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Land suitability assessment of soils for rubber and cashew cultivation in the Coastal Area of Bodo City, Rivers State, Southern Nigeria

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Abstract

The research was carried out in Bodo city in Gokana Local Government of Rivers State, Southern Nigeria to evaluate the land suitability for rubber and cashew cultivation using the relevant land suitability guidelines for the cultivation of the two cash crops of interest. Mapping of the 100 ha of land in Bodo city was done using the rigid grid method of soil survey. The three mapping units (summit, middle slope and valley bottom) were identified and delineated. Three representative soil pedons of 2 m × 2 m × 2 m were dug and described by horizon from top to bottom (0 cm to 200 cm). Soil samples were collected from identifiable horizons and processed for laboratory analysis using standard routine laboratory methods most appropriate. The results showed that pedons 1 and 3 covering 86,000 ha of the entire study area were found to be moderately suitable for rubber cultivation with limitation in soil physical characteristics (texture) and fertility (low base saturation < 50 %). Pedon 2 covering 14,000 ha of the total land of the study area was marginally suitable due to limitation in soil fertility (low base saturation < 80 %). Pedon 1, 2, and 3 were also moderately suitable for cashew cultivation in the study area with limitation in soil physical characteristics (texture) and fertility (low organic carbon), while limitation in wetness (poor drainage) was peculiar to pedon 3 only. Thus, soils in the study area were moderately suitable for both rubber and cashew cultivation in the area.

INTRODUCTION

Land resources of Bodo River bank are threaten by coastal erosion, therefore, it is necessary to assess its suitability for selected tree crops cultivation such as rubber and cashew that are of economic importance, which is at the same time, very useful for shoreline protection purposes. Land suitability assessment is a process of estimating the agricultural potentials of land resources for specific use (Peter and Umweni, 2020 a). According to Peter and Umweni (2021), land suitability is also the compatibility of land productivity potentials for optimum crop production on sustainable basis. Rubber (*Hevea brassilensis*) is an important tree crop belonging to the Euphorbiaecea family cultivated for economic purposes. Diverse kinds of products are obtained directly and indirectly from rubber, in which the most important product with high economic value on commercial bases is the latex producing tissues, which is very useful in the production of synthetic rubber. Besides, rubber trees also produce seed and wood that are of economic value to the producers. Rubber is a quick growing tree crop developing more canopies due to its high population density and subsequently serving as windbreaker, which can be used for seashore line protections against coastal erosion. The dense tree canopies of rubber plants reduce the wind speed and velocity, which can be useful in controlling wind erosion. Rubbers are deep-rooted crops, but they

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also develop lateral roots that emerge from the tap root and produce network of roots at both surface and subsurface layers of the soils. Thus, it compacts the soils and subsequently prevents them from rapid detachment by coastal erosion. Cashew is another important tree crop in the humid tropic that produces both cashew nut and cashew apple. Some species are tall, while some are dwarf. Both qualities make them essential for shoreline protection against erosion. Apart from their shoreline protection value, cashew nut can be used as snack, while the apple can be processed into fruit drinks. Rubber and cashew have great economic potentials due to their commercial values and at the same time, they can be used in coastal area for shoreline protection. Therefore, the main objective of this study was to assess the suitability of soils for rubber and cashew cultivation along Bodo River bank in Gokana Local Government of Rivers State, Southern Nigeria.

MATERIALS AND METHODS

The study was carried out in Bodo city in Gokana Local Government Area of Rivers State. It lies between the Latitude of 4°60'38''N and the Longitude of 7°27'6'E (Figure 1). Rainfall in the study area occurs in late February to late December with the mean annual rainfall of 2000 mm to 2500 mm per annum. It has annual temperature of 25 °C to 28 °C and relative humidity of about 85 % depending on the season of the year. The soils of the study area are derived from the coastal plain sand and alluvium from deltaic marine deposits (Onweremadu and Peter, 2016). The vegetation of the study area is the humid tropic rainforest vegetation that has been drastically altered due to crude oil pollution and excessive deforestation.

Field work

A pre-field study was carried out to identify the various mapping units in the study area using topographic and geological maps. Three mapping units were identified as summit, middle slope and valley bottom. Soil pits were dug at the most representative points of observation in each mapping unit to conduct profile description. The size of soil profile pits was 2 m × 2 m × 2 m. Soil morphological and physical properties were assessed using the Food and Agriculture Organization (1990) guidelines. A handheld GPS was used to determine the geographic coordinates of each profile pit. Soil samples were collected at different horizons from bottom to top (200 cm to 0 cm) to avoid contamination. While soil color was determined using a munsell soil color chart. The disturbed soil samples collected were bagged in a well labeled polyethene bags. Undisturbed soil samples for bulk density determination were also taken using ring sampler.

