H ₂ O	5.62 (S1)	5.05 (S2)	6.38 (S1)
Organic carbon (%)	0.40 (S2)	1.21 (S2)	0.59 (S1)
Slope (%)	4% (S1)	>4 (S2)	>4 (S2)
Erosion hazard	>8% (S2)	>8.% (S2)	>8% (S2)
Flooding hazard (fh)	Fo (S1)	FO (S1)	FO (S1)
Surface stoninies (%)	(S1)	(S1)	(S1)
Rock out crops (%)	(S1)	(S1)	(S1)
Aggregate suitability class	S2 (Fs)	S2 (Fs)	S2 (Fs)

S1- highly suitable, S2, moderately suitable N2- Permanently not suitable, FS - Fertility soil characteristics, WD-Well drain.

Table 5. Summary of Land Suitability Evaluation for coconut production in Pedons 1, 2 and 3.

Land Requirements	P1	P2	P3
Temperature	25-28 (S1)	25-28 (S1)	25-28 (S1)

Land Requirements	P1	P2	P3
Total Rainfall	2000-2500 mm (S1)	2000-2500mm (S1)	2000-2500mm (S1)
Organic Carbon	0.40 (S2)	1.21 (S2)	0.59 (S1)
Flood Harzard	Fo (S1)	Fo (S1)	Fo (S1)
Soil Fertility (base saturation)%	65 (S1)	77 (S1)	95 (S1)
Soil Ph	5.62 (S1)	5.05 (S2)	6.38 (S1)
Aggregate Suitability Class	S2 (fs)	S2 (fs)	S2 (fs)

3.4. Suitability Characteristics of Soils of the Study Area

The climatic condition of the study area were rated as S (highly suitable) in terms of rainfall (2000 – 2500mm), mean annual temperature (25 – 28 °C) and humidity (87%). This was considered to be relatively adequate for coconut cultivation collaborating the report of [2, 8]. The slope, drainage, and flood hazard of the pedon vary and are rated as highly suitable (S1) respectively. The average depth in pedon 1, 2 and 3, was greater than 200cm and were rated as highly suitable (S1). The textural classes of the soils which include loamy sand at surface horizons to sandy loam and loamy sand at sub surface horizon is rated as highly suitable (S1) for pedon 1 2 and 3. Base saturation was high and rated as highly suitable (S1) in pedon 1 and 3, and moderately suitable (S1) for pedon 2. All other fertility requirements considered for this evaluation were optimal and rated as highly suitable (S1) and moderately suitable (S2) and aggregate suitability class of all the pedons were moderately suitable (S2) due to some limitation in soil physical characteristic and fertility (low organic carbon, erosion hazard and flood).

4. Conclusion

Result on some soil morphological, physical and chemical characteristics used for suitability evaluation of the study area indicated that, the study area, toposequence of Ogoni, Andoni and Opobo unity road is moderately suitable for the cultivation of coconut due to certain limitations in soil physical characteristic and fertility (low organic carbon, erosion hazard and flood). Thus, if proper management practices are adopted to remedy low soil fertility, erosion and flood, the study soils could be highly or moderately suitable (S1 or S2) for coconut cultivation in the study area. Currently, the soils is moderately suitable (S2), but potentially, its highly suitable (S1).

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Conflicts of Interest

The authors declare no conflicts of interest.

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