Laboratory analysis

The collected soil samples were air-dried, ground and sieved using 2 mm mesh sieve. The parameters that were analyzed included particle size, which was determined using the bouyoucos hydrometer method (Gee, 2002). Textural class was determined using the soil textural triangle. Bulk Density was determined

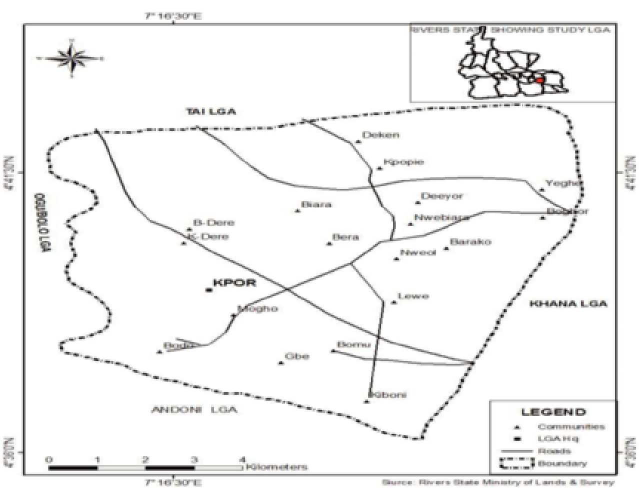

Figure 1. Map of Gokana Local Government Area, source: Government of Rivers State, Office of Surveyor General (2014)

Table 1. Guidelines for suitability evaluation of rubber (*Hevea brasiliensis*) cultivation (Sys, 1985)

Land suitability characteristics	Suitability classes				
	S1	S2	S3	N1	N2
Climate (c)					
Annual rainfall (mm)	> 1,700	> 1,450	> 1,250	-	≥ 1,250
Months of excessive rain (X)	< 2	< 3	Any	-	-
Length of dry season	< 2	< 3	< 4	-	≥ 4
Mean annual rainfall	> 22	> 20	> 18	-	≥ 18
Mean annual max. tempt.	> 27	> 24	> 22	-	≥ 22
Average daily max. coldest months	> 18	> 16	> 14	-	≥ 14
Topography (t)					
Slope (%)	< 8	< 16	< 30	< 45	≥ 45
Wetness (w)					
Flooding	F0	F0	F1 or Less	F3	F4 or less
Drainage	Well	Moderate	Imperfect	Poor Drainage	Any
Soil physical properties					
Texture/structure	C+60s to SCL	C+60s to Lfs	C+60s to fs	C+60s to fs	Cm to Cs
Coarse Fragments (vol %)	< 15	< 35	< 55 ≥	< 55	≥ 55
Soil depth	> 150	> 100	> 50	> 50	≥ 55
$CaSO_4$		No	No	< 1	< 1
Gypsum (%)	No	No	< 0.2	< 0.2	Any
Fertility characteristics					
CEC (meg.100 g^{-1} clay)	Any	Any	Any	Any	Any
Base saturation (%)	< 35	< 50	< 80	Any	Any
Organic matter ($g.kg^{-1}$)	Any	Any	Any	Any	Any
EC ($moles.cm^{-1}$)	< 1	< 1	< 2	< 6	Any

using the procedure described by Blake and Hartge (1986). Soil pH was determined using the electrometric method. Electrical conductivity was determined using the conductivity meter. Organic carbon was determined by Walkley and Black (1934). Total nitrogen was determined by the macro-kjedahl digestion distillation method (Bremner and Mulvaney, 1982). Available phosphorus was determined using Bray and Kurtz No.1 (1945) method. Exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) were extracted using 1N NH_4OAc buffered at pH 7. Ca and Mg were determined using Ethylene diamine tetra acetic acid (EDTA) titration method, while the concentration of Na and K was measured with the flame photometer method. Exchangeable acidity was determined using potassium chloride (KCL) method using a centrifuge.

Land suitability evaluation procedure

The suitability of soils along the coastal area of the study area was assessed for rubber and cashew cultivation. The evaluation was carried out using the various guidelines established for the cultivation of rubber and cashew. The potentials and defects of five land qualities such as climate, topography, wetness, soil physical properties and soil fertility were used in determining the suitability of the soils identified in the study site for the cultivation of both rubber and cashew. This was done in accordance with the established guidelines (Table 1 and Table 2) provided by Sys (1985) and Tyagi (2003). Land suitability classes for both crops (rubber and cashew) were obtained by matching some of the land qualities with the land use requirements for each of them in the study area. Meanwhile, aggregate suitability class revealing the degree of suitability of each pedon was then obtained using the law of minimum (Food and Agriculture Organization, 1984), which states that performance is always determined by the least favorable characteristic or plant nutrients in the lowest supply.

Table 2. Guidelines for suitability evaluation of cashew (*Anacardium occidentale* L.) cultivation (Sys, 1985 modified by Tyagi, 2003)

Land suitability characteristics	Suitability classes				
	S1	S2	S3	N1	N2
Climate (c)					
Annual rainfall (mm)	1,200–3,000	800–3,800	> 500	-	Any
Length of dry season	< 4	< 5	< 6	-	Any
Absolute minimum temperature (°c)	< 18	> 10	> 4	-	Any
Topography (t)					
Slope (%)	< 8	< 16	< 30	< 50	Any
Wetness (w)					
Flooding	No	No	No	No	Any
Drainage (4)	Good -	Imperfect	Imperfect	Poor	Any
(5)	Moderate	Fluctuation water table or best	Permanent high grand water or better	Drainable or better	Any
Soil physical properties					
Texture/structure	C+60s to LS	C+60s to fS	C+60v to cS	C+60v to cS	Any
Coarse Fragments (vol %)	< 15	< 35	< 55	< 55	Any
Soil depth	> 75	> 50	> 25	> 25	Any
$CaSO_4$	-	-	-	-	-
Gypsum (%)	-	-	-	-	-
Fertility characteristics					
CEC (meg.100 g^{-1} clay)	Any	Any	Any	Any	Any
Base saturation (%)	> 20	Any	Any	Any	Any
Organic matter (% c. 0-15)	> 0.8	Any	Any	Any	Any
Salinity and alkaline (n)					
EC (mmhos.cm^{-1})	-	-	-	-	-
Esp. (%)	-	-	-	-	-

RESULTS AND DISCUSSION

Soil morphological properties

Results of soil morphological properties as shown in Table 3 revealed that soils of the study area had very dark brown (10 YR 3/6) to yellowish brown (10 YR 5/8) color in pedon 1 (summit). In pedon 2 (middle slope), soil color ranged from brown (7.5 YR 4/3) to reddish brown (7.5 YR 6/8). It was also observed that in pedon 3 (valley bottom), soil color varied from very dark brown (7.5 YR 5/2) to reddish brown (7.5 YR 6/8). A very dark brown color, especially at surface soils levels, indicated the presence of organic matter and subsequent decomposition, while the reddish brown color (mottles) revealed the drainage condition of the soils. This is in line with the reports of Adegbite and Ogunwale (1997), Brady and Weil (2002) and Peter and Umweni (2020a). According to Amara-Denis et al. (2016), the well-drained nature of soils will assure high yield of crops in the study area. Soil textural classes in the study area were sand, loamy sand and sandy loam, respectively. Soils structures ranged from friable to fine texture with plastic to fine sticky consistence. The textural class indicated the parent materials; the sedimentary rocks and coastal plain sands underlying alluvium from which the soils were formed. This is in agreement with the reports of Peter and Umweni (2020a).

Soil physical characteristics

The particle size distribution data are presented in Table 4. The sand content varied from 834 g.kg^{-1} to 894 g.kg^{-1} . The silt content was low among all the particle size classes, which varied from 28 g.kg^{-1} to

Table 3. Soil morphological characteristics of the study area

Horizon design.	Horizon depth (cm)	Colour	TC	Structure	Consistence	Drainage	Boundary	Roots
				Pedon 1 (Summits)				
Ah	0–18	10 YR $^{4/3}$ very dark brown	Sand	Friable	Plastic	Well drained	Clear smooth	Few micro root
A	18–39	10 YR $^{4/3}$ very dark brown	Loamy sand	Friable	Plastic	Well drained	Clear smooth	Very few micro root
AB	39–82	10 YR $^{3/6}$ dark yellowish brown	Loamy sand	Fine	Sticky	Well drained	Diffused	No micro root
B	82–200	10 YR $^{5/8}$ yellowish brown	Loamy sand	Fine	Sticky	Well drained	Clear smooth	No micro root
				Pedon 2 (Middle slope)				
Ah	0–25	7.5 YR $^{2.5/2}$ very dark brown	Sand	Friable	Plastic	Well drained	Clear smooth	Few micro root
AB	25–50	7.5 YR $^{4/3}$ brown	Loamy sand	Fine	Sticky	Well drained	Diffused	Very few micro root
B	50–200	7.5 YR $^{6/8}$ reddish brown	Loamy sand	Fine	Sticky	Well drained	Clear smooth	No micro root
				Pedon 3 (Valley bottom)				
Ah	0–29	7.5 YR $^{5/2}$ very dark brown	Sandy loam	Friable	Plastic	Well drained	Clear smooth	Few micro root
AB	29–74	7.5 YR $^{4/3}$ brown	Loamy sand	Fine	Sticky	Well drained	Clear smooth	Very few micro root
B	74–200	7.5 YR $^{6/8}$ yellowish brown	Loamy sand	Fine	Sticky	Well drained	Diffused	No micro root

Table 4. Soil physical properties of the study area

Horizon design.	Horizon depth (cm)	Sand ($g.kg^{-1}$)	Silt ($g.kg^{-1}$)	Clay ($g.kg^{-1}$)	Bulk density ($g.cm^{-3}$)	Textural class
			Pedon 1 (Summits)			
Ah	0–18	894	68	38	1. 21	sand
A	18–39	834	88	78	1 .26	loamy sand
AB	39–82	834	68	98	1 .39	loamy sand
B	82–200	840	82	78	1 .45	loamy sand
			Pedon 2 (Middle slope)			
Ah	0–25	880	82	38	1 .00	Sand
AB	25–50	840	82	78	1 .50	Loamy sand
B	50–200	854	28	118	1 .48	Loamy sand
			Pedon 3 (Valley bottom)			
Ah	0–29	887	78	35	1 .01	Sandy loam
AB	29–74	842	80	78	1 .50	Loamy sand
B	74–200	834	46	120	1 .57	Loamy sand

Table 5. Soil chemical properties of the study area

Horizon design.	Horizon depth (cm)	pH (H_2O)	Org. C ($g.kg^{-1}$)	Org. M ($g.kg^{-1}$)	T.N. ($g.kg^{-1}$)	Avail P $mg.kg^{-1}$	Ca^{2+}	Mg^{2+}	K^+	Na^+	$EA1^{3+}$	EH^+	TEA	ECEC	BS %
							←			($cmol.kg^{-1}$)				→	
						Pedon 1 (Summit)									
Ah	0-18	5.66	14.15	24.59	1.39	10.88	0.78	0.40	0.200	0.183	1.76	1.04	2.80	4.483	34.865
A	18-39	5.43	11.11	19.15	1.08	15.63	1.0	0.81	0.189	0.162	1.84	1.65	3.49	5.651	38.039
AB	39-82	6.08	12.08	20.83	1.04	9.27	1.0	0.82	0.177	0.135	1.15	1.03	2.18	4.312	49.44
B	82-200	6.13	5.13	9.75	0.54	12.43	0.60	0.41	0.170	0.140	0.84	0.52	1.36	2.68	49.254
						Pedon 2 (Middle slope)									
Ah	0-25	6.16	10.57	18.23	1.09	6.23	0.63	0.23	0.301	0.607	1.14	0.496	1.64	3.408	51.86
AB	25-50	5.94	8.28	14.27	0.89	4.76	0.37	0.12	0.254	0.47	0.624	0.432	1.056	2.280	54.1
B	50-200	5.96	4.39	7.57	0.39	2.94	0.19	0.05	0.277	0.411	0.720	0.432	1.152	2.06	46.65
						Pedon 3 (Valley bottom)									
Ah	0-29	6.08	10.08	16.31	0.91	39.18	1.51	0.96	0.20	0.22	1.70	1.57	3.25	6.10	46.95
AB	29-74	5.54	7.15	12.05	0.63	26.16	0.20	0.41	0.18	0.21	1.46	1.41	2.86	4.52	34.10
B	74-200	6.11	6.27	10.77	0.60	13.23	1.06	0.34	0.16	0.19	1.33	1.05	2.38	4.08	41.92

Table 6. Summary of suitability evaluation of rubber (*Hevea brasiliensis*) cultivation in pedons 1 – 3

Land suitability characteristics	Suitability classes		
	Pedon 1	Pedon 2	Pedon 3
Climate (c)			
Annual rainfall (mm)	2,000–2,500 (S1)	2,000–2,500 (S1)	2,000–2,500 (S1)
Months of excessive rain (X)	1 (S1)	1 (S1)	
Length of dry season	2 (S1)	2 (S1)	2 (S1)
Mean annual rainfall	23 (S1)	23 (S1)	23 (S1)
Mean annual max. tempt.	28 (S1)	28 (S1)	28 (S1)
Average daily max. coldest months	-	-	-
Topography (t)			
Slope (%)	7 (S1)	7 (S1)	14 (S1)
Wetness (w)			
Flooding	F0 (S1)	F0 (S1)	F0 (S1)
Drainage	WD (S1)	WD (S1)	MWD (S2)
Soil physical properties			
Texture/structure	Loamy sand (S2)	Loamy sand (S2)	Sandy loam (S2)
Coarse Fragments (vol %)	Non (S1)	Non (S1)	
Soil depth	> 200 (S1)	> 200 (S1)	> 200 (S1)
$CaSO_4$	Non (S1)	Non (S1)	Non (S1)
Gypsum (%)	Non (S1)	Non (S1)	Non (S1)
Fertility characteristics			
CEC (meg.100 g^{-1} clay)	3.26 (S1)	2.1 (S1)	3.1 (S1)
Base saturation (%)	40.58 (S2)	52.98 (S3)	36.45 (S2)
Organic matter ($g.kg^{-1}$)	0.55 (S1)	0.67 (S1)	0.62 (S1)
EC ($moles.cm^{-1}$)	0.43 (S1)	0.43 (S1)	0.43 (S1)
Aggregate suitability class	S2 (f)	S3 (f)	S2 (f)
Size (ha)	46,000	14,000	40,000
% coverage	46 %	14 %	40 %

Table 7. Summary of suitability evaluation for cashew (*Anacardium occidentale* L.) cultivation in pedons 1–3

Land suitability characteristics	Suitability classes		
	Pedon 1	Pedon 2	Pedon 3
Climate (c)			
Annual rainfall (mm)	2,000–2,500 (S1)	2,000–2,500 (S1)	2,000–2,500 (S1)
Length of dry season	2 (S1)	2 (S1)	2 (S1)
Absolute minimum temperature (°c)	18 (S1)	18 (S1)	18 (S1)
Topography (t)			
Slope (%)	7 (S1)	7 (S1)	7 (S1)
Wetness (w)			
Flooding	F0 (S1)	F0 (S1)	F0 (S1)
Drainage (4)	WD(S1)	WD (S1)	MWD (S2)
Soil physical properties			
Texture/structure	Loamy sand (S2)	Loamy sand (S2)	Sandy loam (S2)
Coarse Fragments (vol %)	Non (S1)	Non (S1)	Non (S1)
Soil depth	> 200 (S1)	> 200 (S1)	> 200 (S1)
$CaSO_4$	-	-	-
Gypsum (%)	-	-	-
Fertility characteristics			
CEC (meg/100g clay)	3.26 (S1)	2.1 (S1)	3.1 (S1)
Base saturation (%)	63.235 (S1)	74.78 (S1)	54.78 (S2)
Organic matter (%c. 0-15)	0.55 (S2)	0.67 (S2)	0.62 (S2)
Salinity and alkaline (n)			
EC (mmhos.cm^{-1})	-	-	-
Esp. (%)	-	-	-
Aggregate suitability class	S2 (s, f)	S2 (s, f)	S2 (w, s, f)
Size (ha)	46,000	14,000	40,000
% coverage	46 %	14 %	40 %

88 g.kg^{-1} . The clay content also varied from 38 g.kg^{-1} to 120 g.kg^{-1} in pedon 3 (valley bottom). There was an irregular distribution of sand, silt and clay content in some of the pedons, indicating lithological discontinuity of soils. The increase in clay content in pedons 1, 2, and 3 along with soil depth indicates illuviation of clay (Peter and Umweni, 2020a). In pedons 2 and 3, B-horizon had higher content of clay due to washing out of Ah horizon attributed to heavy rainfall as observed in the study. Soil textural classes of the study area ranged from sand to loamy sand. The soil textural class is evidence of the coastal nature of the land and parent material from which the soils are formed. This is also supported by the finding of Peter and Umweni (2020a), reporting that soils of Ogoniland commonly called Ogoni sands are derived from the coastal plain sands buried under alluvium. It was also influenced by the underlying geologic material, the sedimentary rocks weathered into coastal plain sands buried under alluvium at varying degrees at different places in the study area. This is also in conformity with the observation of Mandunda et al. (2014) and Peter and Umweni (2020a) who reported that soils types were greatly influenced by the parent materials and vegetation.

Soil chemical properties of the study area

The soil chemical properties of the study area are presented in Table 5. Soil reaction (pH) revealed that soils of the study area were strongly acidic 5.43 in pedon 1 to slightly acidic 6.16 in pedon 2. Organic carbon ranged from 4.39 g.kg^{-1} in B-horizon of pedon 2 to 14.15 g.kg^{-1} in Ah-horizon of pedon 1. There was a decrease in organic carbon down the depth of the profile across the three pedons except in A-horizon of pedon 1. Generally, organic carbon content of the soils was higher in surface soil than in subsurface soils. The variations in organic carbon content at surface soils was apparently attributed to addition of organic matter from vegetation cover in the study area. Similar findings were also reported by Peter and Umweni (2020a). Total nitrogen (N) varied from 0.39 g.kg^{-1} in B-horizon of pedon 2 to 1.39 g.kg^{-1} in Ah-horizon of pedon 2. Total nitrogen content of the soils was very low, which is in line with the findings of Obasi et al. (2014), Douglas and Peter (2016) and Peter and Umweni (2020 a) who reported that the degradation of organic matter content of soils in southern parts of Nigeria promoted low fertility status of soils in the region. Available Phosphorus varied from 2.94 mg kg in B-horizon of pedon 2 to 39.18 mg kg in Ah–horizon of pedon 3 (valley bottom). The increase in available phosphorus in the soils of pedon3 was the result of the influx of materials from the flood plain due to the seasonal flooding experience in the study area over the years. This is in accordance with the finding of Peter and Umweni (2020a) & Peter and Umweni (2020b). The value of exchangeable bases (Ca^{2+}, Mg^{2+}, K^{+} Na^{+}) in the soils of the study area was very low and varied from one pedon to another. The CECE value was also generally low across the three pedons and ranged from 2.06 cmol.kg^{-1} to 6.10 cmol.kg^{-1}. This low CECE, as observed in the study area, is in line with the findings of Amakhaian and Osemwola (2012), who reported the low value of CECE in the soils of Southern Guinea savanna zone of Nigeria. Generally, low ECEC in the study area might be attributed to the presence of clay minerals. TEA ranged from 1.056 cmol.kg^{-1} to 3.49 cmol.kg^{-1}. Base saturation varied from 34.10 % in AB-horizon of pedon 3 (valley bottom) to 54.10 % in AB-horizon of pedon 2 (middle slope). The lower base saturation might be due to leaching of bases from the soils.

Land suitability evaluation for rubber and cashew

The land suitability characteristics was used for suitability ratings of the site as identified in the various pedons, and detailed soil information as regards to each crop of interest are presented in Table 1 and Table 2. The information was used to determine land suitability classes for both crops in Table 6 and Table 7. Pedon 1 and 3 with a land coverage of 86,000 ha (86 %) of the entire land of the study area were found to be moderately suitable (S2) for rubber cultivation with limitations in soil physical characteristics (texture) and soil fertility (low base saturation < 50 %). Pedon 2 with a land coverage of 14,000 ha (14 %) of the total land of the study area was marginally suitable (S3) for rubber production due to limitation in fertility (low base saturation < 80 %). The suitability classification indicated that pedon 1, 2, and 3 were also moderately suitable (S3) for cashew cultivation in the study area with the limitation in soil physical characteristics (texture) and fertility (low organic carbon), while limitation in wetness (poor drainage) was peculiar to pedon 3 only. The low base saturation could be attributed to acidic nature of soils of the study area and can be ameliorated through effective soil fertility management system as recommended (Douglas and Peter, 2015).

CONCLUSIONS

Soils of the area are generally highly suitable (S1) in term of climate (mean temperature, mean annual rainfall and relative humidity), topography, and soil physical characteristic in spite of its fertility limitation (low base saturation < 80 %). Despite the variation in the physiography position of the mapping units, they were considered moderately suitable (S2) for both rubber and cashew cultivation in the area. An adequate liming operation can be used to improve the base saturation status of the soils.

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